Israel Economic Review Vol. 8, No. 1 (2010), 21–43

THE ISRAELI ECONOMY AND POTENTIAL POST-KYOTO TARGETS[1]

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Abstract

This study aims to quantify the economy-wide consequences for Israel of meeting potential targets of the post-2012 agreement, employing a Computable General Equilibrium (CGE) model of the Israeli economy. A tax per ton of carbon emissions leads to significant emission reductions, followed by a minor decrease in economic variables. The negative impact of auctioned permits and the carbon tax on GDP is minor even when parameter values are changed. The CGE approach followed in this research is applied for the first time to the Israeli economy and should contribute to a better informed debate on environmental policy in Israel.

1. INTRODUCTION

As a party to the United Nations Framework Convention on Climate Change (UNFCCC) since May 1996, and as a signatory to the Kyoto Protocol since December 1998, Israel is committed to fulfilling its obligation to reduce GHG emissions into the atmosphere. Following COP15 Copenhagen Accord, the minister of Environmental Protection, Glad Erdan declared in the official communication to UNFCCC that the Israeli government is committed to reduce CO2 emissions by 20 percent by the year 2020. The aim of this research is to provide Israeli policymakers with first comprehensive assessment of potential commitments and their impacts on the Israeli economy.

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

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Based on the PhD thesis of Ruslana Palatnik, "Analysis of the Impact of Economic Incentives to Control Greenhouse Gas Emissions within the Framework of a General Equilibrium Model of the Israeli Economy", written under the supervision of Prof. Mordechai Shechter in the joint PhD Program in Economics of the Technion – Israel Institute of Technology and the University of Haifa.

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growth in both population and economy which occurred during the first part of the decade. In that period nearly a million immigrants arrived in the country, increasing the population by almost a fifth and bringing about a sharp increase in energy use, hence in GHG emissions.

By far the largest source of CO_2 emissions in Israel is the oxidation of carbon when fossil fuels are burned to produce energy (81%) (IFNCCC, 2000). Cement production is the most important non-energy industrial process emitting CO_2 (6%). The contribution of GHG emissions from agriculture is dominant. Emissions are attributed to direct emissions from agricultural soils, manure management and animal grazing, and indirect emissions from agriculture. The proportions of methane (CH_4 – 15%) and nitrous oxide (N_2O – 3%), as opposed to carbon dioxide (CO_2 – 82%), are small. This analysis centers on carbon dioxide abatement alone. However, since N_2O and CO_2 quantities emitted in fuel combustion are correlated, abatement of the latter will cause some decrease of the former. Methane is already treated through solid waste disposal and therefore may be omitted from the discussion.

To conclude, as a small country, Israel is also a small contributor to global warming. Summary of GHG emissions and removals table updated for 2004 is presented in appendix A. Israel contributes less than 0.5% of global carbon emissions, about the same as such countries as Austria and Denmark. Nevertheless Israel's sensitivity to the impacts of the impending global and regional changes on the one hand, and international incentives on the other, dictate the integration of national policy with international agreements. The underlying research question here is this: **What is the cost of GHG emission restrictions to the Israeli economy as a whole, assuming that the economy will have to bear it in any event?**

The study reported here aims to resolve this question and to quantify the economic consequences of meeting possible targets of post-Kyoto agreements. 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 emission 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 performance. **The model developed here is intended to serve policy makers in examining and evaluating various policy incentives before their adoption and implementation under upcoming Israeli efforts for GHG abatement.**

The next section reviews studies on the economic aspects of global warming in Israel. Section 3 describes the structure of the static energy-environment CGE model employed in the research, followed by a discussion of the data in Section 4. Section 5 presents the results. Section 6 summarizes and draws conclusions, and outlines the areas that warrant further research.

2. LITERATURE REVIEW

Most of the literature concerned with global warming impacts on the Israeli economy evaluates "market damages", i.e., makes an industry-based cost/benefit assessment.

Haim et al. (2008) 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 between 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 two previous serial 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 elaborate 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 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 Contingent Valuation (CVM) and Travel Cost (TCM).

Avnimelech 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 economy-wide costs and benefits to Israel 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 equivalent to US $ 16 per ton of CO_2.

