INTERNATIONAL JOURNAL OF BUSINESS POLICY AND ECONOMICS
Vol. 3, No. 2, (2010) : 249-264

# POLICY MEASURES AIMING AT REDUCING $CO_2$ EMISSIONS: AN ANALYSIS OF THE GREEK EXPERIENCE

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*Nowadays, it is generally acknowledged either by developed or emerging economies that their sustainability depends on capabilities to reduce the levels of $CO_2$ emissions at commonly acceptable levels. However, the way this target is achieved at country-specific level is less recognized since this issue is often marginalized by researchers in the field. In this paper, there is an effort to examine the effectiveness of some energy taxation measures to combating future $CO_2$ emissions associated with projected energy demand. To this end, we focus on the experience of EU member countries such as Greece and analyse relevant measures' effectiveness by using a dynamic forecasting methodology for the period 2004-2015. Our findings reveal that outcomes are differentiated depending on alternative scenarios employed concerning changes in energy taxes. Further, it becomes evident that the government cannot tackle environmental pollution simply by adjusting the level of energy taxation. A unique combination of various government policy measures (tradable permits, command and control measures, etc.) forms a more solid basis to attaining the lower pollution target.*

***JEL:*** *L5.*

***Keywords:*** *Policy measures; Environmental pollution; Energy taxation; Greece.*

## 1. INTRODUCTION

Pollution, more specifically air pollution, constitutes a major global problem that needs to be tackled effectively by all countries or, at least, the major polluting ones (Rapanos and Polemis, 2005, page 1781). In the last two decades, several attempts have been made mainly under the auspices of the United Nations (Rio Earth Summit in 1992, Kyoto Protocol in 1997, Marrakech Accords in 2001, Montreal Conference in 2005) to reach an agreement at a global level to decrease pollution. In this respect, the most prominent event is the Kyoto agreement, which aims at reducing the emissions of a bundle of dangerous gases (greenhouse gases). The Kyoto Protocol sets out specific commitments for the industrialized countries and the European Union (EU) for the period 2008-2012. The overall target agreed is a reduction of the main six greenhouse gases (GHG) by at least 5.0% below 1990 levels over the period 2008-2012[1].

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Within this five years period, Greece, under the Kyoto's principle of countries' 'common but differentiated responsibilities', is committed to limit its greenhouse gas emissions, at +25% against the 1990 baseline year. This target is to be achieved through a number of actions that run across all sectors of the economy at national and European level and, specifically, the energy sector (Rapanos and Polemis, 2005, page 1781). It is worth mentioning that one of the most effective measures apart from energy taxation is the international emissions trading scheme. Greece, as a full member of the EU, has ratified both the Kyoto Protocol (Law 3017/2002) and the European Directive 2003/87/EC that sets out a pan-European emissions trading system.

In Greece, the indirect energy taxes are levied on (liquid) fuels (gasoline, oil for heating or transport purposes, etc) except for electricity and natural gas which when consummed for specific uses (i.e industrial use) are exempted from any form of taxation (i.e. excise tax and VAT). Energy taxes are mainly livied on the consumption of liquid fuels in order to increase governemnt revenues through the financing of the public budget. In 2002, fuel taxes accounted for 12% of total public revenues derived from indirect taxation, the value added tax (VAT) included.

It is woth mentioning that not all liqued fuels bear the same level of an excise tax , since the government makes an effort to place higher specific taxes on products used by final consumers and lower ones on those mainly used by producers or intermediate consumers (i.e industrial users). This is done in an effort to minimise the deadweight loss incurring from taxation on production inputs (Kaplanoglou and Newbery, 2002, page 10).

Compared with other European countries (Denmark, Germany, United Kingdom, France, Sweden, etc), the majority of energy taxes in Greece are well bellow the EU unweighted average. This is especially true for gasoline and heating oil on both of which the allocated excise taxes are set almost at the lowest level permitted by the government, with the excise tax on gasoline (unleaded petrol) and heating oil amounting to 60% of the EU unweighted average. On the other hand, oil for industrial purposes (light fuel oil) is severely taxed, at almost double rates than the EU unweighted average (Kaplanoglou and Newbery, 2002, page 26). The main reason for this discrepancy is mainly attributed to the fact that in the previous decade, Greek government used energy taxation as an anti-inflationary means in order to be able to join successfully the European Monetary Union (EMU). However, within the last few years and following the Spanish proposal concerning the harmonisation of the energy taxes within the EU, a pan-European energy tax reform scheme has become unquestionable. The well functioning of the internal energy market and the objective for a sustainable development which goes hand by hand with a coherent environmental awareness, forced the European leaders to design and implement an integrated energy tax reform scheme[2].

Following a long period of consultation, a new European Directive (2003/96/EC) came into force on the 1st of January 2004. This Directive sets minimum levels of taxation to be laid down at Community level for most energy products, including electricity, natural gas and coal. Table 1 shows the necessary changes for Greece in order to harmonize energy taxes to the levels proposed by this

Directive to sectors and products where the implementation of the minimum rates modifies the existing levels of energy taxation. According to the latter, Greece is well above the proposed rates for products like diesel for heating and industrial purposes (light fuel oil). Further, the existing excise tax for heavy fuel oil (mazout) is by 21% higher than the level proposed by the Directive (15 Euro/1000 kg)[3].

