Pollution Abatement and Economic Growth in the Context of Trade Liberalization: A CGE Approach Applied to Tunisia

Mohamed Abdelbasset Chemingui

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Abstract

This paper tries to evaluate the impact of trade liberalization and regional integration on pollution emissions in Tunisia. It also delves on the economic consequences of taxing thirteen categories of effluents, including air, water and land contaminants as instrument of pollution abatement policy in Tunisia. A recursive dynamic computable general equilibrium model is used for this purpose. Results indicate that economic integration of Tunisia with Europe will increase pollution and environmental degradation. Economic implications of pollution abatement policies for Tunisia show that Tunisia can achieve pollution reduction targets (25% reduction in 2010 compared to the level of pollution emission in 2001) without seriously compromising economic growth objectives. This negligible negative effects on growth may be explained by the changes in the composition of domestic Tunisian economic activity where productive resources are easily shifted from more to less polluting activities.

ضريبة التلوث والنمو الاقتصادي في سياق تحرير التجارة: مقاربة التوازن العام مطبقة لتونس

محمد عبدالباسط شمنقي

ملخص

تحاول هذه الورقة تقييم أثر تحرير التجارة والتكامل الإقليمي على انبعاث الملوثات في تونس. كما أنها تبحث التبعات الاقتصادية لفرض ضريبة على ثلاثة عشر صنفاً من المتدفقات، بما فيها ملوثات الهواء والماء والأرض كأداة في سياسة ضريبة التلوث في تونس. وقد استخدم لهذا الغرض نموذج متحرك للتوازن العام. تبين النتائج أن التكامل الاقتصادي لتونس مع أوروبا سوف يزيد التلوث والفساد البيئي. إن المضامين الاقتصادية لسياسات ضريبة التلوث تبين أنه يمكن لتونس الوصول إلى هدفها المرجو بتخفيض نسبة التلوث (إلى 25% في عام 2010 بالمقارنة مع مستوى الانبعاثات الملوثة في عام 2001) وذلك دون المساس بأهداف النمو الاقتصادي بشكل ملحوظ. إن هذه الآثار السلبية الهامشية على النمو يمكن التعبير عنها ببعض التغييرات في تركيبة النشاط الاقتصادي التونسي، حيث يتم التحول بيسر من نشاطات الانتاج الأكثر تلويثاً إلى نشاطات أقل تلويثاً.

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Introduction

Tunisia is a signatory to the 1992 United Nations Framework Convention on Climate Change (UNFCCC), though not yet to the 1997 Kyoto Protocol (KP) that sets greenhouse gas (GHG) emission targets for Annex 1 (developed country) signatories [(1)]. It thereby affirms the principle of "common but differentiated responsibilities" of Annex 1 and non-Annex 1 countries to take measures to slow down the growth of anthropogenic GHG emissions to the atmosphere. Tunisia has been able to make significant advances towards stabilization of the macro-economic framework over the last five years (1996-2000), by achieving encouraging results. Some of these encouraging results are: sustained growth of the GDP at an average rate of 5.4% at constant prices during the same period; increase in investment at a sustained rate of 13.5% per year allowing Tunisia to raise investment ratio from 23.2% of the GDP in 1996 to 25.7% in 1999, and improvement of external financial balances by reducing the current deficit to only 2.1% of the GDP in 1999.

At the same time, Tunisia has started down the road toward the liberalization of trade by signing two major agreements in 1994 and 1995. The multilateral General Agreement on Tariffs and Trade (GATT) stipulates that consolidated tariffs imposed on imports of agricultural produce, and domestic subsidies on agriculture must be phased out over the period to 2004. The bilateral partnership agreement signed with the European Union (EU) provides for the complete abolition of tariff barriers on industrial products by 2010, following a twelve-year transitional period. However, this does not apply to agricultural products, for which an additional agreement has started in January 2001 thereby providing greater access for Tunisia's agricultural products to the EU's market, and the extension of the preferential quota given by Tunisia to the European's agricultural exports. More trade liberalization will be negotiated in the coming years under the auspices of the World Trade Organization (WTO) and the Euro-Med partnership.

The industrial sector will play a central role in the future economic growth of Tunisia. The Government intends to further liberalize its economy and has set itself a target of over 6% annual growth for the next decade. Industrial growth in manufactured goods particularly, is considered a key economic sector in achieving this goal. It is well known that there is, at least in historical terms, a strong correlation between increased trade and faster economic growth, and that the trend towards further trade liberalization will continue. In recognizing this, it is assumed that governments may have, at least in the near future, more control over their environmental policy and less over international trade regimes. Their main challenge will thus reside in designing a sound environmental policy and to have the institutional capacity to enforce it.

The objective of this study is to investigate how an environmental policy may work in favor of growth by increasing sustainable competitiveness and reducing energy consumption. A crucial set of questions addressed in this study deals with the direct and indirect transmission mechanisms through which environmental policy and its enforcement affect the functioning of an emerging open economy like Tunisia. In other words, it is hoped that the analysis will shed new light on the possible synergies between environmental protection, trade liberalization, sustained growth and sustainable development.

[(1)] Country signatories committed to emission limitation or reduction to promote sustainable development include: Australia, Austria, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, European Community, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom of Great Britain and Northern Ireland and the United States of America.

Firstly, local trade-offs are analyzed focusing on emissions and environmental degradation affecting Tunisia and alternative policies available to the government. In this study however, international-global environmental issues are not considered and therefore does not included the analysis of GHG nor any other transitional emissions. The problem of international policy co-ordination and building suitable international institutions to deal with these issues, is also beyond the scope of analysis. Secondly, both environmental and trade policy have myriad effects on a country's economic structure, its employment pattern, its distributional characteristics and its overall growth performance. The primary objectives consist of identifying the conditions under which a certain environmental policy is conducive to enhance competitiveness (trade) and growth, when and how its enforcement may be improved upon and how this affects its effectiveness, and, possibly, its major distributional effects.

The analysis makes use of a computable general equilibrium (CGE) model of the Tunisian economy to offer a new quantitative analysis of the linkages between economic activity and the environment, and to simulate pollution abatement policies. The main advantage CGE is that it offers a coherent framework for analysis based on highly detailed statistics and a fully explored corpus of economic theory. In recent years, there has been an increasing number of studies seeking to demonstrate the effects of trade liberalization on emissions using CGE models. Most of these studies are directed at modeling the effects of particular liberalization in particular countries, specifically those of Beghin et al. (1995, 1997, 1998), Dessus and Bussolo (1996), Copeland (1994), Perroni and Wigle (1994), and others[(2)].

Relationship between Trade Liberalization and the Environment

The trade and environment debate has heightened considerably in recent years, but theoretically, the impact of trade liberalization on pollution levels is not very clear. To focus on this relationship, Dean (1998) considers the “ability to pollute the environment” as an input to the production process. In the standard Heckscher-Ohlin trade model, a country with a relatively low factor price ratio would be classified as relatively “environment” abundant. Freer trade would then lead to increased specialization in pollution-intensive goods. According to Grossman and Krueger (1995), Selden and Song (1994) and Dean (1998), the amount of environmental damage in a country at any time is endogenous, and depends upon the income level of the country. According to this literature, Dean (1998) argues that income growth has three effects on the existing amount of pollution emissions, i.e. scale, technology and composition effect. Scale effect is observed when greater economic activity raises demand of all inputs and increases emissions. Technique effect exists and tends to reduce emissions when higher effluent charges encourage firms to shift toward cleaner production process. Finally, composition effect occurs when income growth shifts toward cleaner goods and the share of pollution-intensive goods in output falls. This composition effect tends to decrease emissions. Therefore, and according to Copeland and Taylor (1994), free trade may lead to increased income, resulting in scale and technique effects, which offset each other. The net impact on environment is, then, determined by the composition effect. Literature on the impact of trade on growth is abundant, and the readers may refer to Baldwin (2000) for a survey of views of economists and country experiences.

Another way to analyze the impact of trade liberalization on pollution emissions is presented by Beghin, Roland-Holst and van der Mensbrugghe (1995) which started from the idea that pollution level may be attributable to the three components of composition, technology, and scale. The composition component measures the change in pollution induced by a change in the commodity composition of aggregate production. The technology element represents the change in pollution coming from evolving technologies. The scale effect measures the increase in pollution attributable to an increase in aggregate economic activity. Beghin et al. argue that trade exerts important influences

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(2) An extensive list of recent literature on environmental related CGE Models is available in Adkins and Garbaccio (1999). http://www.ksg.harvard.edu/tep/cge.bib.2e.pdf.

on all three dimensions. 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 distortions changes relative input prices, input mix, and hence, the pollution intensity of production. And finally, in the context of trade liberalization, the composition effect reflects the realization of comparative advantages, which may be in either dirty or clean activities.

In addition to these evidences on the linkages between environment, growth and trade; other studies (e.g. Vogel, 2000) suggest that for relatively poor countries, increased economic growth and economic interdependence generally result in a deterioration of domestic environmental quality. Pollution levels increase and natural resources are depleted at an accelerating rate. But 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. Existing literature on ecological tax reforms in open economies tends to focus on a public finance setting, on the interactions between new fiscal instruments and public expenditures on environmental protection and pollution abatement.
Under the condition of environmental standards development in the world, other studies (e.g. Birdsall and Wheeler, 1992) argue that in this case, international trade would be beneficial to the environment by reducing pollution. In fact, by exposing firms to global competition and the development of green export market, trade liberalization has actually improved environmental conditions. For example, in the early 1970s, Japan modeled its automobile emission standards to those of the US– its major export market – to continue to sell at this market.

It may be inferred that the impact of trade liberalization on pollution is still ambiguous, and largely differs between developed and developing countries, and among developing countries themselves. Many of the environmental abuses attributable to trade liberalization, have more to do with domestic policies than international economics. This is why it is difficult to generalize the nature and the scope of the relationship between trade and environment. However, with a specific case study, it is feasible to identify the mechanisms by which international trade may affect environment and pollution levels.

Benefits of Pollution Abatement Policy: Some Evidences

In recent years, there has been an explosion of interest in the potential for benefits of pollution abatement to offset some of the costs of reducing gas emissions. If the list of such effects is long and the benefits from each are large, pollution abatement will yield a far better deal than when these benefits are ignored. Until quite recently, literature on direct and ancillary benefits, came from developed countries, especially the US and Europe. Lee 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.
Methodologies used in the literature for estimating benefits and costs of pollution abatement policy vary (Pearce, 2000). Some of the early literature estimate the money value of the benefits or/and costs of such policy. Other approaches tend to focus on the physical effects without magnetization of those effects. The unit value **V** in the monetary approach, for example, should reflect the economic impacts of the associated pollutants on crops, ecosystems, human health. Thus **V** subsumes a set of dose-response functions relating the pollutants to the various impacts. In non-monetary approaches, the physical effects are highlighted rather than having them valued in monetary terms. Thus, pollution reduction **Y** is linked by dose-response functions to health effects **H**, say lives saved or life-years saved

As estimated by the World Bank (1994 and 2001), the annual cost of environmental damages varies from 4 to 9% of GDP for certain MENA countries. These costs are higher than those for Eastern Europe (5%) and substantially higher than those for OECD countries (2-3%). Overall, it is estimated that the environmental health burden is about 14% of the total health burden in the region.

Of this total, about 3% is attributable to urban air pollution. In the case of Tunisia, the same reports estimate that air pollution in Tunisia leads to the loss of 105000 DALYs (disability adjusted life year) annually[(3)].