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 research which analyzes the economy-wide effects of economic incentives for mitigation of GHG emission. As previously shown, the most important GHG, CO_2, 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 CO_2 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 (Sue Wing, 2004).

Despite the criticism (e.g. Ackerman 2002, DeCanio 2003, McKitrick 1998), CGE models have become the standard tool for the analysis of economy-wide impacts of greenhouse gas abatement policies on resource allocation and associated implications for incomes of economic agents (see, e.g., Bergman 1990, Grubb et al. 1993, Weyant 1999). This is chiefly because the general equilibrium framework represents price-dependent market interactions as well as the origin and spending of income for various economic agents based on rigorous microeconomic theory (Böhringer et al., 2006). To the best of our knowledge, to date no such model has been developed or implemented for the Israeli economy.

Therefore, our first goal is to construct an IGEM- Israeli General Equilibrium Model, which best reflects the economic structure of Israel, with detailed disaggregation of energy flows. Lacking the traditionally used GTAP or SEEA databases, we construct a consistent Social Accounting Matrix for Israel.

3. THE STATIC ENERGY-ENVIRONMENT CGE MODEL FOR THE ISRAELI ECONOMY

Our research introduces the first energy-environment-CGE model for Israel, IGEM. 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.

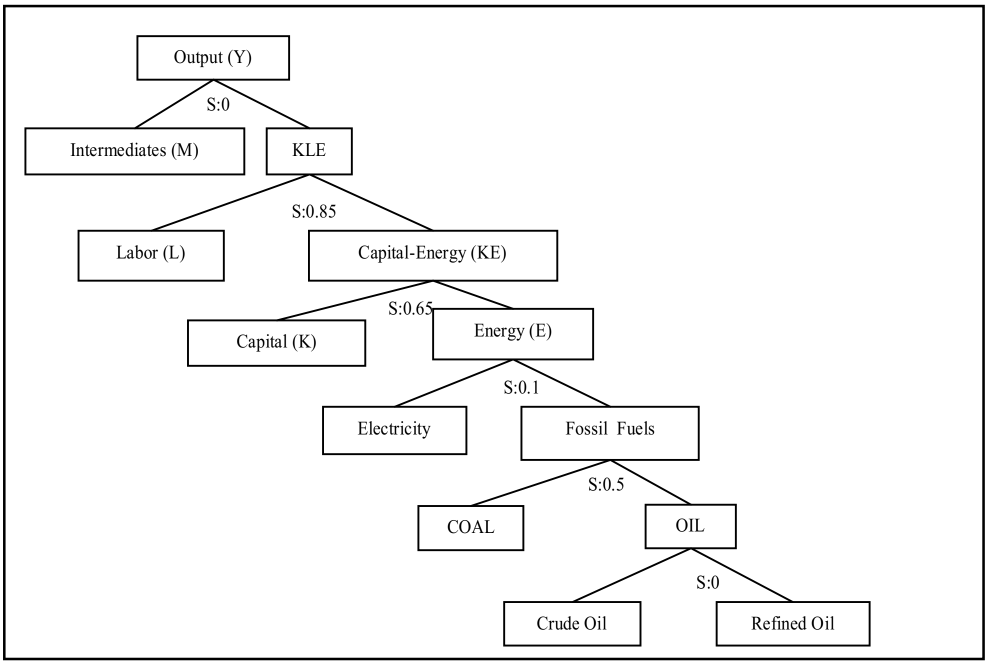
The general structure of this computable general equilibrium model is familiar, having had several applications, including analysis of the effects of GHG emission restrictions as noted above. Assumptions of market clearing, zero excess profits and balanced budget for each agent apply. Commodity markets 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. With world prices fixed, the market for foreign exchange is cleared by fluctuations in the exchange rate. Labor and capital supplies are exogenously fixed. 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. The model also allows export of the imported commodities, adopting the Armington (1969) assumption. 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 analysis[2]. The sectors and commodities are described in appendix B.

[2] 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).