**Table 1**
**Minimum Excise Tax Rates Proposal***

| *Sectors / fuel* | *2004* | *2010* |
|---|---|---|
| | **Residential sector** | |
| Electricity | 1 euro/MW (0 euro/MW) | 1 euro/MW |
| Heating oil | 21 euro/1000l (121 euro/1000l)+ | 21 euro/1000l |
| | **Road sector** | |
| Unleaded petrol | 359 euro/1000l (296 euro/1000l) | 359 euro/1000l |
| Super unleaded /LRP | 421 euro/1000l (337 euro/1000l) | 421 euro/1000l |
| Diesel oil | 302 euro/1000l (245 euro/1000l) | 330 euro/1000l |
| | **Industrial sector** | |
| Electricity | euro/MW (0 euro/MW) | 0.5 euro/MW |
| Light fuel oil | 21 euro/1000l (121 euro/1000l)+ | 21 euro/1000l |
| Heavy fuel oil (mazout) | 15 euro/1000kg (19 euro/1000kg) | 15 euro/1000 kg |

(*) Numbers in parenthesis present the current level of energy excise taxes (2004).

13. (+) The level of taxation accounts for the year 2003.

*Source:* ÉÅÁ (2004) – Energy Prices and Taxes (1st quarter) and European Directive 2003/96/EC.

It is crucial to mention that light fuel oil (LFO) for industrial use stands out as heavily taxed in several EU countries, like Greece, Italy and Portugal, probably due to public authorities difficulties in controlling tax evasion through the use of other means (Newbery, 2001, page 2). Countries like Denmark, the Netherlands, Sweden, Finland and United Kingdom will have to apply only minor changes, while changes are more important in countries such as Ireland, Spain, Portugal and Greece. Hence, the burden of the new energy taxation will differ substantially among the EU member countries.

The forecasting of the evolution of energy demand through independent estimates for the residential, road and industrial energy-consumption sub-sectors is rather a crucial matter towards a sound energy policy development, though a complicated one. This paper is both in time with the European Directive (2003/96/EC) concerning the minimum levels of energy taxation in EU countries and in alignment with the Kyoto Protocol standards. Despite the importance of this topic for the formation of an energy policy able to capture the goal of the full liberalization of the energy markets (electricity and natural gas) in countries like Greece, rather a few studies have dealt with it up to present. Some prior studies have examined the issue of a simulated energy demand and the associated with it $CO_2$ or greenhouse gas emissions (see Christodoulakis *et al.*, 2000, RAE, 2003a, Agoris *et al.*, 2004, MINENV 2004, Polemis, 2006) but they have neglected the study of changes in the energy taxation mechanism. The issue of examining the projected energy consumption combined with the associated $CO_2$ emissions and in turn exploring adjustments on the level of the indirect energy taxation has been traced first by Kouvaritakis *et al.*, (2002). This work exemplifies inter alia the economic and environmental impact of the energy tax policies in the EU by the implementation of the Spanish proposal (imposing EU-wide minimum tax rates on a wide range of energy products). However, this work though originally of great interest, recently has been out-dated due to certain differences realized between the Spanish proposal and the new European Directive 2003/96/EC. This paper aims to fill this research gap.

Energy demand forecasting models can be classified into two major categories. The first one refers to the computable general equilibrium models (CGE). In CGE models (i.e PRIMES, RAINS, ENPEP, GEM-E3, R-MARKAL and WASP IV), the economy is considered to be at an equilibrium state with constant returns to scale, perfect competition in all sectors of production and full employment. The second category (partial equilibrium models) comprises the vast majority of energy models. The latter use an econometric methodology (e.g. Box-Jenkins or VAR methodology) and project energy demand or carbon dioxide emissions for a distinct period in time according to alternative policy scenarios. In partial equilibrium models, the main determinants of energy demand and supply are thoroughly examined through the inclusion of distinct energy sub-models (e.g. division by sector or by fuel). The existence of discrete sub-models, allows a more detailed representation of the energy demand by taking into account its specific structural and technological characteristics (Mantzos, 1997, page 21).

The purpose of this paper is to assess the effectiveness that fuel taxes may have on reducing $CO_2$ emissions in countries like Greece. For this reason, we simulate energy demand decomposed on to three main energy-consumption sub-sectors (residential, road and industrial sector) for the period 2004-2015. The results of the analysis depend on the three policy scenarios that capture both the minimum applied energy tax rates and the compliance with the Kyoto target. The very recent oil crisis, the need to achieve the Kyoto constraints concerning the increase of the greenhouse gases, and the liberalisation of the energy markets, are some of the issues that similar countries should examine in detail in order to establish a sound energy policy for the forthcoming years. The main difference of this paper compared to earlier relevant work is the full consideration of the Directive 2003/96/EC which requires the new indirect taxation levels to cover the majority of the energy products.