Until now, most studies on direct and ancillary benefits[(4)] from pollution abatement has focused on public health benefits of reduced emissions of air pollutants associated with carbon dioxide as by-products of fossil fuel combustion – sulphur dioxide, nitrogen monoxide, suspended particulates, volatile organic compounds, carbon monoxide and ozone. A smaller body of studies have looked at other damages, notably crop damage from ozone, forest damage from sulphur dioxide, and materials damage from sulfate aerosols (O'Connor, 2000).

Recent studies focus on ecological benefit of pollution abatement. Aunan et al. (2000) suggest that forests in large part of Europe are probably adversely affected by air pollution. A modeling effort recently established in Europe is beginning to look beyond airborne nitrogen dioxide (NO_2) emissions and focus on direct water discharges associated with GHG policies (Lee Davis, 2000). Aunan et al. (2000)) project significant reductions in materials damage from implementation of energy-efficiency programs in Hungary, and suggest significant increases in crop yields are likely to be obtained if NO_2 and VOC emissions are reduced in large regions in Europe. Another study in progress by the OECD Development Centre on China (Bussolo and O'Connor, 2001) focuses on the effects of reduced air pollution on crop yields. Their preliminary results confirm the finding of Aunan et al. (2000) for Hungary.

Other recent work focus on other ranges of direct and ancillary benefits of pollution abatement policies. These studies include some economic effects of such policies. Economic benefits of pollution abatement may include a diverse range of issues, i.e. financial benefits, employment change, energy security and induced technological change (Lee Davis et al., 2000). The energy cost savings that are derived from a fuel efficiency policy are best seen as a major financial benefit that should result from pollution abatement policy.

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 increased crop yields. The question is whether the policies of pollution emissions abatement will be feasible and at the first order, whether they will be costly or not. Will the benefits of this kind of policy be higher than its costs? Most studies were done on developed countries, but the number applied in developing countries is very limited.

For this reason, the first objective of this study is to estimate the macroeconomic benefits or costs of implementing a pollution abatement policy in Tunisia. The study is delimited to direct economic effects such as the variations in GDP, Exports, Imports and other indicators. The issue of quantifying the ancillary effects is beyond the scope of this study because it is now accepted that pollution abatement realizes positive ancillary effects such as health improvement, which is more than 70% of ancillary benefits of pollution reduction.

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(3) A disability adjusted life year (DALY) is a measure of the loss of healthy life, based on years lost due to premature mortality combined with those lost as a result of disability (World Bank, 1995).

(4) Ancillary benefits have been defined as the social welfare improvements from GHG abatement policies other than those caused by changes in GHG emissions, which incidentally arise as a consequence of mitigation policies This concept is not unique to climate change policy. However, the heterogeneous sources of GHG throughout the economy, their intricate economic impacts, and the global nature of climate change, make the assessment of ancillary benefits more complex than in many other policy areas (Lee Davis et al., 2000).

Overview of Tunisia's Economy, Energy Use and Pollutant Emissions

Tunisia's Economic and Energy Structure

In the mid-1980s, Tunisia took the strategic choice to become a modern, market-oriented, and internationally integrated economy (World Bank, 1995). Since the introduction of stabilization and structural adjustment reforms in 1986, Tunisia's macroeconomic performance has been impressive. The economy performed relatively well for the period 1991- 1999; real GDP increased on the average, by more than 5% that largely exceeded the population growth rate of 1.3%. This implied an annual growth in per capita income of 3.8%, higher than the rate prevailing in many developing countries[(5)]. However, growth remains subject to large annual fluctuations stemming from the vulnerability of the agriculture sector to shifting weather conditions – and has been mainly driven by rising exports of manufactured goods and tourism. The inflation rate (3% in 2000) is approaching the average rate of developed countries.

Tunisia's economy is also becoming more diversified and more open, as manufactured output and services replace the previous dominance of oil and phosphate production. Real value added in hydrocarbons and mining sectors has stagnated since 1990. The contribution to real GDP of petroleum, gas and other mining activities declined from 6.8% in 1990 to 4.9% in 1999.

The principal sources of primary energy in Tunisia are oil and natural gas. The structure of energy consumption has changed dramatically over the past 30 years in favor of gas, which represented 26% of energy consumed in 1998 compared to only 7% in 1970 (IMF, 1996 and 2000). Electricity demand is growing at 6% annually which will require an expansion of Tunisia's production capacity as shown in Table 1 on Tunisia's energy production and consumption.

Table 1. Tunisia's Energy Production and Consumption, 1991-1995 (in millions of metric tons)

	1991	1992	1993	1994	1995	1996	1997	1998
Production	6.087	6.136	5.583	5.161	5.247	5.853	6.204	6.676
Crude petroleum	5.189	5.188	4.641	4.461	4.309	4.276	3.870	3.987
Gas[1]	0.898	0.948	0.942	0.688	0.929	1.562	2.324	2.653
Production	0.238	0.237	0.362	0.157	0.126	0.724	1.504	1.720
Fees[2]	0.660	0.711	0.580	0.531	0.803	0.838	0.820	0.933
Consumption	4.183	4.473	4.715	4.996	5.115	5.307	5.623	5.917
Liquefied petroleum gas	0.253	0.272	0.282	0.321	0.334	0.357	0.375	0.388
Gas	1.100	1.146	1.208	1.271	1.307	1.378	1.485	1.534
Fuel oil	1.492	1.252	1.351	0.978	0.796	0.812	0.831	0.801
Lighting oil	0.144	0.153	0.164	0.159	0.170	0.173	0.184	0.187
Gasoline	0.272	0.286	0.298	0.321	0.325	0.338	0.354	0.363
Jet fuel	0.132	0.186	0.217	0.259	0.250	0.257	0.292	0.311
Natural gas[1]	0.790	1.178	1.195	1.687	1.933	1.992	2.102	2.333
Surplus	1.904	1.663	0.868	0.165	0.132	0.546	0.581	0.739
Electricity production [3]	5,096	5,479	5,705	6,031	6,625	6,852	7,387	7,573

Source: IMF (1996, 2000)

[1]: In millions of tons of oil equivalent

[2]: Fees from the trans-Tunisia pipeline carrying gas from Algeria to Italy and received in kind (expressed in millions of tons of oil equivalent).

[3]: Production by the state company STEG (excluding production by private plants and expressed in millions of kilowatt-hours.

[(5)] Over 1997-98, average real per capita GDP rose by 2.9% in developing countries, 0.7% in Africa, 1.3% in the Middle East and Europe, and 2.4% in the Western Hemisphere (IMF, 2000).

Total hydrocarbon output[6] (crude petroleum and natural gas) declined from 6.1 million ton of oil equivalent in 1991 to 3.5 million tons in 1995. However, with the start of exploration at the Miskar and Zini gas fields in 1996 and the full operation of the second transcontinental gas pipeline, the hydrocarbon output rose gradually starting in 1995. It accounts for about 6.7 million tons of oil equivalent.

The crude petroleum production in Tunisia decreased from 5.2 million tons in 1991 to 4.0 million tons in 1998. This development is mainly due to the dwindling of reserves in the two most productive hydrocarbon fields in Tunisia, i.e. El Borma and Ashtart.

Over the past decade, electricity production has grown steadily at 5.6% on average over the period 1990-1999 accounting for 7.9 million kwh in 1999, mainly produced by the state company for electricity and gas, the Societe Tunisienne d' Electricite et du Gas (STEG). The production of STEG is generated almost exclusively (99%) by thermal plants using fuel-oil and natural gas.

Tunisia's oil reserves are rather limited and its import dependency has been growing steadily. The structure of Tunisia's imports in hydrocarbons are dominated by refined products as its local production capacity is fully used and thus, unable to satisfy the growing local demand on these products. However, Tunisia's exports in hydrocarbons are dominated by crude oil. Table 2 shows that although exports of crude oil decrease at the annual average rate of 1.4% between 1991 and 1998, imports of refined petroleum products rise at the annual average rate of 1.8% at the same period.

Table 2. Tunisia's Trade Structure and Balance in Hydrocarbons, 1991-1998
(in millions of tons of oil equivalent)

	1991	1992	1993	1994	1995	1996	1997	1998
Crude Oil								6.
Exports	3.304	4.005	3.013	3.367	3.290	3.171	2.794	2.990
Imports	0.118	0.341	0.295	0.656	0.855	0.910	0.853	0.917
Balance	3.186	3.664	2.718	2.710	2.435	2.261	1.941	2.074
Refined Products								
Exports	0.542	0.060	0.445	0.560	0.569	0.727	0.848	0.704
Imports	2.186	2.254	1.872	2.172	1.874	2.285	2.558	2.469
Balance	-1.644	-1.812	-2.077	-1.608	-1.305	-1.558	-1.710	-1.754
Gas								
Exports	0.000	0.000	0.000	0.289	0.257	0.571	0.618	0.68
Imports	0.639	1.118	1.132	1.492	1.774	1.213	0.648	0.682
Balance	-0.639	-1.118	-1.132	-1.207	-1.518	-0.643	-0.028	0.00
Total								
Exports	3.846	4.065	3.058	4.215	4.116	4.469	4.260	4.380
Imports	2.943	3.331	3.548	4.321	4.503	4.408	4.045	4.067
Balance	0.903	0.734	-0.491	-0.105	-0.387	0.061	0.203	0.312

Source: IMF (1996, 2000)

[6] In addition to domestic supply of crude oil and natural gas, the hydrocarbon output in Tunisia covers fees paid by Algeria from the use of the two transcontinental pipelines to export Algerian gas to Italy.

Tunisia's Emissions Profile

To assess the seriousness of Tunisia's pollution problems, the author used inventory information on major air pollutants of concern and emission sources. This step involved collecting existing information on pollutants known to cause significant environmental damage in Tunisia, the corresponding emission sources, and average annual emissions and ambient concentration levels. In this section, all information on Tunisia comes from the World Bank (1995), and non-official Tunisian sources.

Using data from the World Bank's Industrial Pollution Projection system (IPPS), pollution intensities and pollution loads were estimated for 28 sectors for Tunisia (World Bank, 1995). In this study, a number of indicators are chosen to span the range of pollution impacts. Indicators are used for toxic pollution to air, water and land; biological oxygen demand (BOD) and total suspended solids (TSS) are used for water pollution intensity. Nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and volatile organic compounds (VOC) are used for air pollution intensity.

The results of this study show that Tunisia exhibits a relatively high level of intensity of TSS and low level of BOD. According to the World Bank (1995), this may reflect the fact that much more attention is given to wastewater treatment than to sedimentation and industrial waste problems. Table 3 shows that compared to other countries, Tunisia has a high level of pollution intensity from NO_2 usually associated with the thermal combustion of fossil fuels, an indication perhaps of less efficient technologies in the industry and transportation sectors.

Table 3. Comparative Pollution Intensity (lbs/US$1M output)

	Tunisia	Chile	Ecuador	Jordan	Portugal	Thailand	Turkey
Air	801	1285	1024	687	1245	489	874
Water	147	125	223	98	268	51	165
Soil	1469	2849	1915	1163	2793	835	1958
BOD	726	1469	962	1021	809	529	566
TSS	8897	17671	6718	7567	11738	4811	13169
NO_2	4585	2548	2974	3002	2063	2947	3579
SO_2	4579	12642	4380	4979	7582	3405	6509
VOC	1475	1832	1963	1920	3089	1526	2132

Source: World Bank (1995)

The distribution of pollution intensity within the Tunisian industrial sector also exhibits some interesting patterns. As seen in Table 4, the chemical industry is the largest contributor to toxic pollution, with 52% of air pollution, 70% of water pollution, and 60% of land pollution. Other much smaller contributors are paper, iron and steel, and textiles industries. Water pollution is almost entirely attributable to the food (56% of BOD), iron and steel (82% of TSS), paper (21% of BOD and 6% of TSS), and chemical (18% of BOD and 8% of TSS) industries. The non-metallic mineral production, iron and steel, chemical, and petroleum refinery industries are the major air pollutants.

