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**Can Climate Change Mitigation
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A Computable General Equilibrium
Analysis**

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Can Climate Change Mitigation Policy Benefit the Israeli Economy? A Computable General Equilibrium Analysis

Summary

The growing attention to global warming due to greenhouse gas (GHG) emissions in the process of fossil fuel--based energy production is expressed in the Kyoto Protocol, which prescribes, on average, a 7 percent reduction in GHG emissions for developed countries. Although Israel was not included in the list of the obligated countries ("Annex A"), it should consider the economic implications of participating in the emission reduction effort, as such a commitment becomes highly feasible following the Bali roadmap which oblige a successor to the Kyoto Protocol to launch negotiations including all parties to the UNFCCC on a future framework, stressing the role of cooperative action and of common though differentiated responsibility. This study aimed to quantify the economy-wide consequences for Israel of meeting the targets of the Kyoto Protocol, employing a Computable General Equilibrium (CGE) model of the Israeli economy. Initially, to this end, we constructed a social accounting matrix (SAM) to serve as a benchmark by combining physical energy and emission data and economic data from various sources. The efficacy of decentralized economic incentives for CO₂ emission reduction, such as carbon taxes on emissions and auctioned emission permits, was assessed in terms of their impact on economic welfare. In addition, we tested for the ensuing so-called double dividend. Two distinct cases were analyzed. In the first one, we tested a revenue-neutral environmental policy which proportionally cut pre-existing taxes. Labour supply was assumed to be exogenously fixed. The results showed that, although significant CO₂ emission reduction can be achieved, followed by modest economic cost, no double dividend could be discerned. Next, in order to check for the employment double dividend (lower CO₂ emissions and lower unemployment), we introduced labor market imperfections, with the aim of cutting income tax. The results of this case indicate that an employment double dividend is possible under a rather standard set of assumptions. Moreover, for higher substitutability between the energy composite input and the labor-capital one, an even "strong" form of double dividend can be obtained. We performed several sensitivity analyses with respect to the modeled production function, which re-confirmed the finding that higher substitution possibilities lead to lower welfare costs associated with a given emission reduction target. We qualify this general result by also showing that the opposite holds when the emission tax rate is held constant, rather than reduced. It may be concluded on the basis of this analysis that a double dividend may be an achievable goal under a GHG emission reduction policy in the case of economies such as Israel. The CGE approach applied in this research is adopted for the first time to the Israeli economy and should contribute to better informed debate on environmental policy in Israel.

Keywords: Computable General Equilibrium, Climate Change, Environmental Policy, Double Dividend, Israel

JEL Classification: D58, H23, Q43, Q48, Q52

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1. Introduction

As a party to the UNFCCC since May 1996 and as a signatory to the Kyoto Protocol since December 1998, Israel is committed to fulfilling its obligations for reducing GHG emissions into the atmosphere. Israel is defined as a developing country under the Convention and not included in Annex I. However, the roadmap of the Climate Change Conference in Bali identifies that Israel may become obligated for GHG reduction in the following post Kyoto agreements.

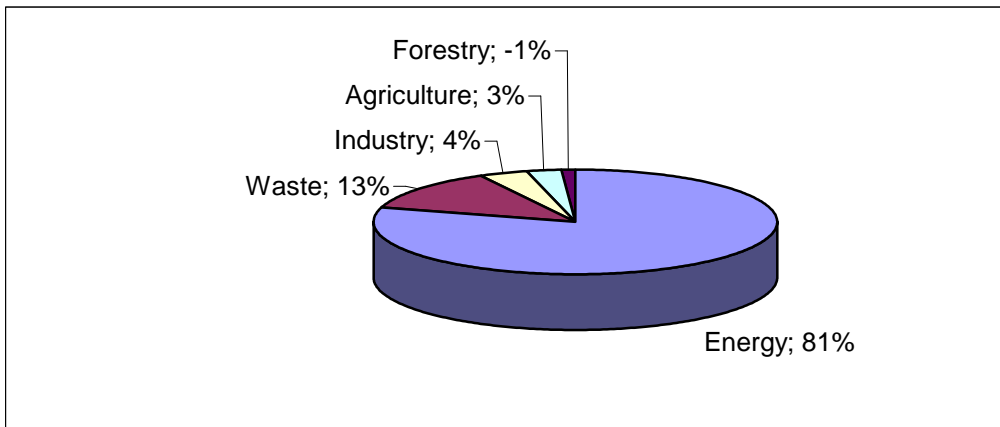
Although the baseline year for Annex I countries is 1990, Israel has set its baseline year for compliance with the obligations of the UNFCCC as 1996 due to the unprecedented growth in both population and economy which occurred during the first part of the decade. During this period, nearly a million immigrants arrived in the country, thus increasing the population by almost a fifth and bringing about a sharp increase in energy use and as a consequence, GHG emissions.

A number of special circumstances dictate the need for mitigating the effects of climate change in Israel including the following (IFNCCC, 2000):

- Israel's population density and its location at the edge of the desert make it especially vulnerable to climate change. Some 60% of the population resides in a narrow coastal strip along the Mediterranean Sea; 90% of the population is concentrated in 30% of the land area in this Mediterranean region.
- Israel's freshwater resources are limited and are dependent on seasonal rainfall to replenish groundwater and surface sources. Climate change may affect the rainfall regime.
- The coastal strip, with its vital infrastructures, natural resources and phreatic aquifer is particularly vulnerable to rising sea levels.
- Technologies for reducing GHG emissions in different sectors (e.g., electricity generation, transport, waste, agriculture, heating/cooling of buildings, etc.) are expected to carry additional advantages such as emission reduction from other pollutants which damage public health, infrastructure and water sources.

The contribution of sectors to total CO₂ equivalent emissions is presented in Figure 1. By far the largest source of CO₂ emissions is the oxidation of carbon when fossil fuels are burned to produce energy. Cement production is the most important non-energy industrial process emitting CO₂. The contribution of GHG emissions from agriculture is dominant. Emissions are attributed to direct emissions from agriculture soils, manure management and animal grazing, and indirect emissions from agriculture.

Figure 1: Contribution of Sectors to Total CO₂ Equivalent Emissions in Israel in 1996:
(Source: IFNCCC, 2000)



The contribution of GHGs to total CO₂ equivalent emissions is shown in Figure 2. The proportions of methane (CH₄) and nitrous oxide (N₂O), as opposed to that of carbon dioxide (CO₂), are small. This analysis centers on carbon dioxide abatement alone. However, since the quantities of N₂O and CO₂ emitted in fuel combustion are correlated, abatement of the latter will cause some decrease of the former. Methane abatement mostly concerns treatment of solid waste and therefore may be omitted from the discussion as it requires a different kind of consideration.

Figure 2. Contribution of Greenhouse Gases to Total CO₂ Equivalent Emissions in Israel in 1996: (Source: Avnimelech, Y. et al., 2000)

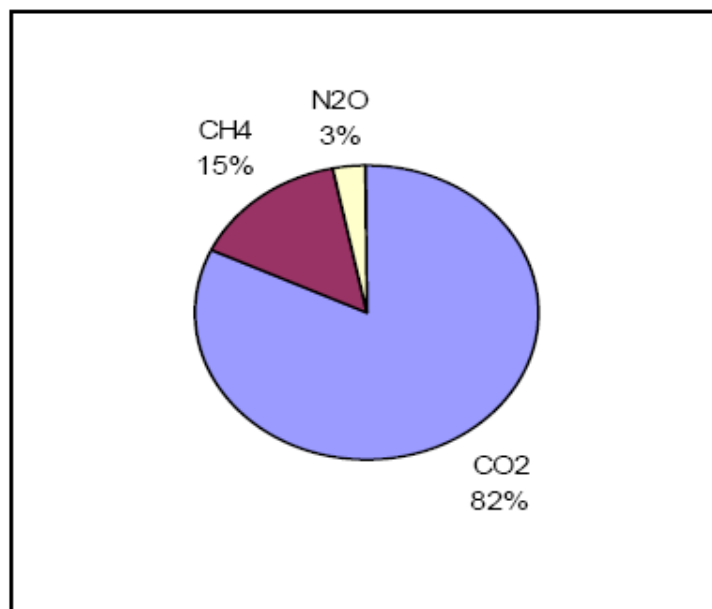


Table 1 summarizes the emissions and removals of CO₂, CH₄ and N₂O from the different sectors of the Israeli economy as estimated for 1996. Methane and nitrous oxide emissions are converted to a CO₂ equivalent by means of the Global Warming Potential (GWP) which is a measure of the radiative effects of the different GHGs relative to CO₂.