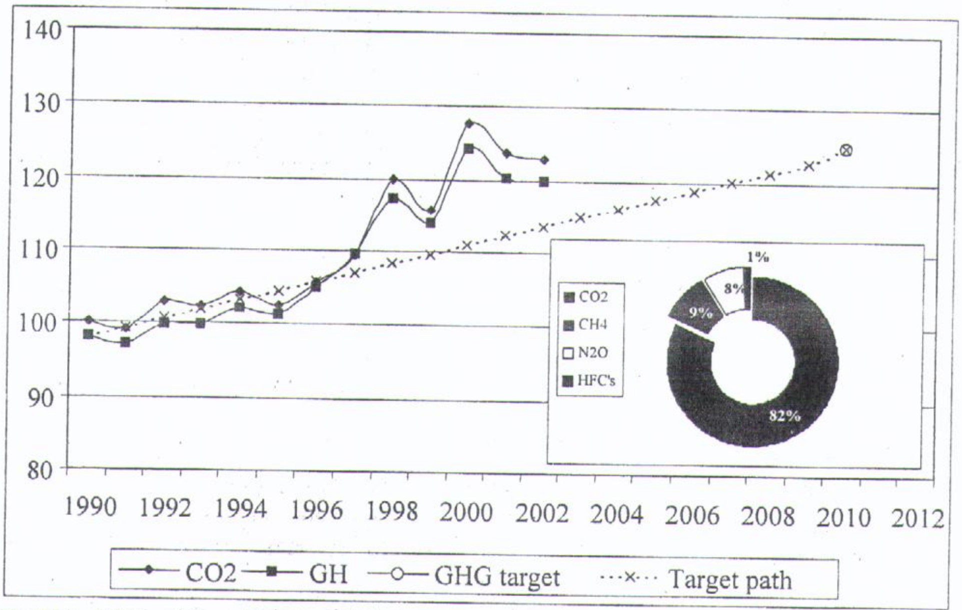
The paper consists of five sections. In Section 2, a detailed overview of the evolution of carbon dioxide emissions in Greece is provided, together with a short presentation of its main determinants. In section 3, a description of the empirical model is presented together with the main points of the energy policy scenarios. Section 4 discusses the main results of the relevant forecasts for the period 2004-2015. Finally, section 5 highlights the main concluding remarks and provides some policy implications.

## 2. CARBON DIOXIDE EMISSIONS IN GREECE

Carbon dioxide is one of the most dangerous greenhouse gases and is released by huge amounts to the atmosphere from the combustion of energy products such as lignite, coal, oil, and natural gas.

The trends of $CO_2$ and GHG emissions from 1990 to 2002 are presented in Fig. 1 together with the decomposition of GHG emissions with reference to the latest year (i.e. 2002). More specifically, carbon dioxide emissions, increased within the reference period (1990-2002) by 23% (1.7% per annum) reaching the level of 103, 6 million tonnes in 2002. This upward trend is mainly attributed to increased electricity production as well as the increased energy consumption in the residential and transport sectors (MINENV, 2004, page 22). GHG emissions have shown a similar upward trend which is equal to 22.4% reaching the level of 135 million tonnes $CO_2$ equivalent at end period (i.e. 2002). This increase was mainly due to the increase of emissions from electricity production sector as a result of the high electricity demand from the residential and tertiary sectors (MINENV, 2004, page 22). It is worth noting that the main source of GHG emissions comes from the energy sector (households, electricity production, transportation, industry and construction) which in 2002 accounted for 77% of total GHG emissions.

**Figure 1**
**Evolution and Decomposition of GHG Emissions in Greece (1990-2002)***




(*) 1990 =100 for $CO_2$ emissions and 1995=100 for GHG emissions.
*Source:* MINENV (2004).

Carbon dioxide emissions from the energy sector have risen continuously within the period 1990-2002 by 28% (2.1% per annum), from 76, 4 million tonnes in 1990 to 97, 8 million tonnes in 2002. Carbon dioxide emissions from the industrial processes have shown a modest rate of growth that equals to 22%. The main causes that trigered $CO_2$ emissions in the above mentioned sector can be attributed to the expanded production of both the non-metallic mineral products industry (cement, lime ammonia, alumina) and the basic metal industry (iron and steel, copper). According to the previous analysis it is obvious that GHG emissions deviate from the critical target path set by the Kyoto Protocol.

Carbon dioxide emissions, from the industrial sector have risen within the period 1990-2002, by 4.1% (0.4% per annum), from 16, 1 million tonnes $CO_2$ in 1990 to 16, 7 million tonnes $CO_2$ in 2002. Despite the overall increase, $CO_2$ emissions in energy industries show a decreasing trend in the period 1990-1994 due to the reduction of the industrial activity in Greece.

Transport sector is also a major contributor of GHG emissions in Greece and is responsible for the 19.4% of total $CO_2$ emissions in the energy sector. The majority of carbon dioxide emissions derived from road transport, the contribution of which increased from 77% in 1990 to approximately 84% of total emissions of the sector, since the vehicle fleet has doubled between 1990 and 2002 (MINENV, 2004, page 48). Transport $CO_2$ emissions have increased substantially within the period 1990-2002 by 26.4% or 2.2% per annum (from 17, 7 million tonnes $CO_2$ in 1990 to 22, 3 million tonnes $CO_2$ in 2002). This evolution is attributed to the increase of motor gasoline and diesel oil consumption, two of the most conventional (road) energy products and to a lesser extent to the electricity consumption (e.g. street lightning, subway, etc.).

Finally, $CO_2$ emissions from the residential sector increased significantly in the period 1990-2002 by 4.6% per annum reaching the level of 13, 6 million tonnes $CO_2$ in 2002. This trend, which is expected to slowdown within the next ten years due to the increasing use of natural gas is explained by the great increase of liquid fuel consumption since 1996 (MINENV, 2004, page 45).

## 3. EMPIRICAL METHODOLOGY

In order to simulate carbon dioxide emissions for the three relevant energy-consumption sectors in Greece, we employed an error-correction methodology. Having specified the error-correction models for each sector (residential, road and industrial sector), we utilized the method of dynamic forecasting and projected energy demand for the period 2004-2015[4].

### 3.1 Dynamic Forecasting

Forecasting is complicated by the presence of lagged dependent variables on the right-hand side of the equation. In other words, some questioning is raised as to how we should assess the lagged value of the dependent variable that appears on the right-hand side of the equation.