Table 4. Distribution of Pollution Intensity in Tunisia (%)

	Air	Water	Soil	BOD	TSS	SO_2	NO_2	VOC
Food Products	3.37	2.43	3.15	56.10	1.56	8.72	12.07	9.87
Textiles, Apparel, and Leather.	4.91	4.25	2.30	0.57	0.08	1.85	3.60	3.63
Footwear, except rubber and plastic	1.01	0.00	0.02	0.24	0.02	0.01	0.00	0.16
Wood products, except furniture	0.58	0.01	0.07	0.18	0.07	0.36	1.09	2.64
Furniture, except metal.	1.62	0.01	0.08	0.00	0.00	0.05	0.05	3.50
Paper and products, printing and publishing.	7.22	9.18	1.52	21.33	5.86	6.31	5.40	4.12
Industrial Chemicals.	52.78	71.75	60.48	18.51	8.04	15.06	20.26	37.96
Petroleum Refineries	2.97	1.22	6.87	0.85	0.35	10.84	9.69	17.83
Rubber and Plastic products	5.23	0.07	1.01	1.20	0.19	0.68	0.36	2.97
Pottery, Glass and products, and other non metallic mineral	5.86	0.57	4.65	0.32	0.38	39.74	36.19	4.70
products	4.62	8.94	14.45	0.07	82.28	14.67	9.90	6.10
Iron and Steel	4.74	1.33	3.16	0.47	0.63	0.94	0.77	3.64
Non-ferrous and								
fabricated metal	3.41	0.20	1.85	0.15	0.02	0.64	0.49	1.35
products	1.66	0.05	0.39	0.00	0.51	0.13	0.11	1.55
Machinery								
Other manufactured products								

Source: World Bank (1995)
Including Beverages and Tobacco

The degree of carbon intensity of Tunisia's economy is quite sensitive to whether one uses market or purchasing power parity (PPP) exchange rates for converting GDP into US dollars. Arguably, the latter is more appropriate (Bussolo and O'Connor, 2002). At PPP exchange rates, Tunisia generated 0.3 kg. CO_2 per $GDP in 1996 (World Bank, 2000). Compared to other countries in the Arab world, Tunisia has the lowest level of carbon intensity (Algeria 0.7, Egypt 0.6, Lebanon 0.9, Morocco 0.3, Saudi Arabia 1.3, Syria 1.0). However, differences in this ratio across countries reflect in part, structural characteristics of each economy, energy efficiency of particular sectors of the economy, and differences in fuel mixes. Of the eight countries, Tunisia also has the lowest ratio of CO_2 emissions to total energy use(7), i.e. 2.4 metric tons CO_2 per ton of energy oil equivalent versus 3.5 for Algeria, 2.5 for Egypt, 2.7 for Lebanon and Saudi Arabia, and 3.0 for Morocco and Syria. Presumably, the values of these ratios reflecting the high share of traditional fuel(8) used in Tunisia (12.7% versus 1.5 for Algeria and 3.5 for Egypt for example).

Modeling the Impacts of Trade Liberalization on the Environment

(7) Using the data from the 2000 world development indicators (World Bank, 2000), the ratio of CO_2 emissions to total energy use was estimated on the basis of commercial energy use expressed in million tons oil equivalent for the year 1997 and the carbon dioxide emissions expressed in million metric tons for the year 1996. Because CO_2 emissions for the year 1996 were used and not those of 1997, this resulted in the under estimation of the ratio of CO_2 emissions to total energy use.

(8) Traditional fuel use includes estimates of the consumption of fuelwood, charcoal, biogases, and animal and vegetable wastes. Total energy use comprises commercial energy use and traditional fuel use.

Many different types of modeling frameworks have been used in demonstrating the implications of international trade on the environment. These include econometric approaches, gravity models, ecological models, biological systems models, partial equilibrium economic models and general equilibrium models. Among others, Martin (1999) [9] argues that it is generally much preferable that the choice of modeling approach emerges from a careful evaluation of the questions to be answered and the nature of the system under study. However, Martin concludes that a general equilibrium approach is seen as suitable for almost all problems.

In this paper, a computable general equilibrium (CGE) model has been used to integrate the economic consequences of climate policy in the context of trade liberalization, both in terms of growth, and more detailed incidence effects. The principal virtue of CGE models lies in their ability to capture feedback in the economic system, e.g., via relative price changes that may lead to results other than those predicted from an examination of first-order, partial equilibrium effects alone. In the context of economic benefits estimation, one of the features of this CGE model is particularly noteworthy. It seldom incorporates a separate abatement technology for local pollutants. This implies that the only way to control those pollutants in the model is via inter-fuel substitution (e.g., switching from coal to gas in power generation) or via substitution of productive factors (e.g., labor) and/or other inputs for polluting energy in a given production process. At the level of the economy as a whole, structural change toward less polluting sectors may achieve the same results (O'Connor, 2000).

The CGE model used in this study is directly derived from a prototype developed at the OECD Development Center (see Beghin et al. 1996 for a detailed specification of this model) and calibrated to a social accounting matrix for Tunisia for 1992.

Model Structure. The model is dynamic and solved recursively[10] for the period 1992-2010. It includes equations describing agents' behavior, market clearing and other accounting relationships. The following sub-sections briefly explain the model's main characteristics and the main extensions introduced to study the economic consequences of climate policy.

Production. Production is modeled using nested Constant Elasticity of Substitution (CES) functions, which describe the substitution and complement relations among the various inputs. Producers are cost-minimizers and constant return to scale is assumed. In the first place, products break down into two aggregates, i.e. intermediate consumption excluding energy, and value-added plus energy consumed. The value-added and energy components are decomposed in two parts namely: aggregate labor and capital plus energy. Labor demand then breaks down into five categories. Within each segment, labor is totally mobile and completely employed. The composite capital/energy factor is disaggregated into capital and energy. Demand for physical capital makes a distinction between "old" capital and "new" capital. The model thus integrates the notion of vintage in order to make a distinction between the process of allocating capital existing at the beginning of the period, or which is already in place from that resulting from contemporary investment (i.e. a production function of putty/semi-putty type).

"New" capital may be allocated more flexibly than already installed or "old' capital. It substitutes for other types of capital more easily (land, natural resources) than does old capital. Accelerating investment therefore strengthens the capacity for adjustment of the productive sector to match changes in relative prices.

Finally, the energy aggregate includes two energy substitutes: oil and electricity. These may be further disaggregated which are targeted by distinct, substitutable demand.

(9) In his paper, Martin provides a series of frameworks in which environmental externalities may be evaluated and the consequences of trade liberalization on environmental impacts assessed.

(10) Recursive dynamic CGE model means that each sequential time period is solved as a static equilibrium problem given an allocation of savings and expenditure on current consumption.

Income Distribution and Absorption. Labor income is allocated between the various households according to a fixed coefficient distribution matrix derived from the original Social Accounting Matrix (SAM). Likewise, capital revenues are distributed among households, corporations and rest of the world (foreign investors). Corporations save the after-tax residual of this revenue.

Household demand is derived from a program for maximizing the utility function following the Extended Linear Expenditure System (ELES)) (11), specific to each household, subject to the constraints of available income and consumer price vector. Household utility is a positive function of consumption of the various products and savings. The calibration of the model determines a per capita subsistence minimum for each product, whose aggregate consumption grows with population, while the remaining demand is derived through an optimization process. The share of the various products in government demand and investment demand (12) is fixed once the aggregate levels of these have been defined.

International Trade. Imperfect substitution among goods originating in different geographical areas is a standard assumption included in this model (Armington, 1969). Imports demand results from a CES aggregation function of domestic and imported goods. Export supply is symmetrically modelled as a Constant Elasticity of Transformation (CET) function. Producers decide to allocate their output to domestic or foreign markets responding to relative prices. At the second stage, importers (exporters) choose the optimal choice of demand (supply) across regions, again as a function of relative imports (exports) prices and the degree of substitution across regions.

The small country assumption holds, i.e. Tunisia being unable to change world prices. Therefore, its imports and exports prices are exogenous. Capital transfers are exogenous as well, and determine the trade balance.

Model Closure and Dynamics. The equilibrium condition on the balance of payments is combined with other closure conditions so that the model may be solved for each period. Firstly, the government budget is considered. Its surplus (or deficit) is fixed and the VAT schedule shifts in order to achieve the predetermined net government position. Secondly, investment must equal savings, which originate from households, corporations, 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 various other factors that affect the growth path of the economy, such as: population and labor, supply growth rates, labor and capital productivity growth rates and energy efficiency factor growth rates. Agents are assumed to be myopic and to base their decisions on static expectations about prices and quantities. The model dynamics are therefore recursive, generating a sequence of static equilibria.

Policy Instruments. The model considers a large set of policy instruments. Some of these have been mentioned above such as production subsidies (by type of activity); consumption subsidies (by product); value added taxes (by activity); other indirect taxes (by activity); tariff barriers (by imported product, and according to origin); non-tariff barriers (by imported product, and according to origin); direct taxes (by household); and taxes on corporate profits. The model also describes the tariff policy implemented by the EU for Tunisian exports. Finally, the model describes tariff quotas policies applied by Tunisia and the EU.

The modeling of these different policy instruments is of conventional type. It defines each instrument as a tax on the relevant resource. For example, a production subsidy is modeled as a

(11) A useful reference for the ELES approach is found in Lluch (1973).

(12) Aggregate investment is set equal to aggregate savings, while aggregate government expenditures are exogenously fixed.

negative tax on production price. In the case of differential tariffs, the process is a little more complex, but boils down to expressing the average tariff level as the average of the preferential and non-preferential tariffs, weighted by the volume of the imported products in each quota. If M is the total imported volume, $\overline{M}$ the volume level below which preferential tariff t_A is applied, and t_B the non-preferential tariff ($t_A < t_B$), then the average tariff t for all imports of a product verifies the following:

$$t\,M = t_A \min\left[M, \overline{M}\right] + t_B \max\left[M - \overline{M}, 0\right] \qquad (1)$$

Since imports subject to these regulatory controls are usually placed under the administrative authority of a public agency, it is assumed that the latter passes on the average tariff to the imported product's domestic price, in order not to penalize one category of importer of the same product more than others. This average tariff is therefore endogenous in the model, since total imports are endogenous. If total demand for imports exceeds quota $\overline{M}$, the nominal level of protection may rise, up to the point at which the domestic price of the imported product is equal to the marginal utility provided by consuming it.

A uniform tax on each unit of polluting emission is also introduced and paid by the polluter agents. This tax may be endogenously determined if specified levels of emission abatement are to be targeted. Otherwise, it may be exogenously fixed. In this latter case, emissions levels become endogenous.

Emissions. Emissions are determined by either intermediate or final[(13)] 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 accounted 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 derived from a previous study (see. next section on emission coefficients) on the determinants of polluting intensity for the US and adapted to the Tunisia case. A change in sectoral output or in consumption vectors, both in levels or composition, therefore, affects emission volumes. Formally, the total value for a given polluting emission takes the form:

$$E_p = \sum_i \beta_i^p XP_i + \sum_i \sum_j \alpha_j^p C_{i,j} + \sum_j \alpha_j^p X_i^{Armington} \qquad (2)$$

where i is the sector index; j the consumed product index; C intermediate consumption; XP output; $X^{Armington}$ final consumption (at the Armington composite goods level); α_j the emission volume of pollutant p associated with one unit consumption of product j and β_i the emission volume of pollutant p 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 represents consumption-generated emissions.