The output is divided among the produced commodities with a Constant Elasticity of Transformation (CET) 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. Because of its focus on climate policy, the model disaggregates the energy supply technologies. Production technologies are described as nested Constant Elasticity of Substitution (CES) functions as depicted in Figure 1 below. The nesting structure is designed to allow flexibility in setting elasticities of substitution particularly with regard to the use of fuels and electricity, as well as other substitutions to which emission and abatement costs are especially sensitive. The production structure for electricity is the most detailed among the sectors because of its importance in energy use and emissions.

Figure 1
Nesting Structure of the Production Function



In the figure, the Allen elasticities of substitution (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). CES functions are applied for levels two to five of the production function. The elasticities of substitution between labor L and composite capital and energy KE, and between aggregate energy E and capital K, are adopted from Kemfert (1998)[3]. Elasticities for the E and FOS nests are borrowed from GTAP-EG (Rutherford and Paltsev, 2000). Finally, crude oil and oil products are aggregated in a Leontief function, as crude oil is only used in oil refinery and no substitution between these two fuels should occur. Since 2004 electricity is produced in Israel by natural gas too, but the latest Input-Output table of 1995, which was used in structuring the benchmark, lacked data on natural gas flows.

The household sector is represented by a single Representative Agent (RA). IGEM therefore abstains from income distribution issues, although in practice they should not be ignored. The RA demands consumption goods and saves the remainder of her disposable income. The consumer's objective is to maximize her Cobb-Douglas type utility, subject to her budget constraint. 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. The government raises taxes to obtain public revenue; at the same time it gives net transfers, to the RA and abroad, and demands goods and services. Exports are traded for foreign exchange, which is used to pay for imports. Balance of payment equals net imports.

The model is relatively detailed in representation of taxation. Seven taxes are modeled, of which pre-existing ones, i.e., those present in the benchmark, are net taxes on products, net taxes on production, taxes on consumption, labor tax, capital tax, and import tariffs. Taxes on consumption are the share of indirect taxes on purchased products paid for by the RA. The shares of labor and capital tax are calculated based on Ben Gad (2004) estimations. The energy tax and the tradable emission permits system are introduced as counter-factual scenarios.

The consumer price index was chosen as the numéraire, the price relative to which all price changes are evaluated, as absolute price levels are undetermined in the model and only relative prices can be assessed. This price, being fixed at unity, means that the total quantity of consumption equals the total value of consumption at all times. In IGEM welfare is measured focusing solely on private household consumption, while government purchases are fixed. A change in total household consumption therefore equals a welfare change as measured by the Hicksian equivalent variation (EV).

In all 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 is therefore matched by a proportional reduction in revenue from pre-existing taxes.

[3] 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.

4. DATA

a. A Social Accounting Matrix (SAM) for Israel

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

The initial task in building a SAM is to compile data from various sources into a SAM framework. The CBS Supply Table (CBS 2002, Table 1, Version B) provides a MAKE(j,i) matrix, at basic prices, and then adds imports, trade margins and net taxes on commodities to arrive at the same totals for each commodity as in the Use Table, at purchaser's prices (CBS 2002, Table 2, Version B). Labor 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 the Ben Gad (2004) calculation. In the SAM, imports are valued at c.i.f (cost, insurance, and freight) prices and import duties are separated from product taxes. The transfers between agents are adopted from the CBS official site. Agent's savings are taken from national accounts (CBS, 1996).

b. Disaggregation of Energy in the SAM

To simulate climate change policies in relation to energy-related CO_2 emissions, it is first essential to model adequately 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, while 'Manufacture' is disaggregated into crude oil (COIL), coal (COAL), refined petroleum (ROIL), and other manufacturing (MNF). In addition, 'Electricity and water' sector is disaggregated into electricity (ELE) and water (WAT). The disaggregation is done by means of a 162-industry aggregation IO Table for the relevant rows and columns. Consequently, 18 commodities/activities are presented in the final SAM.

c. Emissions

To establish the relationship between the levels of production and demand activities and the quantity of emissions we use a common assumption of 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 CO_2 emissions that result from their use. This relationship is estimated using Table C data on CO_2 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 CO_2 emissions in the benchmark year.