The selection of the start of the forecast sample is very important for the dynamic forecasting. Dynamic forecasts are true multi-step forecasts (from the start of the forecast sample), since they use the recursively computed forecast of the lagged value of the dependent variable. These forecasts may be interpreted as the forecasts for subsequent periods that would be computed using information available at the start of the forecast sample. Dynamic forecasting requires that data for the exogenous variables be available for every observation in the forecast sample, and that values for any lagged dependent variables be observed at the start of the forecast sample (here 2003).

In order to explain the mechanism of the dynamic forecasting and for the sake of simplicity we present a single lag specification as given by the following equation:

$$y_t = a + bx_t + cz_t + dy_{t-1} + u_t \tag{1}$$

where $x_t$ and $z_t$ represent explanatory variables and $y_{t-1}$ is the lagged dependent variable. Dynamic forecasting will perform a multi-step forecast of $Y$, beginning at the start of the forecast sample. Therefore, the initial observation in the forecast sample will use the actual value of lagged dependent variable $Y$. Thus, if $S$ is the first observation in the forecast sample, then equation (1) takes the following form:

$$\hat{y}_S = \hat{a} + \hat{b}x_S + \hat{c}z_S + \hat{d}y_{S-1} \tag{2}$$

where $y_{S-1}$ is the value of the lagged endogenous variable in the period prior to the start of the forecast sample (2003). This is one-step ahead forecast. Forecasts for subsequent observations will use the previously forecasted values of $Y$:

$$\hat{y}_{S+K} = \hat{a} + \hat{b}x_{S+K} + \hat{c}z_{S+K} + \hat{d}\hat{y}_{S+K-1} \tag{3}$$

where $\hat{y}_{S+K-1}$ stands for the previously forecasted value.

According to the previous mentioned analysis we applied the method of dynamic forecasting to the following equations (that could be transformed to error-correction models). Equations 4 and 5 refer to residential sector while equations 6 and 7 project energy demand in road sector. Finally, the predicted industrial $CO_2$ emissions stems form the equations 8 and 9.

$$\begin{aligned}\Delta(coil_t) = {} & b_0 + b_1\Delta(gdp_t) + b_2(coil_{t-1}) + b_3(gdp_{t-1}) + b_4\Delta(rpoil_t) \\ & + b_5(rpoil_{t-1}) + b_6(trend_{t-1})\end{aligned} \tag{4}$$

$$\begin{aligned}\Delta(celec_t) = {} & b_0 + b_1\Delta(gdp_t) + b_2(celec_{t-1}) + b_3(gdp_{t-1}) + b_4\Delta(rpelec_t) \\ & + b_5(rpelec_{t-1}) + b_6\Delta(hous_t) + b_7\Delta(hous_{t-1}) + b_8\Delta(hdd_t) \\ & + b_9\Delta(rplpg_t) + b_{10}(rplpg_{t-1}) + b_{11}(trend_{t-1})\end{aligned} \tag{5}$$

$$\begin{aligned}\Delta(gasol_t) = {} & b_0 + b_1\Delta(gdp_t) + b_2(gasol_{t-1}) + b_3(gdp_{t-1}) + b_4\Delta(rpgasol_t) \\ & + b_5(rpgasol_{t-1}) + b_6(rpdiesel_t) + b_7(rpdiesel_{t-1}) \\ & + b_8(trend_{t-1})\end{aligned} \tag{6}$$

$$\begin{aligned}\Delta(diesel_t) = {} & b_0 + b_1\Delta(gdp_t) + b_2(diesel_{t-1}) + b_3(gdp_{t-1}) + b_4\Delta(rpdiesel_t) \\ & + b_5(rpdiesel_{t-1}) + b_6\Delta(gasol_t) + b_7\Delta(rpgasol_{t-1}) \\ & + b_8(parcd_t) + b_9\Delta(parcd_{t-1})\end{aligned} \tag{7}$$

$$\begin{aligned}\Delta(oil_t) = {} & b_0 + b_1\Delta(dbp_t) + b_2(oil_{t-1}) + b_3(dbp_{t-1}) + b_4\Delta(rpoil_t) \\ & + b_5(rpoil_{t-1}) + b_6\Delta(rpelec_t) + b_7(rpelec_{t-1}) + b_8\Delta(hdd_t) \\ & + b_9(trend_{t-1})\end{aligned} \tag{8}$$

$$\Delta(elec_t) = b_0 + b_1\Delta(dbp_t) + b_2(elec_{t-1}) + b_3(dbp_{t-1}) + b_4\Delta(rpelec_t) + b_5(rpelec_{t-1}) + b_6\Delta(rpoil_t) + b_7(rpoil_{t-1}) + b_8\Delta(hous_t) + b_9\Delta(hous_{t-1}) + b_{10}\Delta(hdd_t) + b_{11}(trend_{t-1}) \quad (9)$$

where coil is the annual consumption of heating oil, gdp is the real gross domestic product, rpoil is the price of heating oil deflated by the consumer price index (real price), trend is a linear time trend denoting technological progress, celec is the annual consumption of electricity, rpelec is the real price of electricity, hous is the number of consumers, hdd is the heating degree days, rplpg is the real price of LPG, gasol is the per capita consumption of gasoline, rpgasol is the real price of gasoline, rpdiesel is the real price of diesel oil for transport purposes, parcd is the per capita petrol-engined vehicle fleet, oil is the annual consumption of oil products in the industrial sector (diesel, heavy fuel oil), dbp is the industrial production index and rpoil is the real price of oil in industry.

