Assessing Climate Change Impacts:
A Dynamic CGE Modeling for Israel

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Abstract

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 obliged 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 aims to quantify the economy-wide consequences for Israel of meeting the possible targets of the Post-Kyoto Protocol, employing a dynamic Computable General Equilibrium (CGE) model of the Israeli economy with bottom-up information on abatement techniques. This information is used to ensure a proper assessment of the direct and indirect economic costs of environmental policy in Israel. The efficacy of decentralized economic incentives for GHG emission reduction, such as carbon taxes on emissions and auctioned emission permits, is assessed in terms of their impact on economic welfare. The dynamic 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, Dynamics, Climate Change, Pollution Abatement, Israel.*

JEL Classification: *D58, H23, Q20*

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.

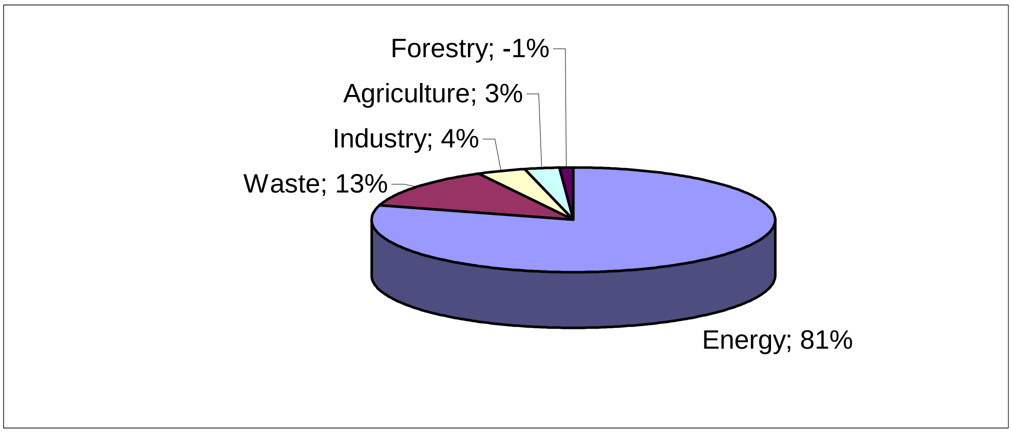
Although the baseline year for Annex I countries is 1990, Israel has set its baseline year for compliance with the obligations of the UNFCCC as 1996 due to the unprecedented growth in both population and economy which occurred during the first part of the decade. During this period, nearly a million 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 CO_2 equivalent emissions is presented in Figure 1. By far the largest source of CO_2 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 CO_2. 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 CO_2 Equivalent Emissions in Israel in 1996:
(Source: IFNCCC, 2000)



The contribution of GHGs to total CO_2 equivalent emissions is shown in Figure 2. The proportions of methane (CH_4) and nitrous oxide (N_2O), as opposed to that of carbon dioxide (CO_2), are small.

Figure 2. Contribution of Greenhouse Gases to Total CO_2 Equivalent Emissions in Israel in 1996: (Source: Avnimelech, Y. et al., 2000)