Table 1: Summary of GHG emissions and removals (1996, kilotons): (Source: IFNCCC, 2000)¹

Sector	CO ₂	CH ₄	N ₂ O	CO ₂ equivalent (20 years)	CO ₂ equivalent (100 years)
Energy (Fuel combustion)	50,344	3.55	0.58	50,705	50,599
Energy Industries	28,466	0.57	0.36	28,599	28,590
Manufacture & Construction	6,720	0.23	0.07	6,752	6,746
Transport	11,031	2.18	0.12	11,187	11,114
Commercial/Institutional/Residential	3,520	0.49	0.029	3,555	3,539
Agriculture	607	0.08	0.005	612	610
Industrial Processes	1,889		1.73	2,373	2,425
Cement Production	1,673			1,673	1,673
Lime Production	107			107	107
Soda Ash Use	17			17	17
Ammonia Production	92				92
Nitric Acid Production			1.73	484	536
Agriculture		42.4	3.81	3,441	2,071
Domestic Livestock		32.4		1,814	680
Manure Management		10	0.8	784	458
Soil Emissions			3.01	843	933
Forestry	-370			-370	-370
Waste		380		21,280	7,980
Municipal Solid Waste		370		20,720	7,770
Waste Treatment		10		560	210
Total	51,863	425.5	6.12	77,429	62,705

To conclude, as a small country, Israel is also a small contributor to global warming. Israel contributes less than 0.5% of global carbon emissions, which is approximately the level of emissions of such countries as Austria and Denmark. Nevertheless the sensitivity of the country to the impacts of the impending global and regional changes, on the one hand, and international incentives, on the other hand, dictate the integration of national policy with international agreements.

This study aims to quantify the economic consequences of meeting the targets of the Kyoto Protocol. Both the Computable General Equilibrium (CGE) model of the Israeli economy and a social accounting matrix (SAM) with energy and emission data are constructed specifically for this purpose. The efficacy of economic incentives for GHG emissions reduction, such as taxes on the emission and auctioned emission permits, are assessed and considered in terms of their impact on the country's economic welfare.

¹ Summary of GHG emissions and removals table updated for 2004 is presented in Appendix A, table A.1.

In addition, the study tests the possibility for double dividend. The question as to whether the strong form of double dividend or employment double dividend holds, heavily depends on the structure of the economy. While a green tax reform is likely to fail to increase non-environmental welfare in economies with functioning labour markets, it may succeed in economies suffering from involuntary unemployment. We check this statement transforming the basic model assumptions on labour market structure and tax revenue recycling system.

The next chapter reviews studies focused on the economic aspects of global warming in Israel. Chapter 3 describes the structure of the static energy-environment CGE model employed in the research, followed by a discussion of the data in Chapter 4. Chapter 5 presents the results of the simulations produced with the model assuming an exogenous labour supply. Alternatively, in Chapter 6 economic incentives to reduce CO₂ emissions are replicated under the assumption of labour market imperfections and different green policy revenue recycling scheme. Chapter 7 summarizes, concludes and outlines the areas that warrant further research.

2. Literature Review

This review focuses on research assessing global warming impacts on the Israeli economy. Most of the related literature deals with evaluation of "market damages", i.e. industry based cost/benefit assessment:

Haim et al. (2007) explored economic aspects of agricultural production under projected climate-change scenarios by the "production function" approach, as applied to two representative crops: wheat and cotton. Results for wheat varied among climate scenarios; net revenues became negative under the severe scenario, but may increase under the moderate one. By contrast, under both scenarios cotton was found to experience a considerable decrease in yield with significant economic losses.

Kan et al. (2007) followed a series of two previous studies: a preliminary study by Yehoshua and Shechter (2003), who employed a simple production function model approach to assess the economic impact of climate change on the agricultural sector in Israel; and a more elaborated study, using the same production function approach, by Kadishi, et al. (2003). Kan et al. developed a model that enables assessment of climate-change impacts on optimal agricultural management, where adaptation to water quality and quantity changes is considered endogenously with respect to both the extensive and intensive margins.

Yehoshua et al. (2007) analyzed the major impact of sea level rise – manifested principally in land loss due to inundation and erosion - on Israel's Mediterranean coast. Given the specific and rather unique nature of the Israeli coastline, this study has employed specific tools to assess the

damages. The economic assessment focused mainly on valuing the beaches as a public resource for recreation, using methods such as CVM and TCM.

Avnimelech, Y. et al. (2000) scanned GHG polluting sectors of the Israeli economy and provided sector based policy guidelines for GHG emission reduction in the form of technical and economic measures.

A small selection of studies attempted to evaluate the economy wide costs and benefits of global warming mitigation. Tiraspolsky (2003) examined the effectiveness of a national carbon tax scheme applied to different emitting sectors and inspected some distributive and competitiveness effects arising from this application. The argument for modest-level regressivity of tax in the residential sector was confirmed by partial analysis of distributional incidence of a modeled carbon tax of NIS² 70 per ton of CO₂.

Gressel et al. (2000) assessed the demand functions for fossil fuels and electricity and analyzed welfare losses caused by carbon taxes on these goods. However, this approach evaluated costs for energy addicted sectors without incorporating substitutes.

The Israeli economic literature lacks a research which analyzes the economy-wide effects of economic incentives for GHGs emission mitigation on a general equilibrium modeling basis. As previously shown, the most important GHG carbon dioxide, which is an anthropogenic emission, is largely due to the combustion of carbon-rich fossil fuels. On the supply side of the economy, fossil fuels are the sole large-scale source of energy, while on the demand side, energy is employed as an input to virtually every activity, raising concerns that even modest taxes or quantitative limits on CO₂ emissions will precipitate large increases in energy prices, reductions in energy use, and a decrease in economic output and welfare. The economy-wide character of the issue implies that elucidating the impacts of carbon taxes requires the kind of analysis for which CGE models are particularly well suited (Wing, 2004). Therefore, our first goal is to construct a CGE model which would best reflect the Israeli economic structure with detailed disaggregation of energy flows. Lacking the traditionally used GTAP³ or SEEA⁴ databases, we constructed a consistent Social Accounting Matrix for Israel in 1995. By applying the model to this benchmark we aim to answer the following research questions:

1. In what range would a carbon energy tax/ tradable permit prices need to lie in order to meet the Israeli potential Kyoto target for energy-related emissions of CO₂ (7% reduction)?

² NIS – New Israeli Sickles is the Israeli national currency.

³The latest available GTAP6 database (Dimaranan, 2006) doesn't include disaggregation for the Israeli economy. The data on the Israeli economy appears as a part of "Rest of the Middle East Countries".

⁴ The system of integrated economic and environmental accounts (SEEA) developed by United Nations et al. (2003) provides a framework for such a dataset, but it has not yet been implemented in Israel.

2. What impact would this type of a carbon tax/ tradable permit system have on the Israeli economy, welfare and emissions?
3. How would this carbon tax/ tradable permit system affect sectoral output, household consumption patterns and demand for the various energy commodities?
4. How will a “sensitivity analysis” effect the model results?
5. Is an (employment) double dividend possible for the Israeli economy?
6. How do the following schemes for recycling the revenue of the carbon tax/ tradable permit system affect the results regarding:
 - Proportional tax reduction
 - Reduction of the labour tax rate

3. The Static Energy-Environment CGE Model for the Israeli Economy

Our research introduces the first energy-environment-CGE model for Israel with specific detail in the area of taxation. It is a structural, real, static model of a small open economy with four energy commodities, 14 other commodities, a government, an investment agent, a foreign agent and a single representative household. It incorporates energy flows among producers and between producers and consumers.

CGE models are simulations that combine the abstract general equilibrium structure formalized by Arrow and Debreu with realistic economic data to solve numerically the levels of supply, demand and price that support equilibrium across a specified set of markets. CGE models are a standard tool of empirical analysis, and are widely used to analyze the aggregate welfare and distributional impacts of policies whose effects may be transmitted through multiple markets, or contain menus of different tax, subsidy, quota or transfer instruments. Examples of their use may be found in areas as diverse as fiscal reform and development planning (e.g., Perry et al 2001; Gunning and Keyzer 1995), international trade (e.g., Shields and Francois 1994; Martin and Winters 1996; Harrison et al. 1997), and increasingly, environmental regulation (e.g., Weyant 1999; Bovenberg and Goulder 1996; Goulder 2002). Kremers et al. (2002) provide a survey of CGE models for climate change policy analysis.

3.1. General Features

The general structure of this computable general equilibrium model is a familiar one which has been used frequently in a number of applications, including the analysis of the effects of greenhouse gas emissions restrictions, as noted above. The standard assumptions of market clearing, zero excess profits and balanced budget for each agent apply. Commodity markets merge primary endowments of households with producer outputs. In equilibrium the aggregate supply of

each good must be at least as great as the total intermediate and final demand. Producer supplies and demands are defined by producer activity levels and relative prices. Final demands are determined by market prices. The model is calibrated to the benchmark data.

A less common feature is the separation of activities from commodities which permits activities to produce multiple commodities, while any commodity may be produced by multiple activities. In addition the model allows to export the imported commodities adopting the Armington assumption, as explained in section 3.3. It is assumed that the economy is in equilibrium in the benchmark. A policy simulation is implemented as a ‘counter-factual’ scenario, which consists of an exogenous set of shocks to the system. The model output shows the state of the economy after all markets have reached a new equilibrium, i.e., we conduct a comparative-static analysis⁵. The sectors and commodities are described in appendix B; the following sections present an overview of the model.

