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# Assessing the Economic Impacts of Climate Change Using a CGE Model with Decentralized Market Instruments

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*This study aimed to quantify the economy-wide consequences for Israel of meeting the potential targets of the post-2012 agreement, employing a Computable General Equilibrium (CGE) model of the Israeli economy, called IGEM. The study enhances the previously developed IGEM model to find the potential for a double or an employment dividend if the revenues raised from a $CO_2$ emission-related environmental policy are recycled through lowering existing labour taxes. The efficacy of decentralized economic incentives for $CO_2$ emission reduction, such as carbon emission taxes and auctioned emission permits, was assessed in terms of their impact on unemployment and economic welfare. The analysis indicates that a double dividend may be an achievable goal under a $CO_2$ emission reduction policy in the case of economies such as Israel. The CGE approach applied in this research should contribute to a better informed debate on environmental policy in Israel.*

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

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## 1. Introduction

Following COP15 Copenhagen Accord, the minister of Environmental Protection, Gil'ad Erdan declared in the official communication to UNFCCC that the Israeli government is committed to reduce $CO_2$ 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. The decision makers are concerned that any emission reduction strategy could have a negative impact

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on economic development. A green policy with a potential for a double dividend, namely emission reductions and an increase in GDP, has the best chances of political support in light of the current economic recession.

The double dividend hypothesis arose as a result of opposing effects of a revenue-neutral green policy. On the one hand the carbon tax, which is levied in proportion to a fuel's carbon content, is passed on to the price of coal, natural gas, and petroleum products, hence into the price of electricity and other energy-intensive products. This reduces export demands and makes imports more attractive, thereby leading to decreased output by trade-exposed sectors (especially if energy-intensive). Labour supply is reallocated to non-traded sectors and employment declines.

On the other hand recycling the green tax revenue by reducing labour tax (for example) reduces production costs, enhancing exports and leading to a shift from non-traded to trade-exposed sectors. It stimulates consumption and increases demand for labour as its price declines relative to capital and costly energy.

Whether these effects are offsetting depends crucially on the structure of the economy, for example, the initial level of unemployment, the substitutability of capital and energy for labour, and the fraction of energy- versus labour-intensive sectors in the economy. 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).

The purpose of this study is to provide Israeli policy makers a comprehensive evaluation of economic impacts of potential GHG abatement commitments. To cope with this goal, the CGE model for Israel, IGEM (Israeli General Equilibrium Model), developed by Palatnik and Shechter (2008), is extended to allow for involuntary unemployment. The modified model more accurately reflects actual labour market imperfections and is better suited for policy analysis. Then, a green tax reform is analysed focusing on welfare implications, consumer response, and distributional aspects occurring owing to changes in greenhouse gas policies in Israel. In addition, the study tests the possibility of a double dividend. **This study is intended to serve policy makers in examining and evaluating various policy incentives prior to taking any action**.

The remainder of this paper is structured as follows: The next section reviews the recent notion of the double/employment dividend. Section 3 briefly describes the structure of the IGEM model which is used for the analysis and modifications made to IGEM for the present purpose. Section 4 presents the results of the simulations done with the extended model. Section 5 summarizes and concludes, and outlines the areas that warrant further research.

## 2. Employment Double Dividend

The economic literature has emphasized the impact that recycled fiscal revenues could have on relevant macroeconomic variables, such as output and employment (e.g. Babiker and Eckaus, 2007; Babiker et al., 2003). Some analysts have studied the potential impact that labour and the environment may have on the potential growth of developing countries (Bhagwati and Hudec, 1996; Krugman, 1997). In Europe, given the high level of taxation on labour and the persistent high levels of unemployment, the debate has concentrated on the existence of a so-called "employment double dividend", that is, the possibility of achieving better environmental quality by taxing pollutants, and of lowering unemployment rates by using green tax revenues to reduce taxes on labour, whose high level is often perceived as one of the causes of high unemployment rates (Daveri and Tabellini, 2000).

The question as to whether the strong form of double dividend or the employment double dividend holds depends heavily on the structure of the economy. While a green tax reform is liable to fail to increase non-environmental welfare in economies with functioning labour markets, it may succeed in economies suffering from involuntary unemployment. One obvious way to reduce unemployment by raising environmental taxes is by recycling the resulting tax revenues through cuts in labour taxes. The high levels of taxes on labour income, combined with the high level of unemployment benefits, are often responsible for unemployment since they distort labour supply and increase wage pressure in labour markets (see OECD 1995). A green tax reform may alleviate the tax burden on labour and thus reduce the resulting disincentive (Schöb, 2003).