5. SIMULATION RESULTS AND ECONOMIC INTERPRETATION

This section outlines results of two policy simulations (carbon tax and auctioned emission permits system) 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.

a. Energy Tax Simulations

IGEM simulates the effect of imposing a range of ad valorem taxes on CO_2 emissions, differentiated according to the emission factor of each energy source. In order to evaluate the potential Israeli Climate Change policy we impose carbon taxes at levels of NIS (New Israeli Sheqels) 50, NIS 100, NIS 150 and NIS 200 per ton of carbon, corresponding to US \$ 16⅔, 33⅓, 50 and 66⅔ in 1995 prices. The values of carbon tax are equivalent to taxes on CO_2 that are less than one-third as large \$4.6, \$9.1, \$13.6 and \$18.17 per ton of CO_2 respectively. The government allocates the carbon tax revenue to uniformly reduce the existing distorting taxes.

The sectoral impacts of carbon taxes are detailed in Table 1. As expected, the most carbon intensive fuel, coal, experiences the highest increase in price as a result of the simulated imposition of carbon tax. 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 of up to less than a half a percent, and agriculture and the rest of the economy consumer prices decline by up to 1 percent.

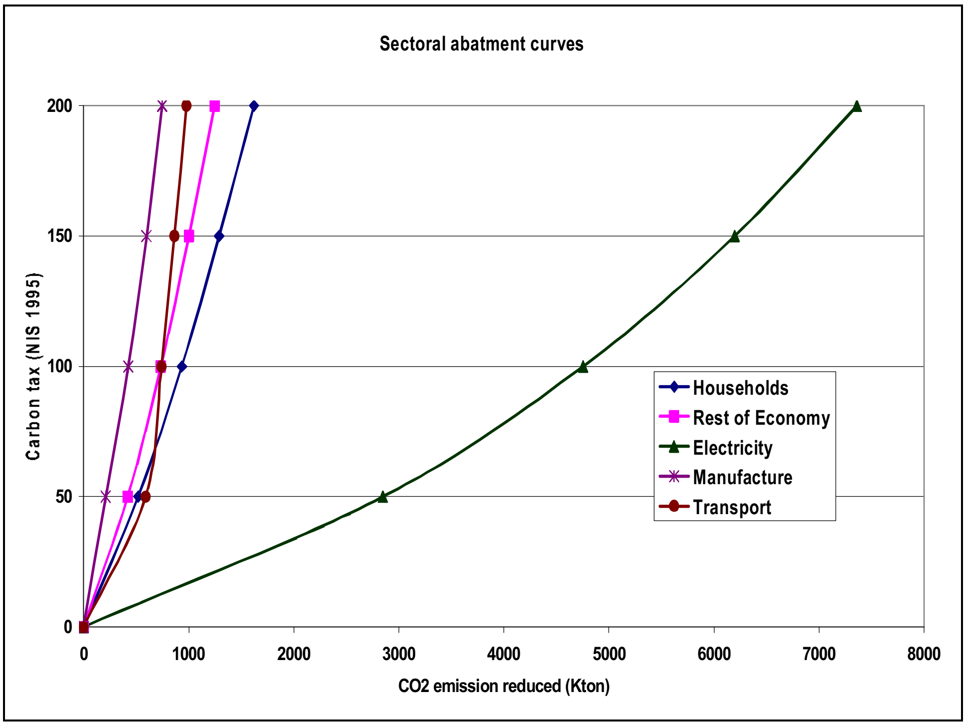
These price changes induce large adjustments in the quantities of fossil fuels used as inputs by producers and households, where inter-fuel substitution facilitates reductions in demand to be concentrated in the most carbon-intensive energy source, coal. Thus, in the second and third panels found in Table 1, sectors see a decline in coal use by 10-40 percent, while in the non-fossil-fuel 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 6-19 percent in refineries, 10-27 percent in the electricity sector itself, and 1-11 percent in the other sectors. As a result, output level falls by 5-17 percent in electric power and refineries; by 2-5 percent in water industry; by 0.2-2 percent in agriculture, manufacture and transportation; and by only 0.1-0.3 percent in the rest of the economy, as indicated by the final panel. These changes in activity levels correspond closely to changes in the consumption of commodities by the representative agent.