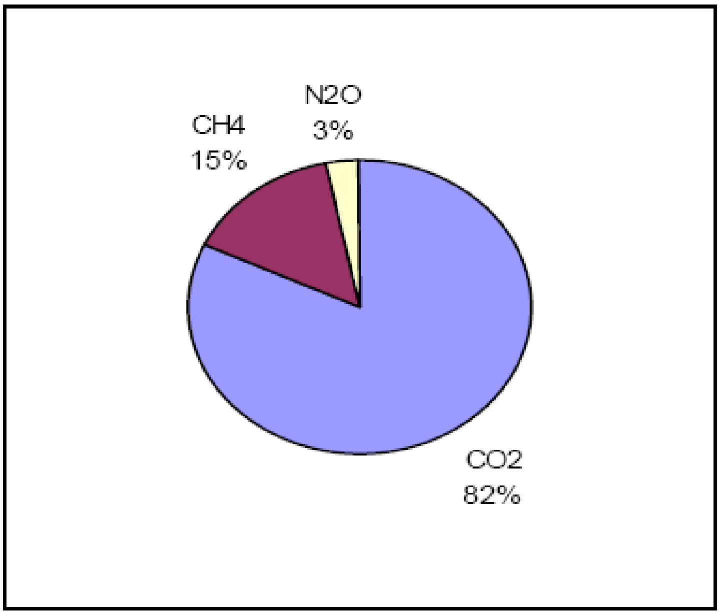


Table 1 summarizes the emissions and removals of CO_2, CH_4 and N_2O from the different sectors of the Israeli economy as estimated for 1996. Methane and nitrous oxide emissions are converted to a CO_2 equivalent by means of the Global Warming Potential (GWP) which is a measure of the radiative effects of the different GHGs relative to CO_2.

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

Sector	CO_2	CH_4	N_2O	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 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 in progress aims to quantify the economic consequences of meeting the targets of the Post-Kyoto agreement. The dynamic Computable General Equilibrium (CGE) model of the Israeli economy is 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.

In addition, following the methodology proposed by Dellink et al. (2004), the research combines the advantages of the top-down approach of CGE models with the information on abatement technologies included in the bottom-up approach in a dynamic setting. An accurate economic assessment of environmental policy is based on the simultaneous specification of multiple

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

GHG pollutants. The methodology is designed to be able to take account the interactions between the different pollutants. The CGE approach is chosen because it provides a consistent framework to analyse the economic impacts of environmental policy: it has sound micro-economic foundations and a complete description of the economy with both direct and indirect effects of policy changes.

The next section reviews studies focused on the economic aspects of global warming in a dynamic framework, followed by researches that aimed to assess the climate change impacts on the Israeli economy. Section 4 describes the structure of the dynamic energy-environment CGE model employed in the research, followed by a discussion of the dynamic behavior of abatement in Section 4. Section 5 presents the expected results.

2. Literature Review

Designing or evaluating environmental policy requires detailed understanding of the relations between economy and environment. Using mathematical models that specify quantitative links between economic activity and environmental pressure can provide an insight into direction and size of economic implications of environmental policies. Given the increasing importance of implementing costly process-integrated measures and restructuring of the economy to achieve required emission reductions, the need for multi-sectoral economic models with special attention to pollution and abatement is eminent.

2.1. Dynamic general equilibrium models

Most energy-economic models assume that end-of-pipe measures are prohibitively costly compared to fuel switches, and therefore can be neglected in the model. All major integrated climate-energy-economy models developed in the 1980s and 1990s share this assumption (Whalley and Wigle, 1991; Burniaux *et al.*, 1992a,b; Manne and Richels, 1992; Peck and Teisberg, 1992; Alcamo, 1994; Nordhaus, 1994; Nordhaus and Yang, 1996; Capros *et al.*, 1998; Naqvi, 1998), as do more recent models (*e.g.* Böhringer and Rutherford, 2002). Recently, attempts have been made to include other sources of greenhouse gasses for which end-of-pipe measures are relevant (Babiker *et al.*, 2001; Hyman *et al.*, 2002).

Blitzer *et al.* (1994) specify a dynamic applied general equilibrium (AGE) model with special attention to energy to analyze carbon emission restrictions for an individual country (Egypt). One of the most distinctive features of this model is that it has a discrete modeling of production technologies (*i.e.* an activity analysis). Carbon emissions are coupled to production and consumption activities via fixed coefficients, much as in the global energy-economy models. They show that the impact of carbon emission restrictions on GDP is highly non-linear and that sector-specific reduction targets have higher economic costs than global targets and may even be infeasible. Smajgl (2002) extends the energy AGE analysis by including fossil fuel extraction and shows how fossil fuel scarcity interacts with carbon emission restrictions.