### 3.2 Policy Scenarios

In order to conduct the emissions projections for the period 2004-2015 we consider three alternative scenarios. The 'most probable' scenario (MP) employs the evolution of energy demand and the relevant carbon dioxide emissions and encapsulates the major trends of present energy policy (liberalisation of electricity and gas markets, continued promotion of renewable energy sources, energy efficiency, etc). However, no measures for complying with the obligations of the Kyoto Protocol are implemented (e.g carbon taxes, emissions-based command and control measures, etc). The scenario assumes a long-term economic growth of Greece above the EU average (see Table 2), while energy prices are assumed to gradually increase from the low levels of the early 2000's following (on average) a smooth ascending path. Finally, energy taxes (taxes on electricity and liquid fuels) are equal to the levels proposed by the European Directive 2003/96/EC.

The 'optimistic' scenario (OP) differs from the former one only to the extent of energy taxation. More specifically, it is assumed that energy taxes are harmonised to the European Union average tax level for the period 2012-2015[5].

Finally, the 'environmental' scenario (EC) adopts a full implementation of the Kyoto Protocol without any greenhouse gas emission (GGE) trading. The distribution of the $CO_2$ emissions reduction between the Member states follows the Burden Sharing Agreement. According to the latter, Greece will have to restrict the average growth of the emissions of al six greeenhouse gases, for the period 2008-2012, to +25% compared to 1990 levels. This target is to be achieved through a number of actions at national and pan-European level that captures all sectors of the economy and particularly the energy sector (Rapanos and Polemis, 2005, pages 1781-1782). Due to certain difficulties in calculating GGE other than $CO_2$ emissions (mispecified methodology) the relevant Kyoto target must be achieved in 2010 and refers solely to carbon dioxide emissions (RAE, 2003a, page 61). The $CO_2$ emissions path by sector of economic activity is presented in the following Table 3[6].

**Table 2**
**The Structure of the Three Scenarios***

| *Variables* | *Most probable scenario (MP)* | *Optimistic scenario (OP)* | *Environmental scenario(EC)* |
|---|---|---|---|
| GDP | 3.9 per cent increase (2004)<br>4.0 per cent increase (2005)<br>3.3 per cent increase (2006-2009)<br>3.0 per cent increase (2010-2015) | 3.9 per cent increase (2004)<br>4.0 per cent increase (2005)<br>3.3 per cent increase (2006-2009)<br>3.0 per cent increase (2010-2015) | 3.9 per cent increase (2004)<br>4.0 per cent increase (2005)<br>3.3 per cent increase (2006-2009)<br>3.0 per cent increase (2010-2015) |
| Energy prices | 0.58 and 0.59 per cent increase in oil and gasoline price respectively and 1.5 per cent decrease in electricity price | 0.58 and 0.59 per cent increase in oil and gasoline price respectively and 1.5 per cent decrease in electricity price | 0.58 and 0.59 per cent increase in oil and gasoline price respectively and 1.5 per cent decrease in electricity price |
| Consumer price index (CPI) | 2,3 per cent increase for the period 2004-2008 and 2 per cent increase thereafter | 2.3 per cent increase for the period 2004-2008 and 2 per cent increase thereafter | 2.3 per cent increase for the period 2004-2008 and 2 percent increase thereafter |
| Wholesale price index (WPI) | 0.5 per cent decrease for the period 2004-2010 and 0.8 per cent increase thereafter | 0.5 per cent decrease for the period 2004-2010 and 0.8 per cent increase thereafter | 0.5 per cent decrease for the period 2004-2010 and 0.8 per cent increase thereafter |
| Taxation | Harmonization to the European Directive 2003/96/EC | Harmonization to the European Union average tax level | Full compliance with the Kyoto target |
| Period | 2004-2015 | 2004-2015 | 2004-2015 |

(*) Forecasted period for residential sector 2003-2015.
*Source:* European Commission (2003).

**Table 3**
**Sectoral Distribution of $CO_2$ Emissions in the Environmental Scenario***

| *$CO_2$ emissions / sector (million tonnes $CO_2$)* | *1990* | *1995* | *2000* | *2005* | *2010* | *2015* |
|---|---|---|---|---|---|---|
| Residential sector | 4.1<br>(0.0) | 4.4<br>(0.0) | 7.3<br>(0.0) | 5.0<br>(−52.8) | 4.2<br>(−74.5) | 4.2<br>(−82.7) |
| Road sector | 11.7<br>(0.0) | 13.7<br>(0.0) | 16.0<br>(0.0) | 16.4<br>(−12.0) | 16.3<br>(−26.9) | 16.1<br>(−40.8) |
| Industrial sector | 5.3<br>(0.0) | 5.0<br>(0.0) | 5.1<br>(0.0) | 5.2<br>(−9.4) | 5.8<br>(−2.1) | 6.0<br>(−45.1) |
| Total | 21.1<br>(0.0) | 23.1<br>(0.0) | 28.5<br>(0.0) | 26.5<br>(−24.4) | 26.3<br>(−41.7) | 26.3<br>(−58.4) |
| | **$CO_2$ increase (1990 = 100)** | | | | | |
| Households | 100.0 | 106.7 | 177.2 | 119.7 | 101.3 | 102.0 |
| Road | 100.0 | 117.4 | 137.1 | 140.8 | 140.0 | 138.4 |
| Industry | 100.0 | 94.6 | 98.0 | 98.2 | 110.0 | 113.4 |
| **Total** | **100.0** | **109.6** | **135.2** | **126.0** | **125.0** | **125.0** |

(*) Numbers in parenthesis reflect changes according to the most probable scenario (MP).
*Source:* Authors' calculations.