Table 1
The Sectoral Impacts of Carbon Taxes on the Israeli Economy

Carbon Tax ($, 1995)	Agri-culture	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 2 plots the sectoral Marginal Abatement Cost (MAC) curves derived from IGEM's solution. The MAC curves are well-behaved (i.e., continuous, smooth, and convex to the business-as-usual origin), which is a reflection of the homotheticity of the model's utility and production. Almost every sector in the economy participates in CO_2 emission abatement via energy inputs. However, the bulk of abatement occurs in the electric power sector, which is responsible for reduction in emissions double that in all the other sectors of the economy combined (approximately 3000-7,360 Kton of CO_2). Less than a quarter as much abatement (500-1600 Kton of CO_2) takes place in the household and rest of the economy sectors. Further abatement (210-980 Kton of CO_2) is accomplished by the manufacture and transportation sectors. The results indicate that while there may be substantial low-cost abatement opportunities (less than \$16.67/ton of carbon) in the transportation industry, incremental emission reductions are likely to be exhausted with higher tax levels.

Figure 2
Sectoral Marginal Abatement Cost Curves for Israel (Year 1995)



The environmental and welfare consequences of carbon taxes are shown in Table 2. The model indicates that the modest carbon tax of \$16.67/ton reduces the overall CO_2 emissions by more than 9 percent from the initial level of 49,748 ktons, 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 reduction in GDP of nearly 1 percent.

Table 2
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

b. Auctioned Emission Permits System

For a global pollutant such as carbon dioxide, a system of auctioned permits works in many ways like a carbon tax, although the total volume is fixed, rather than the marginal abatement cost. Yet a permit scheme enjoys various advantages, particularly if it allows for international trading. Unlike a carbon tax, permits can be saved for future use – which makes sense given that carbon is a long-lasting global pollutant – affording users greater choice over the intertemporal path of consumption (Edwards and Hutton, 2001). Tradable emission permits are the major economic incentive introduced in the Kyoto Protocol to meet national emission caps. Moreover, tradable emission permits are expected to play a vital role in the post-Kyoto agreements. We evaluate the outcomes of this policy instrument to provide decision makers with a broader range of analysis.

In IGEM, 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 among all energy users in the economy and allocates the revenue to reduce the existing distorting taxes uniformly. For simplicity, it is assumed that no net international trading takes place.

The environmental and welfare consequences of a 7 percent emission reduction relative to 1995 levels through an auctioned permit system to encourage the Israeli economy to meet the Protocol Kyoto targets are shown in Table 3.

Table 3
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 CO_2 emissions following the Kyoto agreement, 46,257 permits, each valued at 1 kton of the CO_2 emissions, may be auctioned between the sectors of the economy. The equilibrium price of the permit would reach \$3.6 (\$9.03 per kton of carbon in 1995 prices). Welfare and GDP would decrease by 0.09 and 0.12 percent respectively.

Allocation by means of a regular public auction has economic effects broadly similar to those of a carbon tax. First, energy inputs are made more expensive due to the cost of permits. The price of electricity and refinery increases by slightly more than 2 percent, the price of coal by 11.5 percent. For energy-intensive industries this is the most important effect, liable in the short run to drive their profits down.

For less energy-intensive industries the secondary general equilibrium effects are just as important. Revenue recycling may increase spending on less energy-intensive products. As a result, the final consumption of commodities is reduced by 2 percent in the electricity and refined oil sectors, by 6 percent in coal, and by less than 0.3 percent in the rest of the non-energy sectors. In keeping with consumption, output level falls by more than 2 percent in electric power and refineries, by 0.43 percent in transportation, by 0.2 percent in manufacture, and by only 0.08 percent in the rest of the economy. CO_2 emission abatement is led by the electricity sector, which is responsible for nearly half of the total emission abatement.

c. Sensitivity Analysis

As most of the elasticity parameters in this model are provided by the literature and lack any empirical foundation, CGE modeling commonly examines the fluctuation of results due to changes in assumptions on elasticities of substitution.