In the early 1990s, Jorgenson and Wilcoxen (1990, 1993a,b) used econometric estimation to construct an intertemporal AGE model. A similar study was carried out by Hazilla and Kopp (1990). These models have a much larger basis in empirical data for the specification of model parameters than calibrated models. Since long lasting panel data are not widely available, econometric AGEs have not become popular. Most modelers prefer to calibrate their parameter values using existing literature for practical reasons. Moreover, the econometric approach can only be applied to those environmental problems that are ‘well established’ in the sense that time series data are available on emissions and abatement costs. Since some environmental problems have only recently gained policy attention, such time series data on abatement costs are not available for all major environmental problems.

Vennemo (1997) pays detailed attention to the feedbacks from the environment to the economy based on several air pollutants. These feedbacks go via the impact of environmental quality on utility, via reduced labour productivity and via increased capital depreciation. Using a the Ramsey-type dynamic AGE model, he analyzes what happens in the economy if these feedbacks are introduced and finds substantial reductions in consumption and GDP in the second half of the 21st century.

Rasmussen (2001) extends the Ramsey model with learning-by-doing in the renewable energy sector to capture endogenous technological progress. He finds that the presence of endogenous interactions between carbon abatement and technological progress leads to substantially lower abatement costs and a lower optimal level of short-term emission reductions due to rapidly declining abatement costs over time. Van der Zwaan *et al.* (2002) and Gerlagh and Van der Zwaan (2003) use a similar approach, while specifying multiple technologies. They find that including endogenous innovation will lead to earlier and cheaper emission reductions than models with exogenous technological change predict, especially through the development of carbon-free technologies.

Bye (2000) analyzes an environmental tax reform and the possibilities of a double dividend in a Ramsey-type dynamic AGE model for Norway. She finds that a small welfare gain from the environmental tax reform is possible, partially because a shift from leisure to labour boosts employment. Moreover, existing tax inefficiencies are reduced. In countries where the marginal costs of public funds are high, such as Norway, the welfare gains from reducing distortionary taxes can be substantial. This issue is also emphasized by Goulder (1995), though he concludes that a double dividend cannot be reaped. Babiker *et al.* (2003) show in a large-scale empirical model that redistributing the proceeds of environmental taxes via a reduction of existing distortionary taxes may not always have superior welfare effects than redistributing the proceeds lumpsum.

Jensen (2000) also uses a Ramsey-type model in an analysis of carbon taxes in Denmark. He shows that delaying the abatement activities, while keeping the accumulated emission reductions within the model horizon constant, can substantially reduce the economic costs of environmental policy.

More recent contribution to the literature of dynamic environmental AGE models is from Dissou *et al*. (2002). They introduce monopolistic competition in a Ramsey-type model for Canada with carbon emissions. The numerical results on the costs of compliance with the Kyoto protocol suggest that the competition setting may have only a minor impact on the estimated GDP losses, while the estimated welfare costs are substantially higher in the monopolistic competition setting than in the more common perfect competition framework.

For additional detailed analyses of the welfare implications of an environmental tax reform in an analytical framework, see Bovenberg and De Mooij (1994), Bovenberg and Goulder (1996), Ligthart and Van der Ploeg (1999), Rosson (2001), Palatnik and Shechter (2008), Bussolo and Pinelli (2001), Dellink et al. (2004) and De Mooij (1999).

Given the significant structural differences between a large economy such as the USA and Canada and relatively small open economies such as Norway, Denmark or The Netherlands, comparisons of the numerical results are complicated. Perhaps even more importantly, though all these models share their micro-economic foundation as they are based on a Ramsey-type model with perfect foresight and intertemporal optimisation of utility, there are specific differences between the models, for instance with respect to functional forms of the production functions or assumed mobility of capital across sectors.

2.2. The economic aspects of climate change: The case of Israel

The following section 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 NIS[2] 70 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.