## 4. EMPIRICAL RESULTS

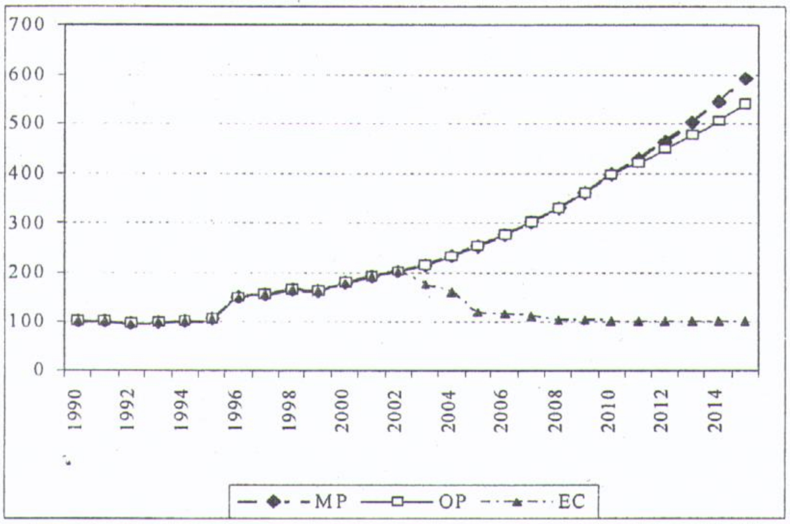
### 4.1 Residential Sector

Carbon dioxide emissions from the residential sector result from energy consumption for heating in order to cover mostly the needs for space and water heating. Thermal needs in households as well as in the tertiary sector, are covered almost exclusively by liquid fuels and to a lesser extent by electricity and other alternative fuels such as fuel woods, LPG, biomass, etc. (MINENV, 2004, page 44)[7].

$CO_2$ emissions for the period 1990-2015 are calculated and presented in the following Figure 2[8]. In the most probable scenario (MP), carbon dioxide emissions are expected to increase by 8.9% within the period 1995-2015 reaching the level of 24, 5 million tonnes $CO_2$ in the long-run (2015). As a result, residential energy intensity (emissions/value added) will follow a similar pattern (4.8% annual increase within the period 2005-2010). This increase could be partially explained by the low level of excise tax in heating oil (21 euro/1000 litres). The low level of heating oil taxation in Greece compared to other European countries (i.e. Italy, Sweden, Denmark) reveals the high degree of households' dependency on this fuel since it has a more 'competitive' final price than its main substitutes (natural gas and to a lesser extent electricity). On the other hand, due to a significant reduction in the number of agriculture households, the use of biomass that can be used as a heating fuel in wooden stoves has shown a significant decrease within the last years. This evolution induced a tremendous rise in the consumption of heating oil (RAE, 2003a, page 33).

The weakness of restricting $CO_2$ emissions to the Kyoto target for 2010 (1.3% compared to 1990 levels), reveals the low penetration of natural gas and the

**Figure 2**
**Residential $CO_2$ Emissions Under the Three Policy Scenarios (1990 = 100)**




*Source:* Authors' calculations.

renewable energy sources (solar and wind energy) in total final residential consumption. However, it must be noted that Greece has been granted derogation as an emerging gas market regarding the implementation of the European Directive (2003/55/EC)[9].

By contrast, the annual growth rate of $CO_2$ emissions in the optimistic scenario (OP) is simulated to slow down since carbon dioxide emissions are expected to increase within the period 2010-2015 by 6.4% compared to 8.3% (MP). However, the harmonization to the EU average tax level – regarding heating oil – does not satisfy the Kyoto target. This means that additional measures should complement the government tax policy in order to make the attainment of the target feasible (Rapanos and Polemis, 2005, page 1787). For example, the government could introduce strict standards for the residential central heating system in order to enhance energy saving and the effectiveness of the sector.

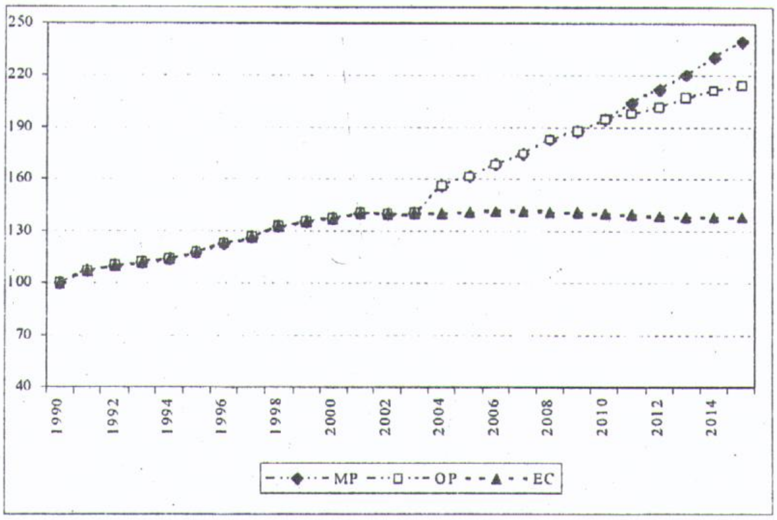
In the environmental scenario (EC), the level of carbon dioxide emissions is expected to decrease by 3.6% within the period 2000-2015 reaching the level of 4,2 million tonnes $CO_2$ (2015). The Kyoto target constraint is equivalent to imposing a relevant high excise tax for heating oil (325 euros/1000 litres), which does not seem to be feasible in the mid-term. The restriction of carbon dioxide emissions to their 'optimum' level is expected to lead to an improvement in the energy intensity (decrease by approximately 2.2% per annum within the period 2000-2015). This means that the Greek households adjust the level of their energy needs more slowly than income variations (energy saving).