Thirteen types of polluting substances are included in the model. Their volumes are independently determined and measured in metric tons. Toxic emissions in air (TOXAIR), water (TOXWAT) and soil (TOXSOL) depend primarily on the consumption of chemicals (especially fertilisers 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 (BIOAIR), water (BIOWAT) and soil (BIOSOL). These emissions are the results of the use of mineral and metal products, generally found in construction-related sectors. There

(13) Final consumption, in this context, is restricted to households, government and investment demand. Exports are not considered since the analysis is limited to local emission.

are 5 types of toxic substances released in the air: sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and carbon monoxide (CO), volatile organic compounds (VOC) and suspended particulates (PART). Their levels depend primarily on fuels consumption: oil and coal derived products. Finally, two additional categories of water-polluting substances are considered: suspended solids (SS) and those measured by their biochemical oxygen demand (BOD). These emissions are related to the consumption of mineral products.

As in the study of Bussolo et al. (2000), the household utility functions do not include among their arguments any term directly related to environmental qualities and pollution levels. Despite the theoretical validity of the utility-environment relationship, empirical applications would require estimates for utility values that household assigns to environmental qualities (Perroni and Wigle, 1994). Likewise, in this model, environmental degradation is assumed not to affect production factors productivity.

A Few Observations on Data Sources and Limitations. The model used here has been constructed and calibrated using information contained in Tunisia's social accounts matrix for 1992[(14)]. It considers two representative Tunisian households, one rural and the other urban, plus one tourist household. The latter receives all its income from abroad and consumes it in its entirety. A total of 57 economic sectors and 5 types of work are taken into account, these being distinguished notably by their levels of qualification and geographical mobility. Three are rural, 1 urban, and 1 allocated to the whole of the country, the latter being a buffer between rural and urban areas. It covers casual workers who react swiftly to fluctuations in labor demand. If the source of this demand is urban for example, they will go to that area and transfer a fixed part of their income to rural households. They therefore cushion the shocks which particularly affect one geographical area — changes in agricultural policy for example.

Of the 57 economic sectors, 25 relate to manufacturing industries. The model takes into account 3 types of capital, i.e. physical capital, reserves of natural resources (crude oil, phosphates) and land. Finally, the model makes a distinction between two trading partners for Tunisia: the EU and the Rest of the World (ROW) .

Key parameters. The model uses a multitude of parameters in order to calibrate the different bloc of functions. This includes production function elasticities, trade elasticities and household consumption elasticities.

Production function and trade elasticities come from the empirical literature devoted to CGE models. They are not specific to Tunisia (see for instance Burniaux et al., 1992). In earlier works, large sensitivity analyses were conducted on the choice of trade elasticities in Armington and CET elasticities (Chemingui and Dessus, 2001) and on the value of substitution elasticities between fixed and mobile factors (Chemingui and Dessus, 2002). The results show that the models output change with very small levels thus supporting the reliability of these results.

Substitution elasticities reflect adjustment possibilities in the demand for factors of production originating from variations in their relative prices. The following were selected: 0.00 between intermediate consumption and value added incorporating new capital plus energy; 0.12 between aggregate labor and the capital-energy aggregate incorporating old capital; 1.00 between aggregate labor and the capital-energy aggregate incorporating new capital; 0.40 between the various categories of labor; 0.00 between old capital and energy; 0.80 between new capital and energy; 0.25 between the various sources of energy linked to old capital; 2.00 between the various sources of energy linked to new capital; 0.0 between the various types of capital (land, natural resources, physical capital) linked

(14) For more information on the data sources and methodology used for the construction of the Tunisia's SAM, see Chemingui and Dessus (1999). The detailed SAM is available at the OECD Development Centre Web Site: http://www.oecd.org/dev/biblio/statistiques/MATRICE.ZIP

to old capital; 0.5 between the various types of capital linked to new capital; and 0.4 between the different types of labor.

Substitution elasticity between domestic and imported products is set at 2.2, and at 5.0 between imported products according to origin (EU or the ROW). The elasticity of transformation between products intended for the domestic market and products for export is 5.0 and 8.0 between the different destinations for export products.

Income elasticities are differentiated by product and by household and vary from 0.75 for staple products for households with the highest income to 1.20 for services. The value of these elasticities comes from many sources (Chemingui and Dessus, 2002).

Treatment of Emissions Coefficient in the Model. The model includes two matrixes of sectoral coefficients for 13 types of polluting substances: one for production activity and one for final consumption. In the first instance, pollution coefficients are derived from estimates for the US of the World Bank's pioneering IPPS project (Hettige et al., 1994). The World Bank's pollution coefficients which are output-based, have been transformed into input-based estimates by regressing them on intermediate inputs[15]. Instead of focusing on pollution output at individual industrial sources, Dessus et al. (1994)_advocate moving up the production process. Factories producing pollution can be numerous and very dispersed geographically. The evidence reported in their study indicates that only a few commodities are responsible for determining pollution levels when they are consumed as intermediates. Their econometric estimates indicate that over 90% of the variation in emission of most toxic pollution may be explained by consumption of less than a dozen intermediate commodities. Their calculations are based on a 345 sector US input-output table.

The implementation of the results estimated for the US for Tunisia uses the methodology developed by Dessus et al. (1994). The first step is to assure the concordance in the composition of sectors between the US and Tunisia (sectors reported in the SAM). When the number of sectors is greater in the US than in the Tunisia's SAM, the input emission coefficient for product **j** in Tunisia is equal the sum of the coefficients for sub sectors of the product **j** in the US weighted by the US shares of each sub sectors that constitute sector **j**. When the number of sectors is lower in the US than in Tunisia's SAM, the sectors are aggregated in Tunisia to conform to US. The second step is to express the coefficient estimated for Tunisia in its local currency (TD), by dividing it by the exchange rate.

The coefficient obtained is also divided by the inflation rate in the US during the period 1987-1992. Coefficients for the dummy variables are transformed in the same way, in terms of sector disagregation and currency. They are also divided by the level of production in the corresponding US sector. This dummy is directly associated to the level of production of the specified sector. 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. Tables 1A and 2A in the Appendix show the pollution coefficients calculated for Tunisia and used to calibrate the model.

This method is the only way to estimate pollution coefficients in developing countries that have little or no industrial pollution data. But the greatest inconvenience of the use of this approach is related to the fact that it considers that the developing country chosen (Tunisia in this case), has the same technological process and then the same pollution level for the same adopted sector as in the US. This is not true because the difference in environmental regulations between countries and the adopted technology is wide. It is known that in most industries, a technology used at period **t** in developed countries will only be available in developing countries after a given period. In other cases, and in the absence of environmental regulation, industry in developing countries is based on old technology in order to minimize cost and in most cases, specialize in "dirty" production. This specific aspect of pollution emissions in developing countries needs detailed data, which is not available for Tunisia.

(15) For a description of the methodology used, see Dessus, Roland-Holts and van der Mensbrugghe, 1994.

Pollution Emissions in Tunisia in the Base Year: Some Evidences. From a static perspective, the top panel of Table 5 shows the estimates for the sectoral emission intensities for production in 1992 (the base year for which SAM is available), i.e. the volume of emission per unit of output. The presentation of Bussolo et al. (2000) is replicated in this study.

For a summary presentation, the Tunisian economy has been aggregated into 6 macro sectors: agricultural and food processing (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 % shares of sectoral production, export to output, and import to demand ratios. The bottom panel shows the same information in another format. The sectoral coefficient is compared to the economy-wide average set equal to 100. From Table5, 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 has a higher value of its own coefficient (Bussolo et al., 2000). By considering the relative weights shown in the last three rows of the top panel of Table 5; it is also possible to see which are the most polluting industries in volume terms and what may be the environmental consequences of changes in competitiveness.

From the bottom panel of Table 5, the normalized coefficients show that the aggregate chemical sector records the highest emission intensities for TOXAIR, TOXWAT, TOXSOL, SO_2, NO_2, CO, VOC and PART effluents (8 from a total of 13 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 5% of the total output. The next two sectors that will be affected by this tax are OthMI and NmanI. OthMI and NmanI output shares (respectively 16% and 14%) are larger than the chemical sector, and may have more serious effects on aggregate GDP growth given the expected increase in their production costs. Therefore, the effects of a tax proportional to emission intensities on output growth of AgriF, TextI, and ServI, will be less important than the previous sectors because they have lower emission intensities coefficients.

Export and Import dependency ratios show the possible effect of increased trade and economic openness. For the more polluting sectors, trade liberalization and green taxes may lead to substitutes imported in lieu of 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 ChemI and TextI sectors, the substitution possibilities of domestic by imported goods, will be less important than for the AgriF and NmanI for which the import to demand ratio is lower. The possibilities of substitution of domestic by imported goods, will be therefore higher f imported goods are used more as intermediates. The final result will depend on the initial level of protection and the sectoral resource distribution, which will 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. Other computational tools must be used in an attempt to assess the consequences of the policies described. CGE models are usually used. However, presently, this study is the first conducted in a country in the MENA region. All previous work have been done mostly on European and American countries.

Table 5. Sectoral Emission Intensities for Production – 1992
(metric tons per millions TD)

Pollutant Type	AgriFood	Chemicals	Textiles	Other Manufacturing	Non Manufacturing Industries	Services	Total
TOXAIR	14.4	275	85.7	57.5	51.3	9.2	44.1
TOXWAT	28.6	706.3	17.8	112.4	69.4	18.9	77.6
TOXSOL	27.1	855.5	17.5	242.2	358.4	25.6	147.8
BIOAIR	42.9	783.8	19.7	602.3	1020.4	44	303.6
BIOWAT	0.4	39.2	0.4	25.3	49	1.7	13.5
BIOSOL	447.5	15787.9	260.3	10954.8	20070.6	769.9	5711.5
SO_2	27.3	750.5	17.4	98.5	60.6	17.5	75.6
NO_2	16.7	453.7	10.6	56.8	28.7	10.4	44.2
CO	10.3	319.1	6.8	73.8	80.4	8.4	44.8
VOC	24.3	484.7	11.1	70.1	49.9	11.5	53
PART	4.6	125.4	2.9	18.2	8.8	2.9	12.7
BOD	12	26.5	0.3	21	33.1	1.2	12.5
TSS	14.4	1470.6	15.2	945.8	1824.2	63.6	503.9
Output%	23	5	9	16	14	33	
Exp/Output	6	34	59	18	14	7	
Imp/Demand	9	72	124	93	12	4	
Normalized coefficients							
TOXAIR	33	624	194	130	116	21	100
TOXWAT	37	910	23	145	89	24	100
TOXSOL	18	579	12	164	242	17	100
BIOAIR	14	258	6	198	336	14	100
BIOWAT	3	290	3	187	363	13	100
BIOSOL	8	276	5	192	351	13	100
SO_2	36	993	23	130	80	23	100
NO_2	38	1026	24	129	65	24	100
CO	23	712	15	165	179	19	100
VOC	46	915	21	132	94	22	100
PART	36	987	23	143	69	23	100
BOD	96	212	2	168	265	10	100
TSS	3	292	3	188	362	13	100

Source: Author's calculations

Although production activity is the worst pollutant in the economy, final consumption of goods and services may equally cause pollution, especially for specific emission categories. Analogous results of emissions intensities for consumption are shown in Table 6. 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, it may be observed that only consumption of ChemI (as the case of refined fuels and fertilizers) and OthMI products generates emissions.

The best way to reduce emissions from final consumption will result from the technical efficiency in the production. 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 pollutant and clean intermediate consumption. Reduction in emissions from final consumption will be the result of changes in emissions from production and not the 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 will depend 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, e.g. premium, super, unleaded, regular, etc.