In applied climate policy models the ease with which one input can be substituted for another is represented by elasticities of substitution. Following a recent empirical estimation of production function for climate policy models for OECD countries (van der Werf, 2007), we check the consistency of our results 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 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 labor 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 1 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 IGEM twice more, implementing the elasticities of substitution evaluated by van der Werf for the Finnish and Italian economies. The Finnish economy was chosen for its relative similarity in magnitude to Israel's, whereas the Italian elasticities were adjusted to reflect the fact that Israel, like Italy, has limited hydrocarbon resources. Figure 3 mirrors the initial and the resulting production function structures. The elasticities of substitution between labor and capital are estimated at about the same value of 0.5 for Italy and Finland, whereas the elasticities of substitution between energy aggregate and labor–capital composite for Italy is half that of Finland, and they are both substantially lower than the one used for the initial simulation. Accordingly, the new production functions represent lower substitution ability between energy and primary factors, with Italian elasticity being the most stringent. From here on we call the initial L(KE) production function "Production Function A", the production function with E(KL) nest and Finnish elasticities "Production Function B", and the production function with E(KL) nest and Italian elasticities "Production Function C".

Figure 3
Nesting Structure of the Modeled Production Functions

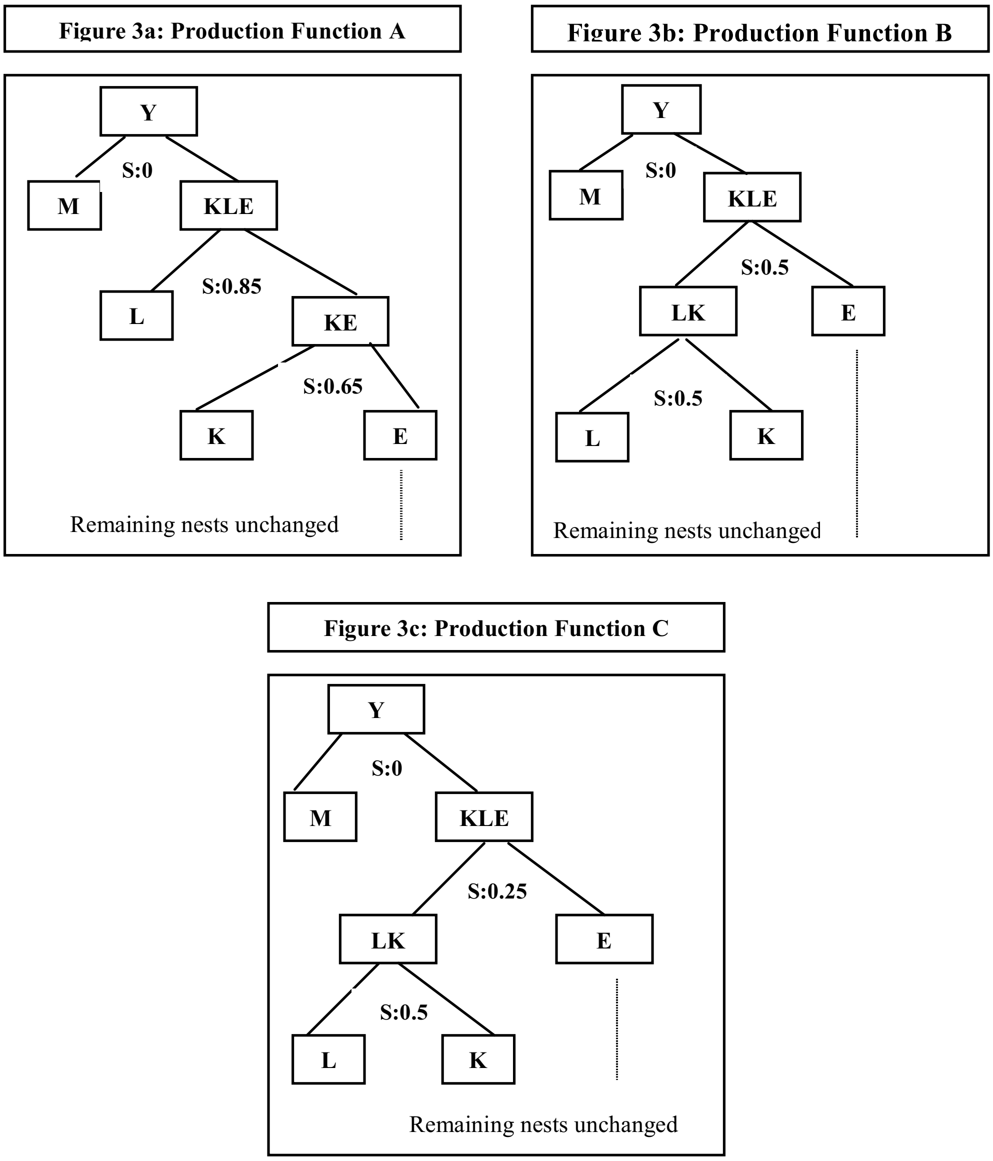
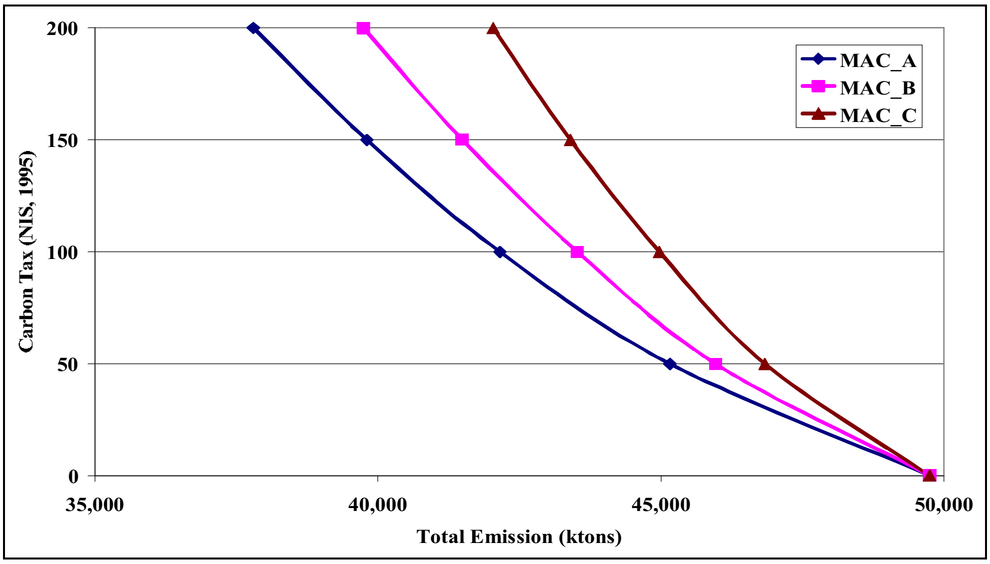