## 4.2 Road Dector

The transportation sector in Greece is a major and steadily increasing source of $CO_2$. Combustion of gasoline, diesel oil and LPG in road transport is the primary sources of carbon dioxide emissions (Agoris *et al.*, 2004, page 2024). It is worth mentioning that $CO_2$ emissions in 2002 increased by approximately 44% compared to 1990 emissions, while $N_2O$ emissions tripled from 1990 due to the increase of new technology (catalytic) passenger cars (Polemis, 2006, page 386).

The future level of carbon dioxide emissions for road sector under the three alternative scenarios is presented in Figure 3. In the most probable scenario, total $CO_2$ emissions from gasoline and diesel oil consumption, are expected to increase by about 3.5% per annum (1990-2015). More specifically, emissions generated from the combustion of motor gasoline will get tripled with an annual growth rate of 4.3% reaching 20, 9 million tonnes of oil equivalent in 2015. $CO_2$ emissions from the consumption of oil for transport purposes (diesel oil) are expected to show a modest annual growth rate (1.5%). This is attributed to the fact that demand for diesel oil, which is mainly used as a propellant in tracks and other commercial vehicles has been stabilized within the last years. The harmonization of the excise taxes to the minimum levels proposed by the Directive will bring a significant increase to the per capita level of emissions. The latter, are expected to rise within the reference period (1990-2015) by about 3.0% annually in order to reach the level of 2, 4 million tonnes of $CO_2$ in 2015.

**Figure 3**
**Road $CO_2$ Emissions Under the Three Policy Scenarios (1990 = 100)**




*Source:* Authors' calculations.

However, if government wishes to implement more strict tax policy by setting the energy excise taxes to the EU average level (OP) then $CO_2$ emissions will increase by 3.0% per annum (from 11, 6 million tonnes $CO_2$ in 1990 to 24, 3 million tonnes $CO_2$ in 2015). In order to follow the Kyoto target path (40% in 2010), energy tax policy must be combined with other (environmental) policy instruments. Two of the most effective measures are the expansion of road network with the 'promotion' of public transportation and the development of an environmental incentive-based framework (Polemis, 2006, page 401)[10].

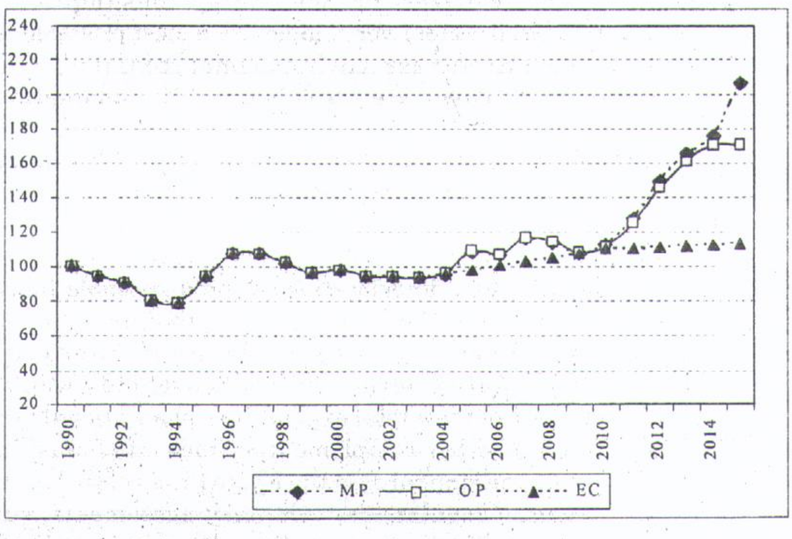
The Kyoto target is achieved through the imposition of higher excise taxes on gasoline and diesel oil. More specifically, the excise tax on gasoline and diesel oil must be set to 592 and 463 euro/1000 litres respectively. $CO_2$ emissions generated by gasoline consumption (super L.R.P and unleaded) are expected to increase by 1.5% per annum within the period 1990-2015 reaching the level of 10, 6 million tonnes $CO_2$ in 2015. This evolution is mainly attributed to the implementation of the Áuto Oil II program, which sets strict environmental regulations for the refining and processing of crude oil and the ACEA/JAMA/KAMA agreement[11]. Finally, carbon dioxide emissions from the consumption of diesel oil will show an increase by about 1.0% relative to 1990 levels for the environmental scenario approaching 5, 6 million tonnes $CO_2$ in the mid-term (2015).

### 4.3 Industrial Sector

Emissions in industry arise from the combustion of fossil fuels to meet the demand for heat and steam production. $CO_2$ emissions from industrial processes are mainly due to the production of cement and lime (Agoris *et al.*, 2004, page 2024).

As presented in Figure 4, both in the most probable (MP) and the optimistic scenario (OP), Greece converges to the Kyoto target within the period 2004-2010, but thereafter the level of excise taxes on industrial sector (light fuel oil, mazout and electricity) is not capable enough to achieve the environmental constraint.

**Figure 4**
**Industrial $CO_2$ Emissions Under the Three Policy Scenarios (1990 = 100)**




*Source:* Authors' calculations.

In the most probable scenario, carbon dioxide emissions are expected to increase by about 3.0% within the critical time period (1990-2015). This evolution brings a negative effect on the energy intensity index (19.3% increase). The main reason for this evolution is related to the competitiveness of natural gas. The implementation of the current excise tax in heavy fuel oil (mazout) as suggested by the Directive is expected to deteriorate the competitiveness of the natural gas by almost 3.0% since mazout and natural gas are substitutes in the industrial process (RAE, 2003b, page 25). However, this evolution will not affect significantly the share of natural gas to the industrial energy balance due to its specific comparative advantages (i.e. efficiency in fuel burning, longer duration, etc.)[12].