Table 6. Sectoral Emission Intensities for Consumption – 1992
(tons per millions TD)

Pollutant Type	AgriFood	Chemicals	Textiles	Other Manufacturing	Non Manufacturing Industries	Services	Total
TOXAIR	0	458.4	0	36.4	0	0	20.1
TOXWAT	0	1303.5	0	15.2	0	0	39.3
TOXSOL	0	1145.6	0	64.7	0	0	45
BIOAIR	0	0	0	326.4	0	0	66.4
BIOWAT	0	0	0	7.4	0	0	1.5
BIOSOL	0	0	0	4458.2	0	0	907.2
SO_2	0	1408.3	0	7.2	0	0	40.5
NO_2	0	864	0	3.1	0	0	24.6
CO	0	511.1	0	11.4	0	0	16.5
VOC	0	892.2	0	6.3	0	0	26
PART	0	237.3	0	1	0	0	6.8
BOD	0	0	0	5	0	0	1
TSS	0	0	0	275	0	0	56
Cons%	24	4	4	15	14	39	
Normalized Coefficients							
TOXAIR	0	2281	0	181	0	0	100
TOXWAT	0	3317	0	39	0	0	100
TOXSOL	0	2546	0	144	0	0	100
BIOAIR	0	0	0	492	0	0	100
BIOWAT	0	0	0	493	0	0	100
BIOSOL	0	0	0	491	0	0	100
SO_2	0	3477	0	18	0	0	100
NO_2	0	3512	0	13	0	0	100
CO	0	3098	0	69	0	0	100
VOC	0	3432	0	24	0	0	100
PART	0	3490	0	15	0	0	100
BOD	0	0	0	500	0	0	100
TSS	0	0	0	491	0	0	100

Source: Author's calculations

The Benchmark Scenarios

The objective of this section is the simulation of the Tunisian economy to the 2010 horizon without any pollution abatement policy and under alternatives hypothesis on trade policy. This allows for exploring the consequences of trade on growth and pollutant emission. The initial simulation which refers to the situation without the changes in trade policy provided by GATT and the partnership agreements, forms the baseline scenario to which alternatives trade liberalization is compared. Two simulations are compared to the baseline scenario. The first one LibEU (Trade Liberalization with Europe) introduces the changes in economic policy and reflects the formal undertakings given by the Tunisian government to the international community, specifically where trade is concerned. This simulation incorporates the changes in trade policy in connection with GATT, the Euro-Med Partnership agreement, and the dismantling of Multi-Fibre Agreement (MFA). The second simulation LibROW (Trade Liberalization with the Rest of the World) introduces a cut in the tariffs applied to industrial and agricultural products from the ROW similar to that implemented on European products alone.

Several assumptions have been made to define what seems to be the plausible development of the Tunisian economy up to 2010. However, this exercise in simulation must not 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 may then be compared to isolate the specific impact of the latter. However, the fact that the value of the exogenous variables are set on *a priori* basis within a realistic confidence interval, does not have any major consequences. When the impact of alternative economic policies is assessed, it may 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 welfare changes.

In recent works (Chemingui and Dessus, 2001 and 2002), sensitivity analyses were conducted on the choice of trade elasticities (Armington and CET elasticities) and model closure. The results show that changes were minor and the model was not sensitive to the choice of the different elasticity values.

Growth hypotheses and Economic Policies Implemented in the Baseline Scenario.

In order to construct a baseline scenario, the values of a number of variables need to be set. The rate of growth in GDP is set for the period to 2010 to estimate a growth rate for total factor productivity compatible with this development. A figure of 5.7% has been identified for the average annual GDP growth rate between 1998 and 2010 based on the targets and forecasts of the Ninth Social And Economic Development Plan. Over the same period, the rural population is assumed to grow at an average annual rate of 1.0% and urban at 1.8%. Between 1998 and 2010, labor market supply grows by 0.9% yearly in rural areas, and by an annual 2.0% in urban areas.

It is assumed that the government continues with its policy of fiscal stabilization. Budget spending (excluding investment) increases in real terms by only 1.5% annually up to 2010. In the baseline scenario, public savings are endogenous. In the alternative scenarios, they are exogenous remaining at the baseline reference level, and are obtained by endogenous shifting of the VAT vector. To neutralize the impact of changing the latter which is judged to cause distortion, (Rutherford, et al., 1995), as a reaction for example to a reduction in tariff revenue, it is assumed that the rate of VAT is gradually unified over the period 1998 to 2010. By 2010, there would be just one VAT rate applicable to all products and equal to the average revenue collected in 1992.

The changes to policy, levels of activity and public expenditure which are introduced, determine budget balance in the baseline scenario before the addition of public investment. This remains stable throughout the period at roughly +4.5% of GDP. The rate of growth in total factor productivity which relates solely to physical capital and labor, is also determined endogenously in the initial scenario. Notably, it is dependent on the rate of growth of the economy and the initial stock of physical capital, which in turn determines the rate at which the latter accumulates. At an annual average GDP growth rate of 5.7%, and with an initial stock of physical capital twice the 1992 product, the annual growth rate in total factor productivity comes out as 0.8% on average over the period 1992 to 2010. Finally, the assumption is made that there will be a hardening in external constraints. In 2010, the deficit in the trade balance will fall to 2.6% of GDP compared to 13.6% in 1992. External prices remain unchanged. Appendix 1 contains the detailed results for this simulation.

Growth and Emissions. To describe the trends in pollution emissions with respect to economic activity in Tunisia, the long-term pollution elasticities are calculated with respect to production and consumption of goods and services. 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 1992-2010 obtained in the baseline scenario. This value of elasticities represents the economic trends in Tunisia without any change in the environmental policy, excluding pollution abatement policy. The value of these elasticities is presented in Table 7.

Results of this simulation shows that except TOXAIR and BOD, aggregate pollution grows at the same level as economic production. This is because most values of these elasticities are near to 1. For TOXAIR and BOD, an increase in production will result in a decrease in the pollution growth. The situation in the case of consumption is not the same. For all pollutants with an increase in consumption, it may be observed a decrease in pollution growth. In general, it may be inferred that the baseline evolution of the Tunisian economy will not increase environmental problems. In other words, the economic growth of Tunisian's economy without trade liberalization, will not accelerate the pollution emissions growth rate. The possibilities of substitution between "clean" and "dirty" goods and services introduced in the model, will help to obtain a stabilization of the pollution growth rate in Tunisia.

Table 7. Emission Elasticities - Baseline Scenario before Trade Liberalization (1992-2010)

	Production	Consumption
TOXAIR	0.94	0.97
TOXWAT	1.00	0.96
TOXSOL	1.01	0.96
BIOAIR	1.02	0.98
BIOWAT	1.01	0.94
BIOSOL	1.01	0.96
SO_2	1.00	0.96
NO_2	1.00	0.96
CO	1.01	0.95
VOC	1.01	0.96
PART	1.01	0.96
BOD	0.97	0.94
TSS	1.01	0.94

Source: Author's calculations

Trade Liberalization and Emissions

The impact of two reforms of trade policy in Tunisia is evaluated. The first one is in connection with the EU partnership agreement with Tunisia signed in 1995. This agreement stipulates a product-related reductions in tariffs applied to imports of European industrial products (see Table 3A in Appendix), between 1998 and 2010. The second reform adds to the first simulation a cut in the tariffs applied to industrial products from the ROW similar to that implemented up to that time on European products alone. Each of the two reforms is assessed separately in an endeavor to evaluate and define its intrinsic impact on the Tunisian economy and its level of pollution emissions.

Aggregate macroeconomics results of the two simulations are presented in Table 8. Industrial trade liberalization with the EU results in a 0.2% rise in real GDP between 2001 and 2010 with respect to the baseline scenario. Both total imports and total exports increase as a result of the partnership agreement with the EU. Exports grow by more than 1% per year between 2001 and 2010 compared with the baseline scenario. This positive effect of trade liberalization with Europe will be augmented when the same cut in tariffs applied to industrial imports from the EU will be applied to imports from the ROW. An elimination of involves all trade partners. This allows Tunisian' s economy to reduce or to eliminate the "diversion effects". The positive results obtained with the two simulations come from an increasingly large share of Tunisian domestic resources that are devoted to export activities with comparative advantages.

Table 8. Macroeconomic Results of Three Simulations

(yearly % average 2001-2010)

	Baseline	LibEU	LibROW
GDP	5.80	6.04	6.11
Production	5.03	5.28	5.45
Consumption	5.23	5.46	5.57
Investment	6.21	6.46	6.59
Exports	5.76	6.98	7.27
Imports	4.88	6.08	6.36
Tariffs Revenue	5.33	-4.43	-7.44
Macro- Sectoral Output			
AgroFood	4.10	4.09	4.14
Extraction	4.56	3.97	4.30
Chemicals	2.61	2.42	4.38
Textiles	-1.74	1.03	0.65
Other Manufacturing	5.48	5.36	5.57
Non Manufactured Industries	4.66	4.84	4.98
Services	7.09	7.29	7.28

Source: Author's calculations

Table 9 indicates the new values of long-term pollution elasticities with respect to production and consumption obtained with the two simulations related to trade liberalization in Tunisia, and calculated during the period 1992-2010. Except in some cases (BOD in production, and BIOWAT, BOD and TSS in consumption), aggregate pollution grows more intensively than production and consumption in the Tunisian economy. This is the case when the value of the elasticity exceeds the unity.

Consider now the growth rates of output and pollution emissions by macro-sectors. Sectoral variations in emissions both by production and consumption are presented in Table 4A (Appendix), which indicates the average growth rate of pollutant emissions between 1992 and 2010. Growth rates of output are presented for the three-benchmark scenarios by pollutant and by aggregate sector in Table 5A (Appendix). For instance, it may be seen that in "unilateral trade liberalization with all partners scenario", the average growth rate of output in chemicals sector between 2001 and 2010 is 1.8% higher than the value in the baseline scenario and 2% higher than its level in the trade integration scenario with Europe. The chemicals sector as previously mentioned, is the most polluting sector in Tunisia. The changes in output growth rate in the remaining polluting sectors (Extraction and Textiles) are quite lower than the chemicals sector. In summary, the basic observation is that Tunisia risks a specialization in dirty production under the two-benchmark trade scenarios explored here if no corrective environmental policy is adopted. This is a consequence of sectoral growth rates of output in polluting sectors and long-term emission elasticities.

Table 9: Emission Elasticities - Scenarios of Trade Liberalization in Tunisia (1992-2010)

	LibEU		LibROW	
	Production	Consumption	Production	Consumption
TOXAIR	1.03	1.07	1.14	1.10
TOXWAT	1.13	1.06	1.27	1.10
TOXSOL	1.10	1.04	1.19	1.07
BIOAIR	1.06	1.02	1.11	1.03
BIOWAT	1.05	0.96	1.11	0.98
BIOSOL	1.06	1.00	1.11	1.01
SO_2	1.15	1.06	1.30	1.10
NO_2	1.15	1.06	1.30	1.10
CO	1.11	1.05	1.22	1.09
VOC	1.14	1.06	1.28	1.10
PART	1.15	1.06	1.29	1.10
BOD	0.99	0.96	1.03	0.98
TSS	1.05	0.96	1.11	0.98

Source: Author's calculations

Decomposition of Pollution Changes

The analysis of the decomposition of emission by origin is very instructive. According to Beghin et al. (1995), three types of effects are distinguished in the variation of emission levels: the composition effect, the technology effect, and the scale effect. The composition effect takes into account the modification of the proportion of polluting products in the aggregate output. The technological effect reflects changes in pollution due to alteration in the production technology. The scale effect describes the impact of increased volumes of output on pollution emissions.