Palatnik and Shechter (2008) quantified 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. They 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 CO_2 emission reduction, such as carbon taxes on emissions and auctioned emission permits, was assessed in terms of their impact on economic welfare. The main result indicates that an employment double dividend is a possible outcome of GHG mitigation policy for the Israeli economy.

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

The study by Palatnik and Shechter is the first attempt to analyze the economy-wide impacts of climate change mitigation policies in Israel. However, the comparative static CGE model that they launch does not contain any explicit time dimension. Since climate change is a long term problem, the introduction of intertemporal dynamics is recommended. A recursive-dynamic CGE model can be linked to a macro-econometric model to produce a ‘business-as-usual’ forecast. The CGE model can then be used to trace out a specific time path of the economy following the change in the policy or introduction of the project. The economic adjustment can then be determined by the difference between the two alternative time paths.

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

The model used in this study is a dynamic CGE model with perfect foresight in the Ramsey tradition. Here, only a general description of the model is given, focusing on the assumptions that are needed to build a multi-sectoral dynamic applied general equilibrium model, including a specification of environmental pollution and abatement options.

Producers (firms) maximise profits under the restriction of their production technology, for given prices. The nested-CES production function consists of the input of labour and capital and intermediate deliveries. As full competition and constant returns to scale are assumed, no excess profits can be reaped and the maximum-profit condition diminishes to a least-cost condition.

The private households are included as a single representative consumer. Private households maximise the present value of current and future utility under a budget constraint, for given prices and given initial endowments. They own the production factors labour and capital and consume produced goods, for which a CES-type utility function is used. A LES-structure is imposed to account for non-unitary income elasticities.

The wage rate is fully flexible and an exogenous growth of the annual labour supply is assumed. This growth in the labour supply, which reflects both increases in the population as well as increases in technological efficiency, drives the growth of the economy. In the version of the model used in this paper, international trade is abstracted from. This implies that the rate of return on investments is determined on the domestic market. The capital stock and investment levels are fully endogenised; households choose to save part of their income until the rate of return on investments equals the exogenously given interest rate. These savings are in turn used by the producers as capital investments.

The forward-looking behaviour of the agents and the endogenous savings rate make this model of the Cass–Koopmans–Ramsey type (Barro and Sala-i-Martin, 1995). The government sector collects taxes on all traded goods and factors and uses the proceeds to finance public consumption of produced goods and pay for a lump-sum transfer to the private households. For government behaviour the equal-yield assumption is made, i.e. government utility follows the balanced growth path as determined in the benchmark projection. This is achieved by changing the lump-sum transfer to compensate changes in income and/or expenditures of the government. Production and consumption processes lead to pollution (emissions). In the model specification, pollution is regarded as a necessary environmental input for the production and utility functions.

Environmental quality is not directly included in the utility function. Instead, it is assumed that the government sets the environmental targets by auctioning a restricted number of tradable pollution permits. The proceeds from the sale of the permits are used by the government to reduce existing taxes. Polluters have the choice between paying for their pollution permits or increasing their expenditures on pollution abatement. This choice is endogenous in the model, and the polluters will always choose the cheaper of the two. A third possibility for producers and consumers is a reduction of their production and consumption of the pollution intensive good, respectively. This becomes a sensible option when both the marginal abatement cost and the price of the permits are higher than the value added foregone in reducing production or utility foregone in reducing consumption. In the benchmark projection, the government auctions exactly the number of permits that allows the producers and consumers to maintain their original behaviour.

4. The dynamic behavior of abatement

The calibration of the available abatement options and their associated costs is important to get a good estimate of the economic impacts of environmental policy. In a large part of the literature, the abatement costs are only implicitly modelled (as profit or utility losses), or modelled through a quadratic abatement cost curve (e.g. Nordhaus and Yang, 1996). Key exceptions are the detailed energy-economic models (e.g. Manne et al., 1995; Palatnik and Shechter, 2008) that specify alternative ways to produce energy (a form of emission abatement), but do not include end-of-pipe abatement. More general specifications of abatement are used by Nestor and Pasurka (1995), Böhringer (1998) and Hyman (2001). Dellink et al. (2004) present a Ramsey-type economic model, in which bottom-up technical and economic information on abatement techniques is integrated in a top-down dynamic CGE context. The model presented in the current study follows this methodology and specifies explicitly expenditures on abatement to capture as much information as possible about the technical measures underlying the abatement options.