3.2. Production Sector

A firm can choose the quantity of each of the commodities it can produce. The output is divided among the produced commodities with a CET⁶ function, where the elasticity of transformation is equal to zero for all industries. This perfectly inelastic function ensures that the shares of commodities produced, in terms of quantity, remain the same during all simulations. The production process is represented by a nested production function as depicted in Figure 3 below. In the figure, the Allen elasticities of substitution are indicated with ‘s:’ and are identical for each industry in the nest. The top-level function is a Leontief function (s:0) which determines the producer’s demand for the aggregate factor input of labor, capital and intermediate energy KLE, and each of the intermediate (non-energy) inputs $M(i)$ (KLEM⁷ structure). CES⁸ functions are applied for levels two to five of the production function. The elasticities of substitution between labour L and composite capital and energy, KE , and between aggregate energy E and capital K are adopted from Kemfert (1998)⁹. Elasticities for the E and FOS nests are borrowed from GTAP-EG (Rutherford & Paltsev, 2000). Finally, crude oil and oil products are aggregated in a Leontief function, as crude oil is only used in the oil refinery and any substitution between these two fuels should not occur.

⁵ Dellink (2005) shows how the modeling framework can be expanded to a fully dynamic analysis and discusses the validity of the comparative-static approach as an approximation. A good example of a dynamic multiregional model for climate policy is given in Böhringer and Welsch (2004).

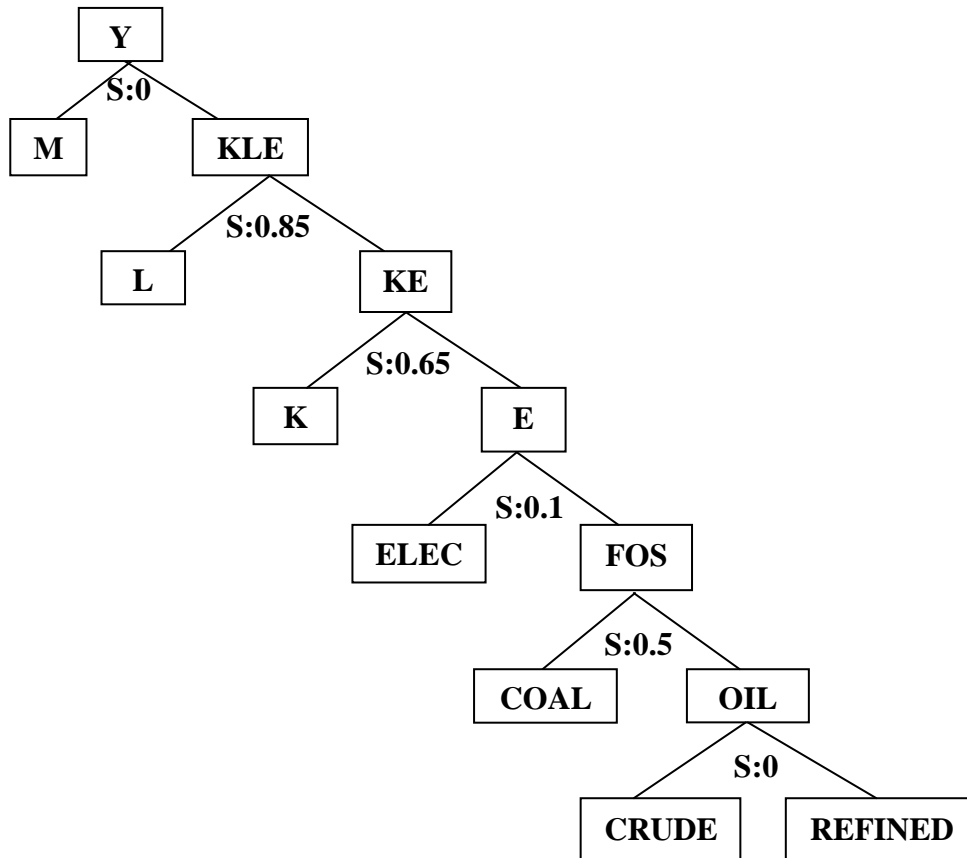
⁶ CET=Constant Elasticity of Transformation

⁷ KLEM is an acronym commonly used in environmental economic modeling to identify production function structure nesting type of capital (K)-labour (L)- intermediate energy composite (E)- intermediate (non-energy) inputs (M)

⁸ CES=Constant Elasticity of Substitution

⁹ Kemfert (1998) econometrically estimates L-KE and K-E elasticities for German industry overall to be 0.846 and 0.653, respectively. It is assumed that the Israeli economy has equal flexibility to German industry.

Figure 3: Nesting Structure of the Production Function



In recent few years, electricity has been produced in Israel using natural gas too, but the latest Input-Output table of 1995 which was used in structuring the benchmark lacked the data on natural gas flows.

3.3. International Trade

To accommodate the possibility that imported commodities are exported, the Armington assumption¹⁰ is applied in combining domestic production Y and imports IM , using a CES function. The resulting homogeneous ‘Armington commodities’ are either sold in Israel or exported. A CET function determines the scope for choice between domestic demand and export. The elasticity of substitution between Israeli made products and imports (the Armington elasticity in the CES function) as well as the elasticity of transformation between domestic sales and exports in the CET function, are set equal to 4 (Dellink, 2005). This creates substantial flexibility in choices about the destination and source of commodities.

¹⁰ Assumption: that imported and domestically produced commodities are substitutes of each other, but not perfect substitutes. This solves the problem that the same kind of good is found to be both exported and imported in actual trade data which is inconsistent with the Heckscher-Ohlin model under perfect competition (Armington, 1969).

3.4. Consumption

Total domestic supply of each commodity is assumed to exactly meet demand (market clearing). Total demand is made up of intermediate demand and final demand, including household and government consumption, investment and exports. Intermediate demand is dealt with in the production discussion. Household consumption, as well as investment are driven by the maximization of a Cobb-Douglas utility function subject to a budget constraint. Therefore, these agents respond to price incentives but keep the share of their budget spent on each commodity fixed.

The household sector is represented by a single Representative Agent (RA). In our model, 18 different goods exist – corresponding to productive sectors. The RA demands consumption goods and saves the remainder of her disposable income. The consumer's objective is to maximize her utility, subject to her budget constraint. Utility is obtained from consumption goods according to a Cobb-Douglas utility function. The RA owns all factors of production, i.e., labour and capital. The RA's income is made up of a net income deriving from the supply of labour and from the rental of capital plus net transfers. Household savings are exogenously fixed and equal to the sum of the government's budget surplus and the balance of trade surplus less investments and the value of increases in stock. This ensures that the financial cycle is closed. RA consumption is taxed at a constant rate. Carbon emitting commodities are also taxed or under the obligation to purchase emission permits in the counter-factual scenarios.

Government consumption and export are driven by the maximization of a Leontief utility function subject to a budget constraint. A Leontief function ensures that the shares of commodities, consumed by government, remain unchanged in terms of quantity during all simulations. This is a logical assumption, since the government consumption decision is hardly driven by the market. The government raises taxes to obtain public revenue; whilst at the same time, gives net transfers, to the RA and abroad, and demands goods and services. Since the behavior of foreign consumers is not included in this single-country model, the Leontief function is used to keep the relative quantities of the different exported commodities fixed. Exports are traded for foreign exchange, which is used to pay for imports. Balance of payment equals net imports.

3.5. Taxation

One of the main distinctive features of the model is its relatively detailed modeling of taxation. Seven taxes are modeled, out of which the pre-existing, *i.e.* present in the benchmark are: net taxes on products; net taxes on production; taxes on consumption; labour tax; capital tax and import tariffs. In some cases the indirect taxes are negative, indicating that subsidies are greater than taxes for that industry. Taxes on consumption are the share of indirect taxes on purchased

products paid by the RA. The share of labour tax and capital tax was calculated based on Ben Gad (2004) estimations. The energy tax and the tradable emission permits system are introduced as counter-factual scenarios. In these simulated scenarios, both firms and households have to pay a tax on energy if their use of the energy commodity causes CO₂ emissions. The tax rate is varied for each fuel, according to its carbon content. All tax revenue is collected by the government. The government spends all revenue (net of subsidies) on the aggregate commodity and exogenous transfers keeping its budget fixed.

3.6. Market clearing conditions

This class of equilibrium conditions refers to the supply of any commodity which must balance the demand by consumers at equilibrium prices and activity levels. Domestic demand equals demand for intermediate inputs to production, public sector use, final consumer demand plus domestic investment and stock change. The model includes supply-demand conditions for the Armington composite goods. On the supply side, Armington composite goods equal the aggregation of import and domestic production, whereas the demand side includes domestic and export components. Primary factor endowment equals primary factor demand. Any commodity which commands a positive price has a balance between aggregate supply and demand, and any commodity in excess supply has an equilibrium price of zero.

3.7. Closure and Welfare Measurement

The price of aggregate private consumption, the consumer price index, was chosen as the numéraire, the price relative to which all price changes are evaluated¹¹. This price being fixed at unity, means the total quantity of consumption equals the total value of consumption at all times. In our model we measure welfare focusing solely on private household consumption while the government purchases are fixed. A change in total household consumption therefore equates a welfare change as measured by the Hicksian equivalent variation (EV).