Consider the following identity which simply states that total emission for each type of pollutant is equal to the sum of sectoral emissions:

$$E = \sum_i E_i = \sum_i ((X_i \,/\, X_{tot}) * (E_i \,/\, X_i) * X_{tot}) \qquad (3)$$

The total variation in emission levels may be measured as the sum of the mentioned three effects by differentiating the shown identity:

$$\partial E = \sum_i \left[\partial(X_i / X_{tot}) * (E_i / X_i) + \partial(E_i / X_i) * X_i + \partial(X_{tot}) * (E_i / X_{tot}) \right] \quad (4)$$

Where ∂ is the partial differential operator; E for total emission volume; Xtot for total output (in real terms); Ei as the sectoral emission volumes and Xi as the sectoral output. The first part of Equation 4 represents the composition effect. The second one represents the technological effect and the last part, the scale effect. A similar formula is used in the case of emissions originating from final consumption, but the technological effect is absent.

Table 6A (Appendix) displays these results for each effluent for the three-benchmark scenarios. Note that changes in the technology component are exogenous for the production in the baseline scenario because of capital productivity calibration, and zero for the consumption because it is assumed there is no technological change embodied in the consumption methods (Bussolo and al, 2001).

On the production side, decomposition of the origin of pollution growth in the baseline scenario reveals that the scale effect is dominant for all pollutants. Their share in the total emissions growth varies between 99.4 and 112.1% of the total emissions growth in this scenario. Technological effect measured by the decreases in the pollution intensity per unit of output, contributes only to approximately 2% in the total emissions growth (except BIOAIR, BIOSOL and TSS, for which the share of technological effect is less than 1%). On the consumption side, only composition and scale effects are observed to be determinants of emissions growth. Composition effect plays a more significant role in the evolution of pollution types in consumption than in production activity. Its share varies between 14.5 and 20.0%.

In the benchmark scenario of trade integration with Europe, trade liberalization seems to increase the composition effect share in the total of pollution emissions growth. This increase of the composition effect depends on the scale effect, which decreases by the same % as the increase in the composition effect. However, the technological effect remains at its levels as in the baseline scenario, except for some pollutants. This includes PART, BOD and TSS pollutants, for which a very small substitution of non-polluting inputs by polluting inputs are observed. As for the consumption activity, trade liberalization with the EU decreases the role of the composition effect in the growth of pollution emissions. This reveals a sensitivity to relative prices.

The impacts of unilateral liberalization of industrial imports from all partners increase the share of composition effect in the growth of emissions. However, the share of technological effect remains at its level in the scenario of trade integration with Europe. In both cases (trade integration with Europe or multilateral trade liberalization with all partners), the cut in tariffs applied on Tunisian industrial imports tends to increase the role of composition effect in the growth of emissions, but the scale effect remains dominant as determinant of pollution emissions growth.

Alternative Environmental Policy Scenarios

Choice of Pollution Abatement Instrument

The objective of this section is to identify the environmental instrument to be used in the CGE model in order to implement a pollution abatement policy. Policy interventions aimed at improving health and welfare are of many sorts, and cost-conscious governments need to estimate the relative cost-effectiveness of different sorts of interventions. Existing literature on pollution abatement instruments distinguish two ways used by the government and for each of them, a different objective of economic evaluation. 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 the macroeconomic and sectoral levels. The second way is when the government fixes a pollution emission level, 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.

At least two instruments may be identified: (a) technological standard and (b) pollution tax. In this study, the pollution tax as instrument for pollution emissions abatement is used. Literature on CGE model based on technological standard uses the notion of product differentiation. For this purpose, the literature distinguishes mostly two categories, i.e. green product and dirty product. This kind of model integrates a specific production and consumption function for each specific product category. The same differentiation is introduced in the international trade specification according to geographical origin. For more information on this kind of models, see Schubert and Zagame (1998).

In this case, and given the modeling and the calibration process of the 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: (a) the effects of trade reforms on the environment and (b) 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. Taxes on effluents, abatement subsidies, marketable pollution permits should be used in this case. Even in a second best world, the optimal policy to abate emissions would be a targeted uniform tax per unit of pollution. 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., 2000).

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 specialization in dirty industries (pollution heavens). Empirical research tends to confirm that developing economies specialize in 'dirty' industries. This could suggest that developing economies have a real comparative advantage in dirty productions, and hence a trade-off between trade liberalization and environmental preservation could occur.
Another set of issues that receive quite a bit of attention, concerns the appealing idea of tax discrimination between 'good things', such as trade (or labor), and 'bad things', such as pollution. In particular, the idea of tax swaps (substituting distortionary taxes' revenues with environmental tax proceeds) suggests the possibility of generating a double dividend (less pollution and a more efficient economy). Numerous studies have analyzed 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.

Introduction of Emission Taxes in the CGE model for Tunisia

Pollution taxes may be generated in the model in either of two ways. It may either be specified exogenously (in which case it is multiplied by a price index to preserve the homogeneity of the model), or it may be generated endogenously by specifying a constraint on the level of emission. In this study and given its objective, the latter case is adopted.

Equation 5 defines the total level of emissions for each type of pollutant *p*. The bulk of the pollution is assigned to the direct consumption of goods which is the second term in the expression. The level of pollution associated with the consumption of each good is constant, i.e. there is no difference in the amount of pollution emitted per unit of consumption whether it is generated in production or in final demand consumption. The first term in Equation 5 represents *process* pollution. It is the residual amount of pollution in production that is not explained by the consumption of inputs. In the estimation procedure, a process dummy has proven to be significant in certain sectors.

The remaining equations reproduce the corresponding equations in the text if a pollution tax is imposed. This is actually endogenously calculated as the shadow price of Equation 5, once a target on the level of emission has been exogenously specified. The tax is implemented as an excise tax, i.e. it is implemented as a 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 6, 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 ton of emission per 10 million Dinars of output. Then the total emission in this case is 10 tons. If the tax rate is equal to 25 Dinars per ton of emission, the total tax bill for this sector is 250 Dinars. In the formula below, β_i^p is equal to 0.1 (ton 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 7). However, the Armington decomposition occurs using basic prices, therefore, the taxes are removed from the Armington price in the decomposition formulae (see Equations 8 and 9). Equation 10 determines the modification to the government revenue equation.

$$E_p = \sum_i \beta_i^p XP_i + \sum_i \sum_j \alpha_j^p C_{i,j} + \sum_j \alpha_j^p X_i^{Ar\min gton} \quad (5)$$

$$PP_i XP_i = PX_i XP_i + \sum_p \beta_i^p XP_i \tau^{Poll} \quad (6)$$

$$PA_i = \left[\beta_i^d PD_i^{1-\sigma_i^m} + \beta_i^m PM_i^{1-\sigma_i^m}\right]^{1/(1-\sigma_i^m)} + \sum_p \alpha_i^p \tau_{Poll} \quad (7)$$

$$XD_i = \beta_i^d \left[(PA_i - \sum_p \alpha_i^p \tau^{Poll}) \Big/ PD_i\right] XA_i \quad (8)$$

$$XM_i = \beta_i^m \left[(PA_i - \sum_p \alpha_i^p \tau^{Poll}) \Big/ PM_i\right] XA_i \quad (9)$$

$$G\mathrm{Re}v = Misc\,\mathrm{Re}v + Tax^h + \sum_p \tau^{Poll} E_p \quad (10)$$

The Effects of Pollution Abatement Policy on Growth in Tunisia

This section deals with the evaluation of the impact of the various pollution abatement policies which might be envisaged by Tunisia as part of a new economic policy aimed to protect environment and increase benefits from pollution reduction. As previously explained, pollution taxes directly targeted to affect polluting agents behavior in order to reduce environmental damage, but they may have some costs in terms of economic growth. For an exogenous reduction rate in emission volumes, the model endogenously calculates the tax rate. The result is analogous to the implementation of tradable pollution rights where the equilibrium price of these rights is equal to the applied tax (Bussolo et al., 2000).

The gradual reduction of pollution emissions between 2001 and 2010 is simulated in addition to trade liberalization of industrial products between Tunisia and the EU. This scenario seems to be a more realistic trend of evolution of the Tunisian economy. Specifically, the environmental policy adopted here, calls for phasing in a 25% reduction with respect to the baseline scenario without trade liberalization. The phasing entails sequential reductions of 10% in 2001, 15% in 2004, 20% in 2007, and 25% in 2010

The results of the 13 simulations combined trade liberalization with Europe and reduction of emissions of each pollutant are compared with the benchmark scenario of trade integration with Europe and baseline scenario. In other words, the average annual growth rate of the macroeconomic ratios in the environmental scenario is compared to the trade integration and baseline scenarios. The main advantage of coordinated reforms is to combine efficiency gains from free trade with distortions implemented to achieve second-best environmental objectives.

Table 10. Results of Air Pollutants Abatement on Macro variables and Sectoral Production Growth Rates (yearly % average in the period 2001-2010)

	Baseline	Trade Integration with EU	PART	SO_2	NO_2	VOC	CO	TOXAIR	BIOAIR
Macro Variables									
Real. GDP	5.80	6.04	6.03	5.83	5.93	6.04	6.02	6.03	5.90
T. Consumption	5.23	5.46	5.44	5.36	5.38	5.45	5.45	5.42	5.35
T. Investment	6.21	6.46	6.25	6.34	6.38	6.46	6.45	6.45	6.35
T. Exports	5.76	6.98	6.93	6.88	6.92	6.97	6.95	6.90	6.60
T. Imports	4.88	6.08	6.05	6.00	6.01	6.08	6.06	6.05	5.94
Sectoral Production									
AgriFood	4.10	4.09	4.10	4.10	4.10	4.09	4.11	4.10	4.12
Extraction	4.56	3.97	3.82	3.95	3.94	3.85	3.95	3.95	3.80
Chemicals	2.61	2.42	2.25	2.28	2.38	2.35	2.38	2.40	2.10
Textiles	-1.74	1.03	1.02	1.05	1.04	1.04	1.04	1.02	1.10
Other Manufacturing	5.48	5.36	5.25	5.35	5.35	5.38	5.28	5.34	5.30
Non. Man. Industries	4.66	4.84	4.89	4.90	4.85	4.85	4.75	4.79	4.85
Services	7.09	7.29	7.22	7.30	7.18	7.18	7.25	7.29	7.23

Source: Author's calculations

Table 11. Results of Water and Land Pollutants Abatement on Macro variables and Sectoral Production Growth Rates (yearly % average 2001-2010)

	Baseline	Trade Integration with EU	BOD	TSS	TOX WAT	BIOWAT	TOXSOL	BIOSOL
Macro Variables								
Real. GDP	5.80	6.04	6.04	5.85	6.02	6.03	6.00	5.60
T. Consumption	5.23	5.46	5.45	5.45	5.40	5.41	5.35	5.25
T. Investment	6.21	6.46	6.39	6.40	6.40	6.39	6.36	6.29
T. Exports	5.76	6.98	6.93	6.63	6.83	6.95	6.80	6.45
T. Imports	4.88	6.08	6.05	5.85	6.06	6.04	6.02	5.72
Sectoral Production								
AgriFood	4.10	4.09	4.10	4.13	4.11	4.09	4.10	4.15
Extraction	4.56	3.97	3.95	3.48	3.78	3.88	3.75	3.25
Chemicals	2.61	2.42	2.40	2.25	2.35	2.39	2.27	2.05
Textiles	-1.74	1.03	1.04	1.20	1.04	1.04	1.05	1.15
Other Manufacturing	5.48	5.36	5.34	5.26	5.34	5.33	5.32	5.12
Non.Man. Industries	4.66	4.84	4.79	4.72	4.80	4.81	4.75	4.63
Services	7.09	7.29	7.26	7.18	7.20	7.25	7.17	7.12

Source: Author's calculations

Tables 10 and 11 elucidate the economic consequences of the abatement policies. The most significant insight here concerns the negligible aggregate cost (negative) of pollution in terms of forgone real average growth rate of GDP between 2001 and 2010 for most simulations, except for four among them. These include SO_2, BIOAIR, TSS and BIOSOL for which average annual growth rate of GDP sharply went down by about 0.2% compared with the trade integration with the EU scenario. The marginal effects on economic growth observed in most pollution abatement simulations may 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 reason is related to the substitution possibilities among inputs, where an increase is observed in the use of less polluting inputs compared with more polluting ones. These changes in the structure of the inputs 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 about the distribution scheme of the new taxes' revenue generated by the green taxes. These taxes according to the closure feature of this model, are used by the government to reduce its budget deficit and then to reduce the VAT rate used by this model as the instrument to substitute the loss generated by the free trade agreement with the EU on tariffs revenue. This decrease in VAT rate applied in Tunisia, reduces the rate of taxation in the economy and consequently, productive activities become more competitive. In other cases, and if the emission taxes were to be redistributed to households for example, the economic cost of environmental policies becomes higher in Tunisia as result of the VAT high level.