The abatement cost curves are constructed, using the detailed technical data for the base year. Avnimelech et al. (2000) made an inventory of all available options to reduce GHG emission in Israel. Every option is characterised as a reduction measure that states how much pollution can be reduced with this option and what the costs of implementing the option are. The pollution reduction realised by each measure is given as a fixed amount in physical units. Therefore, the measures have to be interpreted as additive. In this way, cumulative pollution reductions and the corresponding cumulative abatement costs can be calculated. In the abatement cost curve all measures are ranked by cost-effectiveness. Note that the abatement cost curves comprise all known available options to reduce pollution, both end-of-pipe as well as process-integrated options, including substitution between different inputs (e.g. fuel-switch). The abatement cost curve does not contain economic restructuring, i.e. changing production volumes of the different sectors. Output changes and associated changes in consumption are captured endogenously in the economic model through the markets for produced goods.

In the construction of the abatement cost curves, all costs are transformed into annual costs, including capital costs (annuity interest and depreciation payments) of investments. In the model, these capital costs of abatement investments are treated similar to ‘conventional’ man-made capital, i.e. the firms pay the capital costs while the households provide the means necessary for investments (in the form of savings). This means that the order in which the measures are represented in the abatement cost curve is consistent with the way rational firms decide upon the adoption of a measure.

There are several reasons why the environmental parameters may change over time. The first effect that takes place when moving from period t to period t+1 is that the polluters adopt some abatement measures, i.e. diffusion of abatement technology. As the substitution curve describes the annual abatement costs, a polluter has to pay the costs of the same measure each year again. This means that adopting a measure in year t does not imply adoption of the same measure in year t+1: the decision is reversible. Consequently, the adopted measures should stay in the substitution curve, which does not change due to this effect. Both the technical potential, and the substitution elasticity, are not influenced by this effect.

The second effect is that new abatement measures will emerge through innovation. The impact of the emergence of new measures is partially countered by the removal of old techniques that become obsolete. On average, the substitution curve will be extending to above and to the left, thereby increasing the technical potential. The increase in the technical potential is modelled through an exponential growth function, i.e. every period the technical potential increases with an exogenous constant rate. The effect of these new measures on the substitution elasticity cannot be predicted beforehand, but is likely to be very small, and hence a constant substitution elasticity may be assumed.

The third effect is a reduction of the marginal costs of all existing measures. Learning effects and path-dependent small innovations will induce a reduction in abatement costs that go beyond labour productivity developments. This reduction in abatement costs compared to other goods can be explicitly captured in the model as an efficiency improvement in the abatement production process leading to a growth rate of the abatement sector that exceeds the growth rate of the rest of the economy.

Both the growth rate of the technical potential and the autonomous efficiency improvements in the abatement sector, are implemented in the model only in the sensitivity analysis. In the base specification these parameters are set to zero.

Finally, the model also contains exogenous technological progress in environmental efficiency, governed by an autonomous pollution efficiency improvements parameter. This increase in environmental efficiency leads to an autonomous difference in the growth rate of emissions and the growth rate of production; this effect is present in both the base specification and the sensitivity analysis. Note that the model captures endogenous diffusion of abatement technology via the 'pollution-abatement substitution' (PAS) curve.

5. Summary and Expected Results

This research in progress attempts to produce a multi-sectoral dynamic applied general equilibrium model specified to reflect the structure of the Israeli economy. The dynamic relations between production, consumption, pollution and abatement are investigated. In the model, there is a separate 'abatement production sector' that provides the abatement techniques to the producers and consumers and that has specific characteristics associated with the cost components of abatement. Polluters have the endogenous choice between paying for pollution permits and increasing their expenditures on abatement. The extent to which this substitution is possible and the characteristics of producing abatement are derived from empirical abatement cost curves. Even with a simple specification of the abatement sector, there are dynamic interactions that influence the costs of abatement for polluters, the price of pollution permits and the economic impacts of environmental policy.