In all of the following simulations the government intends to implement the carbon energy tax/ auctioned permits as an equal yield policy, preserving total tax revenue unchanged. The revenue from the new green instrument must therefore be matched by a reduction in revenue from another tax or taxes. With world prices fixed, the market for foreign exchange is cleared by fluctuations in the exchange rate. Labour and capital supplies are exogenously fixed¹². Markets for labour and capital are cleared by endogenous factor prices. The model is calibrated to the 1995 data base. Since the model is static, the output of the model must be interpreted as the new equilibrium is

¹¹ Absolute price levels are undetermined in the model and only relative prices can be assessed. Fixing the consumer price index implies that inflation cannot occur.

¹² We change this assumption in Chapter 6.

reached after the economy has had time to adjust, but where changes in factor supply have not (yet) occurred.

4. Data

4.1. A Social Accounting Matrix for Israel

This section describes the construction of the SAM for Israel for the year 1995. This is the most recent year for which the Central Bureau of Statistics (CBS) has produced Input-Output Tables (CBS, 2002), the main data source for the SAM.

The initial task of building a SAM involves compiling data from various sources into a SAM framework. The CBS Supply Table (CBS 2002, Table 1, Version B) provides MAKE(j,i) matrix, at basic prices and then adds imports, trade margins and net taxes on commodities in order to arrive at the same totals for each commodity as in the Use Table, at purchaser's prices (CBS 2002, Table 2, Version B). Labour and capital costs, net taxes on products and net production taxes are published as part of the CBS Use Table. Direct taxes are introduced following Ben Gad (2004) calculation. In the SAM, imports are valued at c.i.f.¹³ prices and import duties were separated from product taxes. The transfers between agents are adopted from the CBS official site. Agent's savings are embraced from national accounts (CBS, 1996).

4.2. Disaggregation of Energy in the SAM

In order to simulate climate change policies in relation to energy-related carbon dioxide emissions, it is first imperative to adequately model the following features (Wissema and Dellink, 2007):

- Energy flows among industries (intermediate demand);
- Energy flows between industries and consumers (final demand including exports);
- Tax paid on energy products;
- Imports of energy products;
- The cost structure of energy producing industries.

The main energy sources and industries need to be distinguished separately in the model, and therefore also in the SAM. The SAM is built on the basis of a 14-industry aggregation IO Table, whilst implementing the disaggregation of 'Manufacture' into crude oil (COIL), coal (COAL), refined petroleum (ROIL), and other manufacturing (MNF). In addition, 'Electricity and water' sector is disaggregated over electricity (ELE) and water (WAT). The disaggregation procedure is performed using in a 162-industry aggregation IO Table for the relevant rows and columns. Consequently, 18 commodities/activities are presented in the final SAM.

¹³ The c.i.f. (cost, insurance, and freight) value represents the landed value of the merchandise at the first port of arrival in Israel

4.3. Emissions

To establish the relationship between the levels of production and demand activities and the quantity of emissions we assumed a fixed stoichiometric relationship between the aggregate demand for fossil fuel commodities in which carbon is embodied (i.e., coal, refined and crude petroleum) and the quantity of atmospheric CO₂ emissions that result from their use. This relationship was estimated using Table C data on CO₂ emissions by sector presented in Appendix C. The result is a set of commodity-specific emission coefficients, which when multiplied by each fossil fuel's aggregate demand in the SAM, reproduces the economy's CO₂ emissions in the benchmark year.

5. Preliminary Simulation Results and Economic Interpretation

The subsequent sections outline the results of two policy simulations (carbon tax and auctioned emission permits system) in different environments, following the closure rule introduced in Section 3.7. The policy variables are model parameters that are either price-based (carbon taxes) or quantity-based (auctioned carbon emission permits), and whose values are exogenously specified.

5.1. Energy Tax Simulations

Our model simulates the effect of imposing a range of ad-valorem taxes on CO₂ emissions, differentiated according to the emission factor of each energy source. The model is simulated to reproduce the benchmark as a baseline no-policy case, with the imposition of carbon taxes at levels of NIS 50, NIS 100, NIS 150 and NIS 200 per ton of carbon¹⁴. The government allocates the carbon tax revenue to uniformly reduce the existing distorting taxes.

The sectoral impacts of carbon taxes are detailed in Table 2. The top panel shows that a \$ 16.67/ton carbon tax raises the consumer prices of petroleum and electricity by about 5 percent and makes coal more expensive by a quarter, while a \$ 66.67/ton increases the prices of refined oil and electricity by more than 17 percent and the price of coal by almost 100 percent. Crude oil and water prices rise by 1-3 percent; transport sector prices experience a minor increase up to less than a half percent and agriculture and the rest of the economy consumer prices decline up to 1 percent.

These price changes induce large adjustments in the quantities of fossil fuels used as inputs by producers and households, where inter-fuel substitution enables reductions in demand to be concentrated in the most carbon-intensive energy source, coal. Thus, in the second and third panels found in Table 2, sectors see a decline in coal use by 10-40 percent, while in the non-fossil- fuel

¹⁴ Corresponding to US \$ 16⅓, 33⅓, 50 and 60⅓ in 1995 prices. The values of carbon tax are equivalent to taxes on CO₂ that are less than one-third as large \$4.6, \$9.1, \$13.6 and \$18.17 per ton of CO₂ respectively.

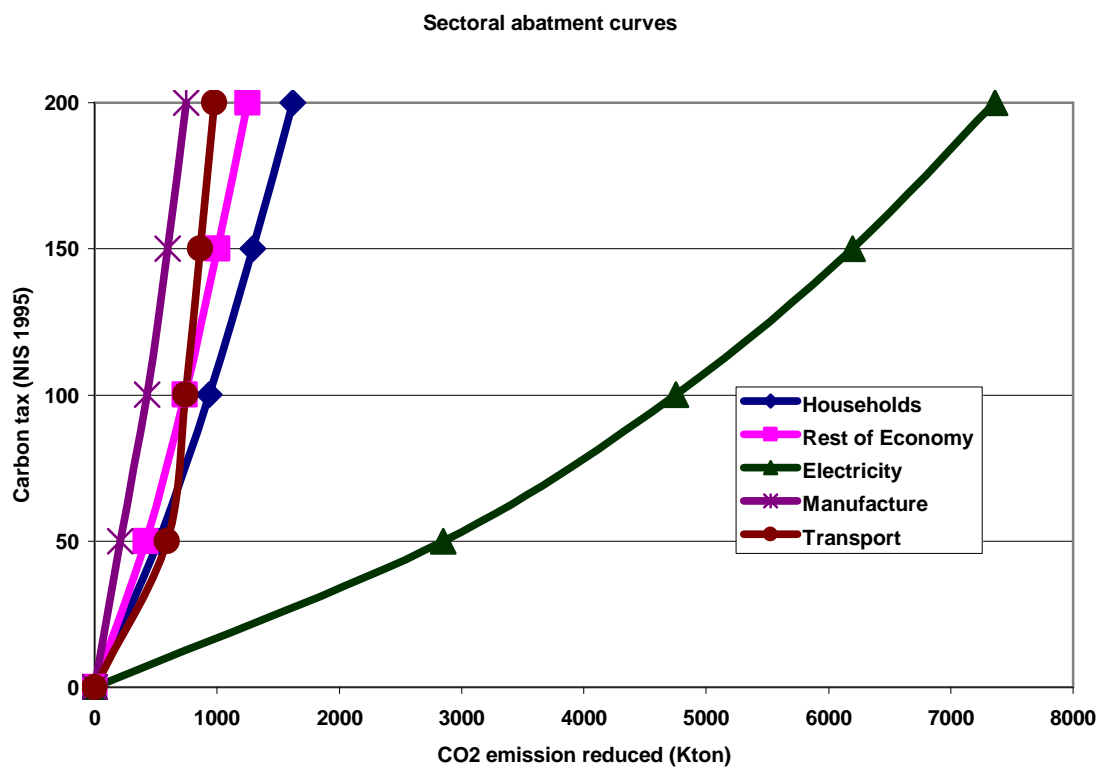
sectors (agriculture, manufacture, water and the rest of the economy in panels 4 and 5 of the table), demands for both petroleum and electricity decline by 2-11 percent. In these latter sectors of the economy, substitution of non-energy inputs for fossil fuels mitigates the transmission of the reductions in the output of primary energy sectors. The fifth panel in the table shows that the reduction in electricity demand is between 6-19 percent in refineries; 10-27 percent in the electricity sector itself and 1-11 percent in the other sectors. As a result, the level of output falls by 5-17 percent in electric power and refineries; 2-5 percent in water industry; 0.2-2 percent in agriculture, manufacture and transportation; and only 0.1-0.3 percent in the rest of the economy, as indicates the final panel. These changes in activity levels correspond closely to changes in the consumption of the corresponding commodities by the representative agent.