Figure 4 illustrates the resulting economy-wide MAC curves for each production function. As the elasticity of substitution between primary factors and energy inputs diminishes, production has less possibility to substitute away from energy. As a result, the MAC becomes less flexible, and fewer emission reductions can be gained for each level of carbon price.

Figure 4
Marginal Abatement Curves of the Israeli Economy for Various Production Function Definitions.



The economic impacts of carbon taxes and auctioned permits in respect of three production functions are compared in Table 4. As expected, production functions B and C allow less substitution between energy inputs and primary factors, so for an equal value of carbon tax, emission reduction is lower. However, even the least flexible elasticity production function C produces almost 6-15.5 percent CO_2 emission reduction for a carbon tax of $16⅔-$66⅔. Experiencing an equal price increase, energy sectors in cases B and C suffer less demand reduction and draw the economy to a smoother change in welfare and the GDP: 0.08-0.14 percent change in cases B and C compared with about a 0.3 percent change in case A.

The comparison of a 7 percent emission reduction using auctioned permits provides additional confirmation for 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 being sufficiently higher for production functions B and C, and the economic cost is larger.

Table 4
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
CO_2 Emission (ktons)	45,158	37,802	46,266	45,966	39,742	46,266	46,837	42,039	46,266
CO_2 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 section 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 indicators. 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. But no double dividend is identified. Changes in the patterns of sectoral production and consumption can be clearly observed. Simulating a stiffer production function, which allows less substitution between capital–labor and energy composites, we find that the tax is less effective in reducing carbon emissions but the economic costs are lower too.