The model will provide an insight into the least cost options of achieving a predetermined environmental policy objective, but cannot calculate the optimal rate of pollution control, as the damages caused by pollution are not taken into account. The environmental submodel focuses on the pollution levels and abatement activities. According to the CGE analysis, environmental policy will, in general, lead to a lower level of consumption and hence a downward pressure on (measured) welfare. This represents the economic costs of environmental policy. On the other hand, the impacts of environmental policy on environmental quality will be positive.

The aggregated numerical example will be provided in future and is expected to show that when environmental policy is not too stringent, there are cheap abatement options available, and the effect on the rest of the economy is minor. However, the more strict environmental policy becomes, the more important it is to get the best possible representation of abatement possibilities. The macro-economic impacts of high marginal abatement costs can be significant, and given the limits to technology, far-reaching emission reductions are only possible at very high costs.

References

Alcamo, J. (ed.), 1994, *IMAGE 2.0: Integrated Modeling of Global Climate Change*, Kluwer, Dordrecht.

Avnimelech, Y. et al. (2000). Alternatives for Greenhouse Gas Emission Reduction in Israel. The Samuel Neaman Institute for Advanced Studies in Science and Technology publication. [Hebrew]

Babiker, M.H., J.M. Reilly, M. Mayer, R.S. Eckaus, I.S. Wing and R.C. Hyman, (2001), *The MIT emissions prediction and policy analysis (EPPA) model: revisions, sensitivities and comparison of results*, Joint program on the science and policy of global change report 71, MIT, Cambridge.

Barro, R.J., Sala-i-Martin, X., 1995. Economic Growth McGraw-Hill, Inc, New York.

Blitzer, C.R., R.S. Eckaus, S. Lahiri and A. Meeraus, (1994), “A general equilibrium analysis of the effects of carbon emission restrictions on economic growth in a developing country: Egypt”, in J. Mercenier and T.N. Srinivasan (eds.), *Applied general equilibrium and economic development*, University of Michigan Press, Ann Arbor.

Bo¨hringer, C., 1998. The synthesis of bottom-up and top-down in energy policy modeling. Energ. Econ. 20, 233– 248.

Böhringer, C. and T. Rutherford, (2002). “Carbon abatement and international spillovers: a decomposition of general equilibrium effects”, *Environmental and Resource Economics* 22, pp. 391-417.

Bovenberg, A.L. and L.H. Goulder, (1996), “Optimal environmental taxation in the presence of other taxes: general-equilibrium analysis”, *American Economic Review* 86, pp. 985-1000.

Bovenberg, A.L. and R.A. de Mooij, 1994, “Environmental levies and distortionary taxation”, *American Economic Review* 84, pp. 1085-108.

Burniaux, J.-M. J. P. Martin, G. Nicoletti and J. Oliveira- Martins (1992b)."The Costs of Reducing CO_2 Emissions: Evidence from GREEN", OECD Economics Department Working Papers No. 115.

Burniaux, J.-M., J.P. Martin, G. Nicoletti and J. Oliveira Martins,(1992a), *GREEN: a multi-sector, multi-region general equilibrium model for quantifying the costs of curbing CO2 emissions*, Economics Department Working Papers 116, OECD, Paris.

Bussolo M. and D. Pinelli (2001). *Green Taxes: Environment, Employment and Growth*. Nota di Lavoro 4.2001

Bye, B., 2000, “Environmental tax reform and producer foresight: an intertemporal computable general equilibrium analysis”, *Journal of Policy Modeling* 22, pp. 719-752.