Table 2: The Sectoral Impacts of Carbon Taxes on the Israeli Economy

Carbon Tax (\$, 1995)	Agriculture	Refined OIL	Crude OIL	COAL	Manu- facture	Electri- city	Water	Trans- port	Rest of Economy
Changes in Gross-of-Tax Commodity Prices (percent)									
16.67	-0.91	4.55	1.08	25.04	-0.01	5.54	1.61	0.10	-0.09
33.3	-1.03	8.92	1.39	49.63	-0.06	9.70	2.12	0.21	-0.18
50	-1.09	13.34	1.76	74.27	-0.17	13.59	2.55	0.27	-0.28
66.67	-1.15	17.78	2.14	98.92	-0.27	17.27	2.94	0.33	-0.37
Changes in Final Consumption by Commodity (percent)									
16.67	-0.53	-6.04	-4.84	-13.70	-0.50	-4.96	-1.31	-0.87	-0.15
33.3	-1.04	-10.24	-9.31	-24.18	-0.98	-8.52	-2.10	-1.73	-0.30
50	-1.29	-13.83	-12.43	-32.01	-1.21	-11.41	-2.55	-2.20	-0.33
66.67	-1.53	-17.14	-15.86	-38.28	-1.43	-13.99	-2.96	-2.65	-0.36
Changes in Demand for Coal by Sector (percent)									
16.67	-10.55	-15.48	-	-	-10.75	-14.36	-	-	-
33.3	-19.32	-25.93	-	-	-19.35	-23.94	-	-	-
50	-25.92	-33.86	-	-	-25.82	-31.14	-	-	-
66.67	-31.25	-40.25	-	-	-31.02	-36.91	-	-	-
Changes in Demand for Petroleum by Sector (percent)									
16.67	-2.17	-6.21	-	-	-2.39	-6.34	-4.30	-3.31	-1.34
33.3	-5.44	-10.46	-	-	-5.48	-10.85	-7.07	-6.47	-2.58
50	-8.14	-14.10	-	-	-8.02	-14.61	-9.30	-9.07	-3.62
66.67	-10.65	-17.46	-	-	-10.35	-18.00	-11.33	-11.49	-4.58
Changes in Demand for Electricity by Sector (percent)									
16.67	-2.33	-6.57	-	-	-2.75	-10.07	-4.39	-3.32	-1.41
33.3	-5.63	-11.08	-	-	-6.03	-17.05	-7.14	-6.45	-2.64
50	-8.33	-14.91	-	-	-8.69	-22.59	-9.32	-9.01	-3.67
66.67	-10.81	-18.42	-	-	-11.11	-27.28	-11.29	-11.37	-4.60
Changes in Sectoral Activity Levels (percent)									
16.67	-0.24	-5.45	-	-	-1.24	-6.34	-2.71	-0.67	-0.16
33.3	-0.72	-9.79	-	-	-1.68	-10.43	-3.78	-1.34	-0.32
50	-0.90	-13.52	-	-	-1.82	-13.71	-4.42	-1.63	-0.32
66.67	-1.08	-16.97	-	-	-1.95	-16.61	-5.00	-1.91	-0.33

Figure 4 plots the sectoral marginal abatement cost (MAC) curves derived from the model's solution. The bulk of abatement occurs in the electric power sector which is responsible for twice as much of a reduction in emissions as in all the other sectors of the economy put together (approximately 3000-7,360 Kton). Less than a quarter as much abatement (500-1600 Kton) takes place in the household and rest of the economy sectors. Further abatement (210-980 Kton) is generated by the manufacture and transportation sectors. The results indicate that while there may be substantial low-cost abatement opportunities (less than \$ 16.67/ton) in the transportation industry, incremental emission reductions are likely to be exhausted with greater tax levels.

Figure 4: Year 1995 Sectoral Marginal Abatement Cost Curves for Israel.



The environmental and welfare consequences of carbon taxes are shown in Table 3. The model indicates that the modest carbon tax of \$ 16.67/ton reduces the overall CO₂ emissions by more than 9 percent from the initial level of 49,748,000 tons, which is more than the Kyoto Protocol target set for most of the European countries, whereas a \$ 66.67/ton tax could cut emissions by almost a quarter, which would incur a welfare cost of almost 0.9 percent and almost a one percent reduction in GDP.

Table 3: The Aggregate Economic Impacts of Carbon Taxes

Carbon tax (1995 \$)	CO ₂ Emissions (ktons)	CO ₂ Abatement (ktons)	Welfare Change from Benchmark (%)	GDP Change from Benchmark (%)
0	49,748.00	-	-	-
16.67	45,158.11	4,589.89	-0.27%	-0.31%
33.3	42,155.29	7,592.71	-0.54%	-0.61%
50	39,804.96	9,943.04	-0.72%	-0.79%
66.67	37,802.36	11,945.65	-0.89%	-0.96%

5.2. Auctioned Emission Permits System

Within our model, the carbon tax policy is equivalent to an auctioned emission permits system where the permit price coincides with the carbon tax. The government auctions permits between all energy users in the economy and allocates the revenue to uniformly reduce the existing distorting taxes. For simplicity, it is assumed that no net international trading takes place.

The environmental and welfare consequences of a 7 percent emissions reduction via an auctioned permit system to simulate Israeli economy meeting the Protocol Kyoto targets is shown in Table 4.

Table 4: The Aggregate Economic Impacts of Auctioned Permits

Permit Price (\$, 1995)	CO ₂ Emissions (ktons)	CO ₂ Abatement (ktons)	Welfare Change from Benchmark (%)	GDP Change from Benchmark (%)
9.03	46,265.6	3,482.36	-0.09	-0.12

If the Israeli economy aims to reduce 7 percent of its CO₂ emissions following the Kyoto agreement, 46 thousand 257 permits valued at 1 kton of the CO₂ emissions each may be auctioned between the sectors of the economy. The equilibrium price of the permit would reach \$ 9.03 (1995 prices). Welfare and GDP would decrease by 0.09 and 0.12 percent respectively.

5.3. Sensitivity Analysis

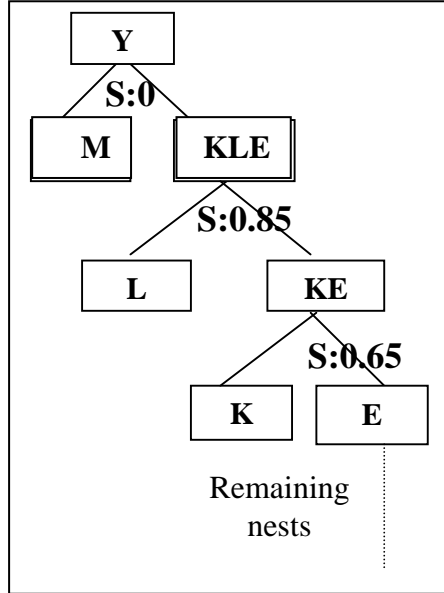
Following van der Werf's (2007) empirical estimation of production function for climate policy models for OECD countries, we checked the consistency of our results not only by continual change of elasticities, but also by modifying the labor-capital-energy nesting structure of the production function.

In our basic analysis capital and energy are combined first, as is done in the GREEN model (Burniaux et al., 1992), since (physical) capital and energy generally operate jointly. However, van der Werf found that the (KL)E nesting structure, in which capital and labour are combined first and

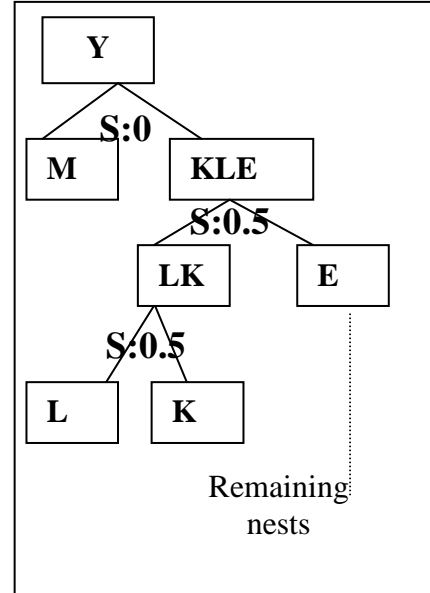
subsequently combined with energy (or an energy-materials composite), fits the data better than (KE)L or (LE)K nesting structures. We adapted the (KL)E nesting structure for the production function leaving the rest of the nests in Figure 3 above unchanged. In addition, lacking an econometric estimation of elasticities of substitution between labor, capital and the energy aggregate for the Israeli economy, we ran the model twice more implementing the elasticities of substitution evaluated by van der Werf for Finnish and Italian economies. The Finnish economy was chosen for its relative similarity in magnitude, whereas the Italian elasticities were adjusted to reflect the lack of natural energy resources common to both Italy and Israel. Figure 5 mirrors the initial and the resulting production function structures. The elasticities of substitution between labour and capital were estimated at about the same value of 0.5 for Italy and Finland, whereas the elasticities of substitution between energy aggregate and labour – capital composite for Italy is half that of Finland, and they are both substantially lower than that used for the initial simulation. Accordingly, the new production functions represent lower substitution ability between energy and primary factors with Italian elasticity representing the lowest substitution possibility. From here on we refer to the initial L(KE) production function as " Production Function A"; the production function with E(KL) nest and Finnish elasticities as "Production Function B"; and to the production function with E(KL) nest and Italian elasticities as "Production Function C".

Figure 5: Nesting Structure of the Modeled Production Functions.