6. SUMMARY AND DISCUSSION

The research presented here expands the academic discussion on climate change mitigation strategies in Israel. Its purpose is to determine whether policy makers in Israel could introduce environmental taxation in the form of a CO_2 emission tax without causing a substantial decrease in welfare and economic performance. It is particularly relevant following recent negotiations on the post-Kyoto agreement, which is expected to engage all UNFCCC parties in 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 has been developed so far. In the current research we adapted the CGE model to the Israeli economy in order to study the effects of green tax reforms on environmental quality and the economic burden of the tax system. To this end, a consistent and balanced disaggregated SAM for Israel in 1995 was constructed.

Our counter-factual analyses simulated imposition of carbon emission taxes ranging from \$16⅔ to \$66⅔ (at 1995 prices) on the revenue neutral basis. Alternatively, the auctioned permits system was devised to achieve a 7 percent abatement. The accumulated income served to proportionally reduce pre-existing taxes.

The main conclusions are the following. First, the reduction target for energy-related CO_2 emissions in Israel of 7 percent as against the 1995 levels can be achieved with a carbon energy tax of between approximately \$9 and \$21 per ton 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 showed that this result is sensitive to producers' possibilities to substitute away from energy use. With lower substitution possibilities emissions will respond less to a given tax level, so that the target has to be reached with higher tax levels.

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

Thirdly, consumption patterns will vary due to changes in relative prices. There will be a shift in demand from fuels with a high emission factor to energy sources with lower carbon-intensity, and from energy to other commodities. Structural changes will also occur on the production side. Relatively ‘dirty’ sectors, i.e., sectors with a high CO_2 emission intensity, will suffer substantially from cost increases and decreased demand. Sectoral and economy-wide marginal abatement curves following a range of assumptions on production function structure were presented.

The major limitation of the analysis is the age of the data base. An operational data base was compiled using official published input–output tables, expenditure surveys, and national product and income accounts. Unfortunately, these data sources are not updated at the required pace, at least not for the modeler, and a few compromises linking and unifying them in a micro-consistent way have to be made. For this reason simulation results 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 problematic for drawing policy implications: 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 to the use of natural gas became possible following an agreement signed in 2005 between Israel and Egypt which enabled 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 rose from about 1 percent in 2004 to 18 percent in 2006, and is expected to rise up to 40 percent in the coming decade. This new energy source, which is characterized by lower carbon intensity, may reduce the economic costs of the mitigating policies investigated even more than this research projects.

Moreover, the information and communications technologies (ICT) sectors, which contributed only a tiny fraction to Israeli industrial production in 1995, have become important economic players, contributing 17 percent to industrial production in 2007 (CBS, 2008). These labor-intensive sectors will suffer less from the environmental tax reform presented in this paper so the overall economic costs could be even lower.

Possible improvements to the model include further disaggregation of indirect taxes, and the introduction of unemployment and endogenous labor supply. 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 commodity 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, as well as foreign energy policies affecting 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 drive certain households into poverty and exacerbate existing problems of fuel poverty (Healy, 2004). Our research used a single representative household and therefore does not offer this kind of insight. For that analysis different income groups have to be distinguished, and model the relevant linkages between these household groups and the rest of the economy, including the government have to be modeled in sufficient detail.

Despite all these qualifications, and on general economic grounds, a strong point can be made to support energy tax policies as a singular tool of choice for achieving better environmental quality and a lower inefficiency level to the Israeli economy.

APPENDIX A: Summary of GHG emissions and removals (2004)
(Source: Israeli Union for Environmental Defense, 2007)

Sector	CO_2	CH_4	N_2O	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.

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, vehicle repair 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 CO_2 emission
(Source: Avnimelech et al., 2000)

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					2,159	6,657		
Diesel Oil	137	435	900	2,859	1,013	2,876	199	632
Naphtha			769					
Residual Fuel Oil	2,031	6,252	2,277	7,099				
Petrol. Coke			168	675				
Tar					267	821		
Coal	8,190	19,882						
Total CO_2 emissions		**26,569**		**10,999**		**10,354**		**1,826**
% of total emission		53.47%		22.13%		20.84%		3.67%

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