Capros, P., T. Georgakopoulos, A. Filippoupolitis, S. Kotsomiti, G. Atsaves, S. Proost, D. van Regemorter, K. Conrad and T.F.N. Schmidt, 1998, *The GEM-E3 model reference manual*, Report, National Technical University, Athens.

Dellink R., M. Hofkes, E. van Ierland, H. Verbruggen (2004). Dynamic modelling of pollution abatement in a CGE framework. Economic Modelling 21 (2004) 965–989

Dissou, Y., C. MacLeod and M. Souissi, 2002, “Compliance costs of the Kyoto protocol and market structure in Canada: a dynamic general equilibrium analysis”, *Journal of Policy Modeling* 24, pp. 751-779.

Gerlagh, R. and B.C.C. van der Zwaan, 2003, “Gross World Product and consumption in a global warming model with endogenous technological change”, *Resource and Envrgy Economics* 25, pp. 35-57.

Goulder, L., ed. (2002). Environmental Policy Making in Economies With Prior Tax Distortions, Northampton MA: Edward Elgar.

Goulder, L.H., (1995), “Effects of carbon taxes in an economy with prior tax distortions: an intertemporal general equilibrium analysis”, *Journal of Environmental Economics and Management* 29, pp. 271-297.

Gressel N., N. Becker and D. Lavee (2000). "A National Climate Change ActionPlan for Israel". Israel Environmental Policy Research Center, Jerusalem Institute for Israel Studies, and the Arava Institute for Environmental Studies, Israel.[Hebrew]

Haim D., M. Shechter. and P. Berliner (2007) "Assessing the Impact of Climate Change on Representative Field Crops in Israeli Agriculture: A Case Study of Wheat and Cotton". Accepted for publication: *Climatic Change Journal*.

Hazilla, M. and R.J. Kopp, 1990, “Social cost of environmental quality regulations: a general equilibrium analysis”, *Journal of Political Economy* 98, pp. 853-873.

Hyman, R.C., 2001. A more cost-effective strategy for reducing greenhouse gas emissions: modeling the impact of methane abatement opportunities, M.Sc. Thesis. Massachusetts Institute of Technology, Massachusetts.

Hyman, R.C., J.M. Reilly, M.H. Babiker, A. DeMasin and H.D. Jacoby, 2002, *Modeling non-CO2 greenhouse gas abatement*, Joint program on the science and policy of global change Report 94, MIT, Cambridge.

IFNCCC (2000) Israel National Report on Climate Change - First National Communication to the Conference of the Parties to the United Nations Framework Convention on Climate Change. State of Israel Ministry of the Environment

Jensen, J., 2000, “How valuable are delayed cutbacks in Danish carbon emissions?”, in G.W. Harrison, S.E. Hougaard Jensen, L. Haagen Pedersen and T.F. Rutherford (eds.), *Using dynamic general equilibrium models for policy analysis*, North-Holland, Amsterdam.

Jorgenson, D.W. and P.J. Wilcoxen, 1990, “Intertemporal general equilibrium modeling of U.S. environmental regulation”, *Journal of Policy Modeling* 12, pp. 715-744

Jorgenson, D.W. and P.J. Wilcoxen, 1993a, “Reducing US carbon emissions: an econometric general equilibrium assessment”, *Resource and Energy Economics* 15.

Jorgenson, D.W. and P.J. Wilcoxen, 1993b, “Reducing U.S. carbon dioxide emissions: an assessment of different instruments”, *Journal of Policy Modeling* 15, pp. 491-520.

Kadishi, N., Kan, I. and Zeitouni, N. (2003). "Impacts of Changes in Regional Rainfall Distribution Patterns on Winter Agriculture in Israel." Studies in Natural and Environmental Resource Management, pp. 123-130 [Hebrew].

Kan I., Rapaport-Rom M. and Shechter, M. (2007). "Economic Analysis of Climate-Change Impacts on Agricultural Profitability and Land Use: The Case of Israel". Paper presented at the 15th Annual Meeting of the European Association of Environmental and Resource Economists (EAERE), Thessaloniki, Greece, June.