**Figure 5a: Production
Function A**



**Figure 5b: Production
Function B**



**Figure 5c: Production
Function C**

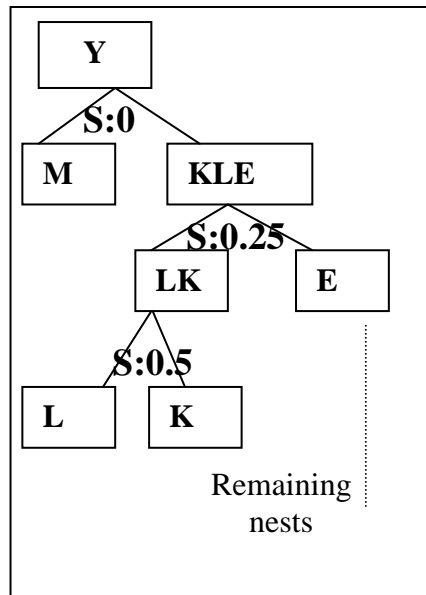
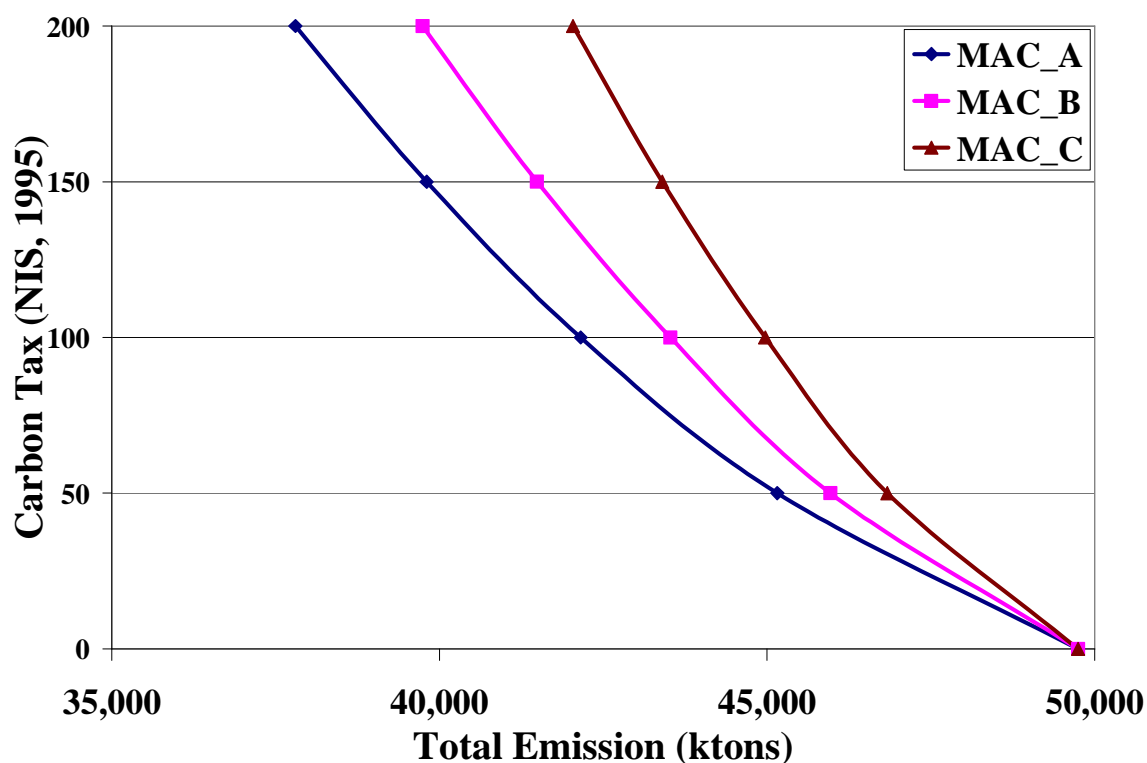


Figure 6 illustrates the resulting economy-wide MAC curves for each production function. As the elasticity of substitution between primary factors and energy inputs lowers, production has lower possibility to substitute away from energy. As a result, the MAC becomes more inflexible and less emission reductions can be gained for each level of carbon price.

Figure 6: Marginal Abatement Curves of the Israeli Economy for Various Production Function Definitions.



The economic impacts of carbon taxes and auctioned permits in the view of 3 production functions are compared in Table 5. As expected, production functions B and C allow less substitution between energy inputs and primary factors, thus for an equal value of carbon tax, the emission reduction is lower. However, even the least flexible elasticity production function C produces almost 6-15.5 percent CO₂ emission reduction for carbon tax of \$16²/₃-\$66²/₃. Experiencing an equate price increase, energy sectors in cases B and C suffer lower demand reduction and pull the economy to a smoother change in welfare and the GDP: 0.08-0.14 percent change in cases B and C compared to about a 0.3 percent change in case A.

The comparison of a 7 percent emission reduction using auctioned permits provides an additional confirmation to the preceding results. Following the previous observation that, for a carbon tax the emission reduction is lower in stiffer elasticities of substitution functions, the equivalent emission decrease level results in the equilibrium permit price as sufficiently higher for production functions B and C and the economic cost is larger.

Table 5: The Aggregate Economic Impacts of Carbon Taxes and Auctioned Permits via Production Function definition.

(\$, 1995)	Production Function A			Production Function B			Production Function C		
	Carbon tax		Permit	Carbon tax		Permit	Carbon tax		Permit
	16.67	66.67	9.03	16.67	66.67	14.2	16.67	66.67	21
CO₂ Emission (ktons)	45,158	37,802	46,266	45,966	39,742	46,266	46,837	42,039	46,266
CO₂ Abatm. (%)	9.23 %	24.0 %	7 %	7.61%	20.1%	7%	5.85 %	15.5%	7%
Welfare Change (%)	-0.27	-0.89	-0.09	-0.11	-0.50	-0.10	-0.08	-0.36	-0.11
GDP Change (%)	-0.31	-0.96	-0.12	-0.14	-0.57	-0.13	-0.12	-0.49	-0.16

This chapter shows that a carbon energy tax, *i.e.*, a specific energy tax related to carbon dioxide emissions from energy use of \$ 16.67-66.67, leads to significant emission reductions followed by a minor decrease in economic parameters. The model tells us that the negative impact of auctioned permits and the carbon tax on overall welfare and GDP is minor even when parameter values are changed. No double dividend is identified though. Changes in the patterns of sectoral production and consumption can be clearly observed. Simulating a stiffer production function which allows less substitution between capital – labour and energy composites, we find that the tax is less effective in reducing carbon emissions yet the economic costs are lower too.

6. Introducing Labour Market Imperfections

The economic literature has emphasized the impact that recycled fiscal revenues could have on relevant macroeconomic variables, such as output and employment. In Europe, given the high level of taxation on labour and the persistent high levels of unemployment, the debate has been concentrated upon the existence of a so-called “employment double dividend” *i.e.* the possibility of achieving better environmental quality by taxing pollutants and lower unemployment rates by using green tax revenues to lower taxes on labour, the high level of these often being perceived as one of the causes of high unemployment rates (Daveri and Tabellini, 2000). The debate in Israel may also focus on achieving the “employment double dividend” because of high preliminary labour taxation and unemployment levels. Since the unemployment level in Israel has been above 7% for more than a decade, we consider the importance of indicating the possibility of the “employment double dividend” for the Israeli economy. For this purpose we introduce unemployment in our base model.

6.1. Model Extensions

In order to investigate the double and employment dividend hypotheses unemployment was introduced in the model. The unemployment rate is determined through a wage equation which postulates a negative relationship between the real wage rate and the rate of employment:

$$\frac{w}{p} = f(u)$$

where P denotes a consumer goods price index (CPI) and u is the unemployment rate, taken to be 6.9% for 1995 in Israel. This type of wage equation can be derived from trade union wage models, as well as from efficiency wage models (e.g., Hutton and Ruocco, 1999). To implement the wage equation into the modelling procedure we followed the methodology provided by Kuster et al. (2007).

In the current chapter we continue to use production function C, following van der Werf's (2007) recommendation upon E(KL) nesting structure and to implement elasticities of substitution as evaluated for Italy, between the energy aggregate and the labor-capital composite to reflect the absence of natural energy resources in Israel. This chapter enhances the model presented in chapter 3 with the following major:

- Endogenous labour supply
- Involuntary unemployment

Labour supply is endogenous and depends on relative changes in the wage rate. Endogenous involuntary unemployment is controlled by a real wage rate. The unemployment rate has a minimum bound equal to 5 percent, to reflect frictional unemployment (Layard *et al.*, 1991). A relatively high frictional unemployment rate is assumed due to the unique structure of the Israeli labour force, where a fairly significant fraction of persons of a working age stay unemployed for social or religious reasons. Other assumptions on model agents' behaviour remain unchanged.

6.2. Green Policy Simulations

The energy tax simulations continue to employ the carbon tax range of \$ 16.67-66.67 in 1995 prices. However, contrary to previous chapter simulations where carbon tax/auctioned permits revenue was recycled to proportionally reduce all the existing taxes, in the simulations presented in this chapter, once the environmental tax rate is exogenously fixed, the compensating income tax (IT) is decreased with the criterion of keeping real public deficit unchanged.

Table 6 displays the main results, including the CO₂ emissions (ktons), emission abatement (%), the welfare change (%), the real GDP change (%), the labour/capital index change (%) and unemployment (%) with respect to the benchmark situation.

Table 6: The Aggregate Economic Impacts of Environmental Policy: Labour Market Imperfections.