The debate in Israel may also focus on achieving the employment double dividend because of high preliminary labour taxation and unemployment levels. The economic crisis caused a sharp increase in the rate of unemployment which jumped from 5.9 % in August 2008 to 8.4 % in May 2009. The prime minister of Israel, Benjamin Netaniahu, declared more than once that lowering an income tax is one of the main engines of the economy to overcome recession. Still, his initial intention of 2 % reduction of income tax in 2009-2010 wasn't possible due to budget constrains. A green tax reform which copes with both environmental and economic objectives may be politically favourable option.

The Israeli academic debate on aspects of climate change focuses mainly on evaluation of "market damages", that is, industry-based cost/benefit assessment. Palatnik and Shechter's (2008) research is the only Israeli representative to analyse the economy-wide effects of economic incentives for GHGs emission mitigation on a general equilibrium modelling basis in Israel. However, IGEM, developed in that research, like most economic modelling techniques currently used to project emissions and the effects of their limitations, assumes the existence of instantaneous and perfect markets in inputs and outputs. The necessary economic adjustments, therefore, occur smoothly and completely. The model passes over the consequences of the various rigidities that actually exist in the economy. The current study elaborates IGEM to better reflect the Israeli labour market structure, by embodying rigidity in wage adjustments. The extended model serves to test the employment dividend hypothesis for the Israeli economy.

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

The general structure of IGEM, the computable general equilibrium economic model, is familiar having had several applications, including analysis of the effects of GHG emission restrictions as noted above. CGE models are able to quantify the economy-wide impacts and effects in secondary markets in the framework of a multi-market analysis. CGE models calculate a vector of prices such that all markets of the economy are in equilibrium. All demand and supply equations are derived from microeconomic principles. Based on economic theory, CGEs show a high level of theoretical coherence. Parameters and coefficients of the assumed functional forms are calibrated to match a base-year dataset. The benchmark data is structured as a Social Accounting Matrix (SAM) for Israel in 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. In addition to economic data, IGEM incorporates data on $CO_2$ emissions.

IGEM 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 standard assumptions of market clearing, zero excess profits, and a 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.

A less common feature is the separation of activities from commodities; this permits activities to produce multiple commodities, while any commodity may be produced by multiple activities. In addition the model allows export of imported commodities, adopting the Armington assumption.[1] It is assumed that the economy is at equilibrium at 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. The sectors and commodities are described in Appendix A.

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 (see Appendix B). 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.

One of the main distinctive features of the model is its relatively detailed modelling of taxation. Seven taxes are modelled, out of which the pre-existing, namely present in the benchmark, are net taxes on products, net taxes on production, taxes on consumption, labour tax, capital tax, and import tariffs. The energy tax and the tradable emission permits system are introduced as counter-factual scenarios.

In IGEM, welfare is measured solely by private household consumption, while government purchases are fixed. A change in total household consumption therefore equals a welfare change as considered 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 must therefore be matched by a reduction in revenue from another tax or other taxes. In the following simulations carbon tax/auctioned permits revenue is used to reduce labour tax (LT).

In the standard version of IGEM the labour market is assumed to clear instantaneously and labour is modelled as perfectly mobile across sectors in the economy. In order to investigate the double and employment dividend hypotheses, endogenous labour supply and involuntary unemployment have been introduced into 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 and $u$ is the unemployment rate, taken to be 6.9 percent 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).

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.

## 4. Green Policy Simulations

A carbon tax is implemented in the model as a counter-factual scenario. Both firms and households have to pay this tax when purchasing energy if their use of the energy commodity causes $CO_2$ emissions. The tax rate is differentiated according to the emission factor of each energy source, which depends on its carbon content. The carbon tax is technically implemented in the model as an ad valorem energy tax.

Instead of performing the simulation for a single value of the environmental tax rate (as in most related studies), and in order to obtain more accurate quantitative information concerning the sensitivity of different economic variables, the simulation for a parametric range, with a minimum of NIS[2] 50 and a maximum of NIS 200 per ton of carbon (in 1995 US$ the range is about $16⅔ to $66⅔ per ton of carbon) was performed. Once the environmental tax rate is exogenously fixed, the compensating LT is decreased with the criterion of keeping the real public deficit unchanged. Section 4.2 simulates also a 7 percent emission reduction via the system of tradable permits.