Layard R., S. Nickell and R. Jackman (1991). “Unemployment: Macroeconomic Performance and the Labour Market”, Oxford University Press, 1991

Ligthart, J.E. and F. Ploeg, van der, 1999, “Environmental policy, tax incidence and the cost of public funds”, *Environmental and Resource Economics* 13, pp. 187-207.

Manne, A.S. and R.G. Richels, (1992), *Buying greenhouse insurance*, MIT Press, Cambridge.

Manne, A.S., Mendelsohn, R., Richels, R.G., 1995. Merge: a model for evaluating regional and global effects of GHG reduction policies. Energ. Policy 23, 17– 34.

Mooij, R.A., de, 1999, *Environmental taxation and the double dividend*, thesis, Voorburg.

Naqvi, F., 1998, “A computable general equilibrium model of energy, economy and equity interactions in Pakistan”, *Energy Economics* 20, pp. 347-373.

Nestor, D.V., Pasurka, C.A., 1995. CGE model of pollution abatement processes for assessing the economic effects of environmental policy. Econ. Model. 12, 53–59.

Nordhaus, W.D. and Z. Yang, 1996, "RICE: a regional dynamic general equilibrium model of optimal climate change policy", *American Economic Review* 86, pp. 741-765.

Nordhaus, W.D., 1994, *Managing the global commons*, MIT Press, Cambridge.

Peck, S.C. and T.J. Teisberg, 1992, "CETA: a model for carbon emissions trajectory assessment", *The Energy Journal* 13, pp. 55-75.

Nordhaus, W.D., Yang, Z., 1996. A regional dynamic general-equilibrium model of alternative climate-change strategies. Am. Econ. Rev. 86, 741–765.

Palatnik R. and M. Shechter (2008). "Can Climate Change Mitigation Policy Benefit the Israeli Economy? A Computable General Equilibrium Analysis", FEEM Working Papers N 2.2008.

Peck, S.C. and T.J. Teisberg, 1992, "CETA: a model for carbon emissions trajectory assessment", *The Energy Journal* 13, pp. 55-75.

Rasmussen, T.N., 2001, "CO2 abatement policy with learning-by-doing in renewable energy", *Resource and Energy Economics*, 23, pp. 297-325.

Roson R. (2001), *Carbon Leakage in a Small Open Economy with Capital Mobility*, FEEM working paper n. 50.01, Milan.

Tiraspolsky A. (2003). Incorporating Economic Incentives in Reducing Greenhouse Gas Emissions under the Kyoto Protocol: The Case of Israel. A thesis submitted for the degree "Master of Science in Economics", Haifa University, The Faculty of Economics. [Hebrew]

Vennemo, H., 1997, "A dynamic applied general equilibrium model with environmental feedbacks", *Economic Modelling* 14, pp. 99-154.

Whalley, J. and R. Wigle, 1991, "The international incidence of carbon taxes", in R. Dornbusch and J.M. Poterba (eds.), *Global warming: economic policy responses*, MIT Press, Cambridge.

Yehoshua, N. and Shechter, M. (2003) "Climate Change and Agriculture: An Israeli Perspective." In: Giupponi C. and Shechter M. (Eds.) Climate Change and the Mediterranean: Socio-Economic Perspectives of Impacts, Vulnerability and Adaptation. Edward Elgar, UK. pp. 196-212.

Yehoshua, N., Shechter, M. an Greenbaum, N. (2007). "An Economic Valuation of Land Loss Damages Due to Sea Level Rise Induced by Climate Change: The Case of Israel". Paper presented at the 1st ENCORA Thematic Meeting on Coastal Environments, Venice, February.

Zwaan, B.C.C. van der, R. Gerlagh, G. Klaassen and L. Schrattenholzer, 2002, "Endogenous technological change in climate change modelling", *Energy Economics* 24, pp. 1-19.