Carbon tax (\$, 1995)	CO₂ Emissions (ktons)	CO₂ Abatement	Welfare Change from Benchmark	GDP Change from Benchmark	Labour/Capital Price Index Change	Unemployment
-	49,748.00	-	-	-	-	6.90%
16.67	46,663.13	6.2%	-0.05%	-0.08%	0.2%	5.96%
33.3	45256.75	9.0%	-0.14%	-0.21%	0.5%	5.32%
50	43652.38	12.3%	-0.24%	-0.33%	0.7%	5.11%
66.67	41765.44	16.0%	-0.34%	-0.45%	1.0%	5.01%
Permit Price (\$ 21.67)	46,265.6	7%	-0.08%	-0.12%	0.3%	5.79%

When the carbon tax is compensated with IT, emissions monotonically decrease with the tax rate, as expected, reaching the 16 percent reduction for the highest carbon tax level. Nominal output increases but as prices also increase, the GDP decreases in real terms of up to 0.45 percent. As a consequence of lower labour costs, unemployment rate monotonically decreases, almost reaching the frictional unemployment level, so that an employment double dividend arises. At this point we indicate that reduction in IT overpowers the distorting effects of the environmental tax.

The introduction of carbon taxes has an inflationary effect, which is especially evident at the welfare stage, causing an increase in nominal wages. However, this effect is counteracted by labour tax cuts. The fact that welfare falls up to 0.34 percent can also be partly explained by the drop in income: income from labour increases (by 1.85%) due to higher labour demand, but income from capital falls (by more than 2.64%) due to the lower rental rate. Capital supply is fixed and demand must equal supply, so the actual quantity demanded cannot change, but the price of capital drops to more than the net wage rate (labour/capital price index decrease), reflecting the relative abundance of capital in the new equilibrium, compared to the other production inputs.

Inspecting the sectoral impacts of the carbon taxation provides the explanation for an increase in employment: the reduction in income tax lowers the labour costs for employers in relation to other factors and in particular to the simultaneously increased price of energy due to the carbon tax. Therefore, the demand for labour in non energy-intensive sectors increases. The offsetting effect is the overall activity decrease of the economy induced by more expensive energy factors (prices increased from about 4 to 17 and a half percent in case of refined oil and electricity and up to 98 percent for coal).

Employing corresponding auctioned permit system to reduce 7 percent of CO₂ emissions the model results indicate that the equilibrium price of the permit will reach about \$21²/₃ (in 1995 prices). Welfare and GDP would decrease by 0.08 and 0.12 percent respectively, while the unemployment levels may decrease according to our simulation by a considerable 1.3%. Correspondingly, an employment double dividend arises in this case too.

Our main result reflects the possibility to gain an employment dividend and follows the evidence obtained by several studies, concerning the strongly distorting effects of labour taxes (Manresa and Sancho, 2005). While the effect of a green tax reform does not yield a second dividend in the standard model assuming perfect functioning of all markets, as we confirm in Chapter 5, it yields a welfare improving employment effect in the model which allows for labour market imperfections.

However, there are two effects in our model that decrease the overall cost of carbon emission control: First, the “carbon leakage” phenomenon, which means that reduced domestic emissions may cause higher emissions abroad (Lee and Roland-Holst (2000), Roson (2001)). Second, since foreign and domestic goods are imperfect substitutes, there are changes in the terms of trade, implying that foreign consumers actually bear part of the carbon tax burden. These changes in the terms of trade are partly explained by the fact that our research focuses on a single country, ignoring international policy feedbacks. Evidently, refined oil import increases by up to 4 percent for the highest carbon tax level, substituting away the local production. However, the Kyoto protocol imposes similar reductions in CO₂ emissions for several Israeli trade partners; if foreign prices also arise, there would be less scope for substituting domestic products with imports, and a less significant impact on the terms of trade.

6.3. Sensitivity Analysis

This section compares some of the results presented above with those obtained when the elasticities of substitution are changed, in order to test how sensitive welfare, abatement and unemployment results to variations in parameters’ values.

At the first stage of the sensitivity analysis we altered the elasticity of substitution between labour-capital composite and the energy composite (LKE) holding the carbon tax at \$ 16²/₃ level. The values varied from 0 to 1 (van der Werf’s, 2007, estimated LKE elasticities of substitution for OECD countries show 0.17-0.61 range). The transformations obtained with the default elasticity value are given in bold, with which the changes above and below can be compared. The simulation results summarized in Table 7 appear to be quite robust. As the elasticity of substitution between the labour-capital composite and the energy composite grows, energy conservation is achieved more easily by substitution towards labour and capital. Therefore the emission abatement and

employment increase. However, the welfare cost increases too, identifying that higher elasticity values tend to increase the distortionary effect of the carbon tax. Behaviour, in terms of quantities purchased or produced further changes, creating a bigger deadweight loss.

Table 7: Sensitivity of economic indicators to individual changes in the value of the elasticity of substitution between labour-capital and energy composites (compared to the benchmark); carbon tax \$ 16%.

S(LKE)	CO ₂ Emissions (ktons)	CO ₂ Abatement	Welfare Change from Benchmark	Real GDP Change from Benchmark	Unemployment
0	48594.15	2.32%	-0.04%	-0.06%	5.98%
0.25	47658.09	4.20%	-0.05%	-0.08%	5.96%
0.5	46749.05	6.03%	-0.06%	-0.10%	5.94%
0.75	45866.06	7.80%	-0.08%	-0.13%	5.93%
1	45008.18	9.53%	-0.11%	-0.15%	5.91%

Alternatively we vary the values of LKE elasticity of substitution while keeping the emission reduction target at 7% employing the auctioned permits system. In this case, results presented in Table 8 show that, as the LKE elasticity of substitution increases, the abatement target can be received with lower economic costs. In equilibrium, the auctioned permit price declines, indicating that lower carbon tax is needed in order to achieve the desirable abatement level. Furthermore, for the value of LKE elasticity of substitution equalled 0.5 and higher, not only the employment but also the welfare and GDP changes are positive. In fact, this simulation shows a (limited) strong double dividend result.

Table 8: Sensitivity of economic indicators to individual changes in the value of the elasticities of substitution between labour-capital and energy composites (compared to the benchmark); 7% abatement target.

S:LKE	Permit Price (\$, 1995)	Welfare Change from Benchmark	Real GDP Change from Benchmark	Unemployment
0	34.21	-0.30%	-0.40%	6.09%
0.25	21.33	-0.08%	-0.12%	5.59%
0.50	15.57	0.03%	0.02%	5.39%
0.75	11.98	0.04%	0.10%	5.29%
1.00	9.46	0.05%	0.15%	5.22%

The value of the elasticity of substitution at the top level S(TOP) is also mildly influential. The top level of the production function is normally Leontief, but for the analysis it was changed to Cobb-Douglas. This creates the opportunity to conserve energy by substituting other intermediate inputs for composite labour-capital-energy in order to avoid paying the carbon tax. Indeed, the non energy-intensive sectors, indicated as “Rest of the economy” in the previous analyses, show very

limited participation in abatement in the case of Cobb-Douglas top level elasticity of substitution. As shown in Table 9, this magnitude tends to distort the economy more and brings down welfare for a given carbon tax level. Alternatively, if a 7 percent emission abatement is the goal, it can be reached by lower permit price/ carbon tax when the top level elasticity of substitution is Cobb-Douglas. The welfare cost is lower, but the unemployment decrease is lower too, signalling that the higher substitution of intermediate inputs for labour-capital-energy composite limits the effect of increased demand for labour through lowering the income tax. Consequently, we can only argue for an employment double dividend for the higher top level elasticity of substitution.

Table 9: Sensitivity of economic indicators to individual changes in the value of the top level elasticity of substitution (compared to the benchmark): carbon tax range \$ 16²/₃; 7% abatement via tradable permits.

	CO ₂ Abatement		Welfare Change from Benchmark		Unemployment	
	Stop=0	Stop=1	Stop=0	Stop=1	Stop=0	Stop=1
Carbon tax (\$, 1995)						
\$ 16 ² / ₃	6.2%	6.37%	-0.05%	-0.17%	5.96%	6.7%
7% Abatement - Auctionable Permits						
7%	\$21.33	\$19.65	-0.08%	-0.06%	5.59%	6.6%

7. Summary and Discussion

The research presented here expands the academic discussion on climate change mitigation strategies in Israel. The purpose of this study is to determine whether policy makers in Israel could introduce environmental taxation in the form of the CO₂ emission tax, without aggravating the problems of unemployment and decrease in welfare. It is particularly relevant following recent negotiation for Post Kyoto agreement which is expected to engage all UNFCCC parties for the mutual mitigation effort.

Our literature survey revealed that although CGE models are commonly used in economic literature to investigate the economy-wide nature of carbon tax schemes, no such model for Israel had been previously developed.

In the current research we adopt the CGE model to the Israeli economy in order to study the effects of green tax reforms on environmental quality, the economic burden of the tax system and, eventually, the level of unemployment. To this end, a consistent and balanced disaggregated SAM for Israel in 1995 is constructed.

Our counter-factual analyses started by imposing carbon emission taxes ranging from \$ 16²/₃ to \$ 66²/₃ (in 1995 prices) on the revenue neutral basis. Alternatively, the auctioned permits system was established to achieve a 7 percent abatement. The accumulated income served to proportionally

reduce the pre-existing taxes. In these preliminary simulations an exogenous labour supply was assumed.