The harmonization of the excise taxes to the European Union average level (OP) equals a small and negligible $CO_2$ emissions reduction compared to the reference case scenario (MP). It is worth mentioning that the emissions are expected to increase by 2.2% per annum within the period 1990-2015. In other words, carbon dioxide emissions from the level of 5, 3 million tonnes $CO_2$ in 1990 will reach 9 million tonnes $CO_2$ at the end of 2015.

However, if we impose Kyoto restriction (10% increase in 2010 relative to 1990 levels) $CO_2$ emissions will decrease within the period 1990-2010 by 2.1% compared to the most probable scenario. A significant amount of this reduction is ought to general improvements in the industrial processes (i.e. material recycling, heat pumps, etc) combined with a better utilization of natural gas (fuel substitution by natural gas and increase in cogeneration capacity).

## 5. CONCLUSIONS

In this paper, we tried to examine the role and effectiveness of selected energy taxation measures to combating $CO_2$ emissions that are generated from the combustion of fossil fuels in countries like Greece. Using a dynamic forecasting methodology, three policy scenarios for the energy consumption sectors (residential, road and industrial sector) were employed: a most probable scenario, an optimistic scenario and a Kyoto case (environmental scenario).

The main findings of the paper are the following: the adaptation of the minimum energy taxation rates (Directive 2003/96/EC) does not seem to be an effective measure in terms of compliance with the Kyoto target. The main reason for this outcome is that the government must levy excise taxes on energy products (light fuel oil, gasoline diesel oil, mazout, electricity) well above the EU average. However, such a policy measure cannot be implemented as it will entail distribution distortions, inflation, deterioration of the disposable income, etc. The situation is getting even worse if someone considers that many of the energy taxes in Greece (i.e tax on heating oil, tax on electricity) are of a clearly regressive nature, denoting that in relative terms poorer households would pay a disproportionally larger share of their total expenditure in additional taxes than the more well offs. Therefore, other complementary measures must be taken into account in order to meet the standards of the Kyoto Protocol such as tradable permits, strict environmental regulations, voluntary agreements, subsidies, energy-saving technologies etc. The application of the above mentioned measures must be also in line with the wider diffusion of natural gas in households and industry. However, this is a difficult task since the successful implementation of such environmental policies coincides with a suitable solid regulatory framework agreed by all the involved agents in Greece (Ministry of Development, Regulatory Authority for Energy, National Observatory of Athens, Centre for Renewable Energy Sources).

Concluding, our analysis has shown that setting energy taxes to the minimum levels proposed by the European Directive (2003/96/EC) cannot be the unique policy instrument to satisfy the Kyoto target. To avoid misfits, the adoption of several additional measures is required particularly for the period 2008–2012. Further, the environmental effectiveness of an energy tax system needs to be complemented by an analysis of its consequences, since an implementation of an energy consumption tax or even a carbon tax may have significant adverse socio-economic effects that may outweigh the relevant benefits. Such an impact analysis is worthy for further research.

## *Notes*

1. The reference year for the three basic greenhouse gases ($CO_2$, $CH_4$ and $N_2O$) is 1990, while the remaining three f-gases have 1995 as a base year.
2. The EU Commission has made several proposals in the past regarding the energy taxation. In 1997, it adopted a proposal for a directive restructuring the Community framework for the taxation of energy products (COM (97) 30 final), which meant to update an older directive (Kouvaritakis *et al.*, 2002, page 3).
3. However, Greece does not belong to the European countries where mazout is heavily taxed such as Sweden and Austria (Newbery 2001, page 2).
4. Due to space limitations, in this paper we present only the results of dynamic forecasting without referring to the error-correction methodology (unit roots testing, magnitude of income and price elasticities). However, the results from the estimation of the error-correction models are available from the authors upon request.
5. The relevant hypothesis refers only to the level of excise taxes while VAT imposed on energy products remains stable to 19%.
6. $CO_2$ emissions distribution according with the environmental scenario (EC), is in line with the main results and hypothesis of an earlier study (RAE 2003a, page 61), whilst other considerations have been taken into account (i.e. Green paper amendment for energy saving, higher price demand elasticities in road sector, etc).
7. Two basic technologies are considered in Greece: central heating boilers and other stationary equipment (old stoves, fireplaces, etc.). The consumption of liquid fuels (diesel oil, heavy fuel oil) and natural gas concern central heating boilers whilst the consumption of the rest of the fuels (coal, fuel woods, biomass, etc.) concerns the other stationary equipment (MINENV 2004, page 44).
8. Residential $CO_2$ emissions comprise only emissions generated by the consumption of heating oil and not electricity due to certain difficulties.
9. However, according to the provisions of the Law 3175/2003 from 1st of July 2005 gas-fired power producers and producers using co-generation with a consumption of more than 25 million m3 of natural gas per year have become eligible customers, enjoying the right to choose their supplier. These two customer categories represent more than 70% of the current gas consumption in Greece.
10. $CO_2$ emissions in the road sector might be reduced in 2010 by 916 thousand tonnes of $CO_2$ equivalent (Sarafidis *et al.*, 2002, page 190).

11. Agreement between the EU and car industries regarding the decrease of fuel consumption in new cars with the aim to achieve an average $CO_2$ emission factor of 140 gr/km by 2008 (with an intermediate target of 170 gr/km by 2003).
12. Further decrease of excise tax on mazout to 15 euro/1000kg is expected to bring additional delay to the diffusion of natural gas in industry at least in the short-run and therefore should be avoided (RAE 2003b, page 25).

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