The major consequence of pollution abatement policies is to reduce production generated by more environmental polluting activities (e.g. Extraction, Chemicals, Other Manufacturing) and to increase production of activities less polluting (e.g. AgriFood, Textiles, Non-Manufacturing, and Services). This is the immediate result of pulling resources from polluting to less or nonpolluting sectors. As may be observed in the detailed results of these simulations, the changes in the average annual growth rates in production are not considerable. In the more detailed industrial classification, the changes are more significant, especially in the polluting sectors such as chemicals and extraction.

To summarize, the economic results indicate that the potential exists for significant reduction of pollution in many effluent categories,without seriously compromising economic growth objectives, except for SO_2, BIOAIR, TSS and BIOSOL. To do this however, and as Bussolo et al. (1999) suggest, it would entail appreciable changes in the composition of domestic production, employment, and other resource allocation, which may lead to policy challenges in the Tunisian social and political agenda.

Conclusion and Policy Implications

The Kyoto Protocol to the United Nation Convention on Climate Change signed in Kyoto in December 1997 sets goals for emissions reduction for countries included in Annex I (Footnote 1), which includes mainly developed countries. Non Annex I countries (mainly developing countries), do not need to abide to any emission reductions. However, the protocol devised an emissions trading framework that would allow countries (mainly Annex I) to invest in GGHG reduction projects in other countries (non Annex I), and share part of the emissions credits (Cifuentes et al., 2000). It is common knowledge however, that in order to stabilize the global concentrations of GHG, it is necessary for all countries, including developing countries, to reduce emissions. However, 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 priority development like poverty and unemployment reduction, improve growth and exports, and exports diversification. In these countries, governments may be hesitant to consider any emission abatement policies, justified by their beliefs on the significant economic costs related to the adoption of such policies.

Recently, a number of studies has focused on the direct and ancillary benefits of reduced emissions. Most of these studies highlight the public health benefits of reduced emissions of air pollutants and energy saving mechanism. Other studies have looked at damages, notably crop damage, forest damage and materials damage caused by emissions. On the basis of these studies, the possibility of reaping direct and ancillary benefits from pollution abatement are generally accepted(16).

This paper has analyzed the economic implications of pollution abatement policies for Tunisia in the context of trade liberalization. Empirical results show the impacts of trade liberalization on pollution emissions and pollution abatement policies on the Tunisian economic growth. Economic integration of Tunisia with the EU would lead to an increase in pollution and environmental degradation. The pollution elasticities with respect to production and consumption increase as result of trade liberalization with the EU. The extension of the abolition of tariffs on industrial products

(16) For a survey of thess studies and their estimations of the benefits of pollution abatement policy, readers may refer to the Proceedings of the Workshop on the Ancillary Benefits and Costs of Green House Gas Mitigation Strategies, Resources for the Future, Washington D.C., 27-29 March 2000.

imported from the EU increases the long-term elasticities of pollution. Trade liberalization seems to attract productive resources to polluting or "dirty" activities. This appears on the composition of the pollution growth in Tunisia where the technological effect increases between the baseline scenario and benchmark scenarios with trade liberalization. However, the scale effect remains dominant as determinant of pollution emission growth in Tunisia.

The economic implications of pollution abatement policies for Tunisia show that Tunisia may achieve pollution reduction targets (25% reduction in 2010 compared to the level of pollution emission in 2001) without seriously compromising economic growth objectives. This negligible negative effects on growth may be explained by the changes in the composition of domestic Tunisian economic activity, where productive resources are easily shifted from more to less polluting activities. These results may also be explained by the substitution of more to less polluting inputs. An example is the case of petroleum and electricity. Environmental policy reforms that target emissions linked to the utilization of polluting goods (in either intermediate or final use), are the best ways to achieve pollution mitigation. Furthermore, free trade and trade integration represent important sources of growth opportunities. When combined with appropriate environmental policies, it may raise material living standards in Tunisia and reduce environmental degradation.

However, extensions of the present work are manifold and necessary. 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 to re-estimate the economic impacts of pollution abatement. Following should be an analysis of the difference in these results when the IPPS method or specific data for pollution in Tunisia are used. In addition, the technological effect is ignored in the estimations of emission coefficients, which remains constant before and after trade liberalization. Generated alternative estimates in which emission coefficients are allowed to vary with trade liberalization, may provide more realistic results of the economic impact of pollution abatement in the context of trade liberalization.

Secondly, it may be desirable to expand the model to include measurable ancillary effects mainly on public health and crop yield effects, as has been done by Chemingui et al. (2001) for India and Bussolo and O'Connor (2001) for China. This allows the estimation of the net effect of pollution abatement in Tunisia taking into account economic costs and direct and ancillary benefits of such policies.

The last aspect of extension of the present work is related to dynamic features of the CGE model used. Agents are assumed to be myopic and to base their decisions on static expectations about prices and quantities. The introduction of emission taxes may affect agents' decision on investment and consumption. The introduction of agents anticipations about taxes seem to be a significant issue in the analysis.

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Statistical Appendix

Table 1. Production Dummies – Emission Coefficients (pounds per thousand TD)

	TOXAIR	TOXWAT	TOXSOL	BIOAIR	BIOWAT	BIOSOL	SO_2	NO_2	CO	VOC	PART	BOD	TSS
Agri (15 activities)	0	0	0	0	0	0	0	0	0	0	0	0	0
Livestock	0	0	0	0	0	0	0	0	0	0	0	0	0
Forestry	0	0	0	0	0	0	0	0	0	0	0	0	0
Fishing	0	0	0	0	0	0	0	0	0	0	0	0	0
Meat	0	0	0	0	0	0	0	0	0	0	0	0	0
Milk	0	0	0	0	0	0	0	0	0	0	0	0	0
Flour-milling	0	0	0	0	0	0	0	0	0	0	0	0	0
Edible Oils	0	0	0	0	0	0	0	0	0	0	0	0	0
Canned Goods	0	0	0	0	0	0	0	0	0	0	0	0	0
Sugar	0	0	0	0	0	0	0	0	0	0	0	0	0
Other food products	0	0	0	0	0	0	0	0	0	0	0	0	0
Beverages	0	0	0	0	0	0	0	0	0	0	0	0	0
Mining and quarrying	4250.1	5239.97	30922.1	80.7583	4.47779	1731.17	4362.93	1899.16	6924.15	3818.79	608.942	3029.6	166826
Steel-Making	0	0	0	0	0	0	0	0	0	0	0	0	0
Metals	0	0	3042.68	42.6902	0	354.314	0	0	0	0	0	0	0
Agricultural Machinery	0	0	0	0	0	0	0	0	0	0	0	0	0
Transport materials	0	0	0	0	0	0	0	0	0	0	0	0	0
Electrical Materials	0	0	0	0	0	0	0	0	0	0	0	0	0
Electronic Materials	0	0	0	0	0	0	0	0	0	0	0	0	0
Household Equipment	0	0	0	0	0	0	0	0	0	0	0	0	0
Chemicals	4907.8	13955.2	12264.2	0	0	0	15076.9	9250.22	5471.18	9551.17	2540.55	0	0
Yarn	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpets	0	0	0	0	0	0	0	0	0	0	0	0	0
Clothing	0	0	0	0	0	0	0	0	0	0	0	0	0
Leather	0	0	0	0	0	0	0	0	0	0	0	0	0
Wood Industry	0	0	0	0	0	0	0	0	0	0	0	0	0
Paper industry	510.055	2446.52	0	0	0	0	0	0	0	0	0	0	0
Plastics	9038.41	0	0	0	0	0	0	0	0	0	0	0	0
Other Manufactured Products	0	0	0	0	0	0	0	0	0	0	0	0	0
Petroleum Oil and Gas	0	0	0	0	0	0	0	0	0	0	0	0	0
Electricity	0	0	0	0	0	0	0	0	0	0	0	0	0
Water	0	0	0	0	0	0	0	0	0	0	0	0	0
Other services													

Table 2. Consumption Emission Coefficients (pounds per thousand TD)

	TOXAIR	TOXWAT	TOXSOL	BIOAIR	BIOWAT	BIOSOL	SO_2	NO_2	CO	VOC	PART	BOD	TSS
Agri (15 activities)	0	0	0	0	0	0	0	0	0	0	0	0	0
Livestock	0	0	0	0	0	0	0	0	0	0	0	0	0
Forestry	0	0	0	0	0	0	0	0	0	0	0	0	0
Fishing	0	0	0	0	0	0	0	0	0	0	0	0	0
Meat	0	0	0	0	0	0	0	0	0	0	0	0	0
1. Ea 0	0	0	0	0	0	0	0	0	0	0	4417.048	0	
Flour-milling	0	0	0	0	0	0	0	0	0	0	0	0	0
Edible Oils	0	0	0	0	0	0	0	0	0	0	0	0	0
Canned Goods	0	0	0	0	0	0	0	0	0	0	0	0	0
Sugar	0	0	0	0	0	0	0	0	0	0	0	0	0
Other food products	0	0	0	0	0	0	0	0	0	0	0	0	0
Beverages	0	0	0	0	0	0	0	0	0	1922.13	0	0	0
Mining and quarrying	0	0	0	0	0	0	37.1835	92.4067	0	0	7.805	0	0
Steel-Making	0	0	0	0	0	0	0	0	0	0	0	0	0
Metals	0	0	0	0.46363	0	0	0	0	0	0	0	0	0
Agricultural Machinery	0	0	0	0	0	0	0	0	0	0	0	0	0
Transport materials	0	0	0	0.00401	0	0	0	0	0	0	0	0	0
Electrical Materials	0	0	0	0	0	0	0	0	0	0	0	0	0
Electronic Materials	0	0	0	0	0	0	0	0	0	0	0	0	0
Household Equipment	0	0	0	0	0	0	0	0	0	0	0	0	0
Chemicals	0	0	0	0	0	0	0	0	0	0	0	0	117.49
Yarn	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpets	0	0	0	0	0	0	0	0	0	0	0	0	0
Clothing	1110.3	0	0	0	0	0	0	0	0	0	0	0	0
Leather	0	0	0	0	0	0	0	0	0	0	0	0	0
Wood Industry	0	0	0	0	0	0	0	0	841.148	380.812	255.338	0	0
Paper industry	85.42	1457.56	233.036	0	0	0	616.813	273.142	226.651	0	78.372	546.2285	575.966
Plastics	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Manufactured Products	0	0	0	0	0	0	0	0	0	396.646	0	0	0
Petroleum Oil and Gas	0	0	0	0	0	0	0	0	0	0	0	0	0
Electricity	0	0	0	0	0	0	0	0	0	0	0	0	0
Water	0	0	0	0	0	0	0	0	0	0	0	0	0
Other services													

Table 3. Planned Removal of Tariffs on Imports from the EU (%)

	1995	1998	2001	2004	2007	2010
Meat	64	64	64	64	64	64
Milk	55	55	55	55	55	55
Flour-milling	35	35	35	35	35	35
Edible oils	29	28	27	25	25	25
Canned goods	39	39	39	39	39	39
Sugar	18	18	17	17	17	17
Other food products	214	211	202	193	192	191
Beverages	49	49	49	46	44	41
Mining and quarrying	31	27	20	10	5	0
Steel-making	18	13	7	1	1	0
Metals	33	28	23	14	7	0
Agricultural machinery	14	7	5	3	1	0
Transport materials	34	31	23	14	6	0
Electrical materials	17	9	6	3	1	0
Electronic materials	25	13	9	4	2	0
Household equipment	48	42	35	22	11	0
Chemicals	24	20	12	3	2	0
Yarn	5	5	4	3	1	0
Carpets	69	62	48	30	21	12
Clothing	2	2	2	1	0	0
Leather	5	5	4	2	1	0
Wood industry	33	31	26	16	8	0
Paper industry	28	25	22	14	7	0
Plastics	29	24	15	7	3	0
Other manufactured products	8	7	5	3	1	0

Source: Chemingui and Dessus (2001).