The main conclusions from this part of the study are the following: First, the reduction target for energy related CO₂ emissions in Israel of 7 percent compared to 1995 levels can be achieved with a carbon energy tax of between approximately \$ 9 and \$ 21 per tonne of carbon under various assumptions considering the structure of production function. Fuel switching is an important part of achieving the target, and the sensitivity analysis shows that this result is sensitive to the possibilities for producers to substitute away from energy use. Lower substitution possibilities make emissions respond less to a given tax level, so that the target should be reached with higher tax levels.

Secondly, the macroeconomic impact of the tax would not be very strong, as GDP decreased by less than 1 percent even at the highest \$ 66⅔ per tonne of carbon tax level. Welfare would be affected downwards, but only by a small percentage even at relatively high tax levels. However, no double dividend was identified.

In attempt to approximate the model to better reflect the Israeli labour market, involuntary unemployment was introduced. The mitigating policy was yet again implying \$ 16⅔ to \$ 66⅔ tax per ton of carbon or simulating the 7 percent emission reduction via auctioned permits system, but this time the revenues were directed to cut the labour tax.

The simulated environmental policy implied a large negative shock to domestic energy-intensive production. This entailed significant stranded costs and a large reduction in employment in the energy-intensive industries. However, income tax cuts reduced the labour costs in relation to other factors and the demand for labour from non-energy intensive sectors increased lowering the overall unemployment level. Therefore, we can conclude that an employment double dividend is an empirical possibility under a rather standard set of model characteristics. Moreover, for a higher substitutability between energy composite and the labour-capital one, a (limited) strong double dividend can be obtained.

While model results are not greatly affected by changes in most of the parameters' values, the most influential elasticities are those that affect the possibilities for energy conservation by substitution towards labour - capital composite. In the event that the carbon tax level is kept constant, increasing their values implies welfare reduction while the emission target is overshoot. However, when the possibilities for energy conservation are thus increased and steady emission reduction is the aim, a lower, less distortionary, carbon tax level is required or alternatively the auctioned equilibrium permit price will be inferior. We conclude therefore that for Israel, energy conservation appears to be the key to a double dividend.

In conclusion, a second dividend of environmental taxes in the form of an employment dividend exists is an achievable goal in the case of the Israeli economy. Using green tax revenues to reduce labour taxes will reduce unemployment and for high energy-labour-capital substituting possibilities may even raise welfare. Our research verifies that pre-existing market distortions provide another rationale for the introduction of environmental taxes.

The major limitation of the analysis is the age of the data base. An operational data base is compiled using officially published input–output tables, expenditure surveys, and national product and income accounts. Unfortunately, these data sources are not updated with the required speed, at least not for the modeler, and a few compromises linking and unifying them in a micro consistent way have to be adopted. It is for this reason why simulation results showing a double dividend should be taken as an indication of what may be possible and not as any definite proof.

In the case of the Input – Output table for Israel in 1995 which served as the main basis for the SAM not only is the age of the data is problematic for drawing policy implications, but so is the absence of the natural gas sector in the data. Indeed, as recently as 2004, the Israeli primary energy supply did not include natural gas. However, a structural change using natural gas was possible following an agreement signed in 2005 between Israel and Egypt which enables Israel to purchase natural gas from Egypt, to be used by the Israel Electric Corporation (IEC) for a period of 15 years. In addition, natural gas reserves have been discovered off the coast of Israel. As a result, the share of natural gas in the primary energy supply mix grew from about 1 percent in 2004 to 18 percent in 2006 and is expected to rise up to 50 percent in the following decade. This new energy source, which is characterized by lower carbon intensity may reduce the economic costs of the explored mitigating policies even further than projected in this research.

Next important shortcoming is the model’s neglect of the “putty-clay” nature of capital. Jacoby and Sue Wing (1999) demonstrated the importance of capital rigidity in determining the short-run costs of the U.S. economy’s adjustment to GHG emission constraints. Yet, in our analysis production is modeled as being completely reversible, and capital is modeled as a homogeneous, mobile factor whose input may be reallocated frictionally among producers as relative prices change. In reality, reductions in activity would likely entail substantial capital scrappage and associated short-run costs. The analysis can therefore be significantly improved by specifying all or some of the capital input to each individual sector as a separate factor that is inelastically supplied and has its own sector-specific price. The likely consequence would be a substantial reduction in the mobility of and returns to capital — especially in declining sectors, with concomitant additional reductions in the representative agent’s income and increases in the welfare costs of abatement.

In addition, our efficiency notion is essentially neoclassical. We measured induced tax distortions using a direct intra-personal percentage utility change based only on private commodities consumption. Publicly provided goods, environmental quality or leisure do not enter the utility function. A broader welfare concept could possibly include these magnitudes, but it is not immediately obvious how they would affect the preference relation.

The representation of the energy industry can be enhanced by disaggregating renewable energy commodities and by introducing imperfect competition; a feature that is still relevant for the Israeli electricity market. The representation of demand for energy can be improved by modeling the use of renewable energy sources such as solar energy by households. Since climate change is a long term problem, the introduction of intertemporal dynamics is recommended. It is further recommended to introduce foreign energy policies to affect the world price. Alternative revenue recycling schemes should be explored. Moreover, it is possible and desirable to include other greenhouse gases than carbon dioxide and even to incorporate other environmental problems and solutions. Different environmental problems and their solutions tend to interact and are best analyzed in an integrated manner (Dellink, 2005).

It is important to assess the impact of different combinations of policy measures on income distribution in general and on the welfare of households of different income groups in particular. Low-income households need special attention because a carbon energy tax may push certain households into poverty and enhance the existing problems with fuel-poverty (Healy, 2003). Our research uses a single representative household and therefore does not offer this kind of insight. For this analysis it would be necessary to distinguish different income groups and model the relevant linkages between these household groups and the rest of the economy, including the government, in sufficient detail.

Despite all qualifications above, and on general economic grounds, a strong point can be made to support energy tax policies as a singular tool of choice for achieving a better environmental quality and a lower inefficiency level (in utility or unemployment) at zero revenue cost for the Israeli economy.

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APPENDIX A GHG Emission 2004

Table A: Summary of GHG emissions and removals (2004).

(Source: Israeli Union for Environmental Defense, 2007)

Sector	CO ₂	CH ₄	N ₂ O	Total CO ₂ equivalent
Energy (Fuel combustion)	63,134	3.34	0.724	63,428
Energy Industries	41,615	0.697	0.53	41,794
Manufacture & Construction	6,041	0.15	0.05	6,058
Transport	14,320	2.32	0.14	14,412
Commercial/institutional/Residential/Other	1,157	0.172	0.01	1,164
Industrial Processes	2,115		1.95	2,719
Agriculture		67.26	4.62	2,846
Forestry	-370			-370
Waste		236		4,948
Total	65,249	306.2	7.3	73,572

APPENDIX B SECTORS AND COMMODITIES IN THE SAM

The sectors and commodities have the same acronyms, as each commodity is produced mainly by one corresponding sector. Each industry can thus be regarded as the main producer or manufacturer of the product with the same acronym. Table B therefore gives descriptions of commodities only.

Table B. Commodities in the SAM and the Model

Sector i	Model Acronyms	CBS code	Descriptions
1	AFF	A	Agriculture
2	ROIL	B 70	Refined petroleum
3	COIL	B 37	Extraction of crude petroleum and natural gas
4	COAL	B 36	Mining and agglomeration of hard coal
5	MNF	B	Manufacturing
6	ELE	C 124	Electricity
7	WAT	C 125	Water
8	CON	D	Construction (building and civil engineering projects)
9	TRD	E	Wholesale and retail trade, repairs of vehicles and other repairs
10	ASR	F	Accommodation services and restaurants
11	TRC	G	Transport, storage and communications
12	BIF	H	Banking, insurance and other financial institutions
13	BAC	I	Real estate, renting and business activities
14	PAD	J	Public administration
15	EDU	K	Education
16	HWS	L	Health services, and welfare and social work
17	CSS	M,N	Community, social, personal and other services, and services for households by domestic personnel
18	IBS	162	Imputed bank services and general expenses

APPENDIX C Sectoral fuel consumption and emission

Table C: Fuel consumption and CO₂ emissions by sectors. (Source: Avnimelech, 2002)

Sector	Electricity production		Manufacture		Transport		Residential and commercial	
	Fuel cons' (ktons)	CO ₂ (ktons)	Fuel cons' (ktons)	CO ₂ (ktons)	Fuel cons' (ktons)	CO ₂ (ktons)	Fuel cons' (ktons)	CO ₂ (ktons)
LPG			124	366			404	1,194
Gasoline	137	435	900	2,859	2,159	6,657	199	632
Diesel Oil			769		1,013	2,876		
Naphtha	2,031	6,252	2,277	7,099				
Residual Fuel Oil			168	675				
Petrol.					267	821		
Coke								
Tar								
Coal	8,190	19,882						
Total CO₂ emissions		26,569		10,999		10,354		1,826
% of total emission		53.47%		22.13%		20.84%		3.67%

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