Table 4. Average Annual Growth Rate of Sectoral Emissions by Production and Consumption 1992-2010 (in %)

Pollutant Type	Baseline Production							Lib EU Production							Lib ROW Production						
	AgFo.	Extr.	Chem.	Text.	O.Man	N.Man	Serv.	AgFo.	Extr.	Chem.	Text.	O.Man	N.Man	Serv.	AgFo.	Extr.	Chem.	Text.	O.Man	N.Man	Serv.
TOXAIR	4.5	5.1	5.4	1.6	7.2	6.1	7.5	4.4	5.3	7.3	1.2	7.8	6.5	7.5	4.4	5.7	9.1	0.9	8.0	6.6	7.4
TOXWAT	4.2	5.1	5.4	3.0	7.1	6.0	6.4	4.2	5.3	7.3	2.6	7.7	6.4	6.4	4.2	5.7	9.1	2.3	7.8	6.5	6.4
TOXSOL	4.3	5.1	5.4	2.9	6.7	6.2	5.8	4.2	5.3	7.3	2.5	7.3	6.6	5.8	4.2	5.7	9.1	2.3	7.5	6.7	5.8
BIOAIR	5.2	5.1	5.4	2.0	6.4	6.2	5.2	5.2	5.3	7.3	1.6	6.8	6.5	5.2	5.2	5.7	9.1	1.3	6.9	6.7	5.2
BIOWAT	5.7	5.1	5.4	2.4	5.1	6.3	4.4	5.7	5.3	7.3	2.0	5.3	6.6	4.3	5.7	5.7	9.1	1.8	5.5	6.7	4.3
BIOSOL	5.3	5.1	5.4	2.1	6.0	6.2	4.8	5.3	5.3	7.3	1.8	6.3	6.6	4.8	5.3	5.7	9.1	1.5	6.4	6.7	4.8
SO_2	4.0	5.1	5.4	3.1	7.3	6.0	6.6	3.9	5.3	7.3	2.7	8.0	6.3	6.6	4.0	5.7	9.1	2.4	8.2	6.4	6.6
NO_2	4.0	5.1	5.4	3.1	7.4	5.9	6.6	3.9	5.3	7.3	2.7	8.1	6.2	6.6	4.0	5.6	9.1	2.4	8.3	6.3	6.6
CO	4.1	5.1	5.4	3.1	6.8	6.2	6.1	4.0	5.3	7.3	2.6	7.3	6.5	6.1	4.0	5.7	9.1	2.4	7.4	6.7	6.1
VOC	4.9	5.1	5.4	3.1	7.3	6.0	6.5	4.9	5.3	7.3	2.7	8.0	6.4	6.5	4.9	5.7	9.1	2.4	8.1	6.5	6.5
PART	4.0	5.1	5.4	3.1	7.2	5.9	6.6	3.9	5.3	7.3	2.7	7.8	6.3	6.6	4.0	5.7	9.1	2.4	7.9	6.4	6.6
BOD	4.8	5.1	5.4	2.3	5.5	6.3	4.4	4.7	5.3	7.3	2.0	5.3	6.6	4.3	4.7	5.7	9.1	1.8	5.4	6.7	4.3
TSS	5.7	5.1	5.4	2.4	5.1	6.3	4.4	5.7	5.3	7.3	2.0	5.3	6.6	4.3	5.7	5.7	9.1	1.7	5.5	6.7	4.3
	Consumption							Consumption							Consumption						
	AgFo.	Extr.	Chem.	Text.	O.Man	N.Man	Serv.	AgFo.	Extr.	Chem.	Text.	O.Man	N.Man	Serv.	AgFo.	Extr.	Chem.	Text.	O.Man	N.Man	Serv.
TOXAIR	0	5.4	5.5	0	5.7	0	0	0	5.6	6.2	0	6.5	0	0	0	5.7	6.5	0	6.7	0	0
TOXWAT	0	5.4	5.5	0	5.5	0	0	0	5.6	6.2	0	6.1	0	0	0	5.7	6.5	0	6.3	0	0
TOXSOL	0	5.4	5.5	0	5.7	0	0	0	5.6	6.2	0	6.2	0	0	0	5.7	6.5	0	6.3	0	0
BIOAIR	0	5.4	0	0	5.7	0	0	0	5.8	0	0	6.2	0	0	0	5.7	0	0	6.3	0	0
BIOWAT	0	5.4	0	0	0	0	0	0	5.6	0	0	0	0	0	0	5.7	0	0	0	0	0
BIOSOL	0	5.4	0	0	5.7	0	0	0	5.8	0	0	6.2	0	0	0	5.7	0	0	6.3	0	0
SO_2	0	5.4	5.5	0	0	0	0	0	5.6	6.2	0	0	0	0	0	5.7	6.5	0	0	0	0
NO_2	0	5.4	5.5	0	0	0	0	0	5.6	6.2	0	0	0	0	0	5.7	6.5	0	0	0	0
CO	0	5.4	5.5	0	0	0	0	0	5.6	6.2	0	0	0	0	0	5.7	6.5	0	0	0	0
VOC	0	5.4	5.5	0	0	0	0	0	5.6	6.2	0	0	0	0	0	5.7	6.5	0	0	0	0
PART	0	5.4	5.5	0	0	0	0	0	5.6	6.2	0	0	0	0	0	5.7	6.5	0	0	0	0
BOD	0	5.4	0	0	0	0	0	0	5.6	0	0	0	0	0	0	5.7	0	0	0	0	0
TSS	0	5.4	0	0	0	0	0	0	5.8	0	0	0	0	0	0	5.7	0	0	0	0	0

Table 5. Annual Growth Rate of Production in the Three Benchmark Scenarios (2001-2010 in %)

	Baseline	Lib EU	Lib ROW		Baseline	Lib EU	Lib ROW
AgriFood	4.2	4.1	4.1	Paper industry	5.8	5.3	5.3
Mining and quarrying	5.1	5.2	5.6	Plastics	6.5	6.5	6.9
Steel-making	4.0	3.7	3.8	Other manufactured products	7.3	7.7	7.8
Metals	6.7	6.4	6.6	Petroleum oil and gas	0.3	0.3	0.3
Agricultural machinery	6.3	5.9	5.9	Electricity	4.0	4.2	4.6
Transport materials	6.3	5.7	5.7	Water	4.0	4.1	4.2
Electrical materials	6.1	8.0	8.5	Construction	6.3	6.6	6.7
Electronic materials	3.0	3.6	3.9	Commerce	6.1	6.4	6.6
Household equipment	6.1	6.1	6.2	Transport	7.2	7.2	7.2
Chemicals	5.4	7.2	9.0	Communication	7.5	7.7	7.6
Yarn	3.5	3.0	2.8	Hotels and restaurants	6.5	6.4	6.4
Carpets	7.3	7.1	7.1	Finance	6.9	7.0	7.2
Clothing	1.5	1.1	0.7	Real estate	9.5	9.6	9.6
Leather	13.2	15.8	15.8	Repairs	8.6	8.8	8.8
Wood industry	6.3	6.1	5.9	Health	7.7	7.7	7.8

Table 6. Emission Growth Decomposition (%)

With Respect to Production

Pollutant Type	Baseline scenario			Lib EU			Lib ROW		
	Tech	Scale	Comp	Tech	Scale	Comp	Tech	Scale	Comp
TOXAIR	-13.9	1.8	112.1	5.4	2	92.6	21.6	1.8	76.6
TOXWAT	0.2	1.8	98	19.3	1.9	78.7	34.9	1.7	63.4
TOXSOL	0.5	1.5	98	18	1.7	80.3	32.8	1.5	65.6
BIOAIR	4.4	0.4	95.2	13.4	0.9	85.7	22.5	1.0	76.5
BIOWAT	0	2.0	98	13.6	1.5	84.8	27.2	1.2	71.6
BIOSOL	2.2	0.6	97.2	13.6	1.1	85.3	24.9	1.1	73.9
SO_2	0	2.1	97.9	20.8	2.1	77.1	37	1.8	61.3
NO_2	-0.3	2.2	98.1	20.9	2.0	77.1	37.2	1.7	61.1
CO	0.7	1.7	97.6	18.9	1.8	79.3	34	1.6	64.4
VOC	1.4	1.8	96.8	20.1	1.9	78	35.3	1.6	63.1
PART	0.9	1.9	97.2	20.6	2.1	77.3	36.3	1.6	62.1
BOD	-5.7	0	105.7	-1.7	0.8	100.8	3.9	0.8	95.3
TSS	-0.3	0.9	99.4	13.8	1.3	84.9	27.3	1.3	71.4

With Respect to Consumption

Pollutant Type	Baseline scenario			Lib EU			Lib ROW		
	Comp	Tech	Scale	Comp	Tech	Scale	Comp	Tech	Scale
TOXAIR	13.7	0.0	86.3	26.7	0.0	73.3	34.3	0.0	65.7
TOXWAT	18.1	0.0	81.9	46.1	0.0	53.9	60.2	0.0	39.8
TOXSOL	17.8	0.0	82.2	40.8	0.0	59.2	54.0	0.0	46.0
BIOAIR	16.8	0.0	83.2	21.5	0.0	78.5	24.6	0.0	75.4
BIOWAT	20.0	0.0	80.0	20.0	0.0	80.0	33.3	0.0	66.7
BIOSOL	16.1	0.0	83.9	21.9	0.0	78.1	26.8	0.0	73.2
SO_2	19.0	0.0	81.0	49.2	0.0	50.8	63.7	0.0	36.3
NO_2	18.8	0.0	81.3	50.0	0.0	50.0	63.7	0.0	36.3
CO	17.6	0.0	82.4	46.2	0.0	53.8	60.3	0.0	39.7
VOC	19.2	0.0	80.8	48.8	0.0	51.2	63.6	0.0	36.4
PART	15.4	0.0	84.6	50.0	0.0	50.0	64.3	0.0	35.7
BOD	0.0	0.0	100.0	25.0	0.0	75.0	25.0	0.0	75.0

TSS	14.5	0.0	85.5	23.2	0.0	76.8	31.5	0.0	68.5