### *4.1. Results and discussion*

Table 1 displays the main results, including the $CO_2$ emissions (ktons), emission abatement (%), welfare change (%), real GDP change (%), labour/capital index change (%) and unemployment (%) with respect to the benchmark situation.

When the carbon tax is compensated with LT, emissions monotonically decrease with the tax rate, as expected, reaching 16 percent reduction for the highest carbon tax level. 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. It indicates that reduction in LT overpowers the distorting effects of the environmental tax.

The fact that welfare falls up to 0.34 percent is partly explained by the drop in RA's real 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. As capital supply is fixed, and demand must equal supply, the actual quantity demanded cannot change, but the price of capital drops to more than the net wage rate (labour/capital price

Table 1. Aggregate economic impacts of environmental policy

| Carbon tax ($, 1995) | $CO_2$ emissions (ktons) | $CO_2$ abatement | Welfare change from benchmark | GDP change from benchmark | Labour/ capital price index change | Unemp-loyment |
|---|---|---|---|---|---|---|
| - | 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 % |

index increase), reflecting the relative abundance of capital at the new equilibrium, compared with other production inputs.

Table 2 depicts sectoral impacts of the carbon taxation and provides a detailed explanation for an increase in employment: 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 4 percent and makes coal more expensive by a quarter, while a $66.67/ton tax 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 0.15-2.5 percent; transport and agricultural sector prices experience a minor increase up to less than 1.5 percent, and the rest of the economy consumer prices increase only up to 0.1 percent.

These price changes induce large adjustments in the quantities of fossil fuels used as inputs by producers and households, where inter-fuel substitution allows reductions in demand to be concentrated in the most carbon-intensive energy source, coal. Thus, in the second and third panels in Table 2, sectors see a decline in coal use by 6-34 percent, while in the non-fossil fuel sectors (agriculture, manufacture, water and the rest of the economy in panels 4 and 5 in the table), demands for both petroleum and electricity decline by 0.5-8 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 the primary energy sectors. The fifth panel in the table shows that the reduction in electricity demand is 3-13 percent in refineries, 2-8 percent in the electricity sector itself, and 0.5-5 percent in the other sectors. Panel six demonstrates the decline of employment in energy-intensive sectors, and an increase in the others. As a result, the level of output falls by 2-13 percent in electric power and refineries, by 0.8-3 percent in water industry, by 0.4-1.7 percent in agriculture, manufacture and transportation, and by only 0.1-0.3 percent in the rest of the economy, as the final panel indicates. These changes in activity levels correspond closely to changes in the consumption of commodities by the representative agent.

The reduction in labour tax lowers the labour costs for employers in relation to other factors, 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. In these simulations the first effect prevails, so the unemployment rate falls.

Figure 1 depicts the sectoral marginal abatement curves (MACs). The bulk of abatement occurs in the electric power sector, which is responsible for half the emission reduction of the economy altogether (approximately 1550-4360 kton). The household sector is the second largest abating sector, with about 16 percent of abatement (350-1340 kton). Further abatement of (540-715 kton) is accomplished by the 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 at higher tax levels. Refineries are the next abating sector, slightly overtaking the manufacturing sector (100-350 kton and 45-254 kton respectively). This is mainly due to a relatively low decrease in activity (up to 0.64 percent, as shown in Table 2) of the non-energy-intensive manufacturing sector where decreased real wages induced employment (labour demand in this sector rose by up to 1.03

Table 2. Sectoral impacts of carbon taxes on the Israeli economy

| Carbon tax ($, 1995) | Refined oil | Crude oil | Coal | Manu-facturing | Electricity | Tansport | Water | Agriculture | Rest of economy |
|---|---|---|---|---|---|---|---|---|---|
| **Changes in gross-of-tax commodity prices (percent)** | | | | | | | | | |
| 16.67 | 4.12 | 0.15 | 24.42 | 0.42 | 4.68 | 0.38 | 0.93 | 0.37 | 0.03 |
| 33.3 | 8.55 | 0.53 | 49.06 | 0.53 | 9.10 | 0.75 | 1.45 | 0.73 | 0.06 |
| 50 | 12.99 | 0.91 | 73.71 | 0.64 | 13.38 | 1.11 | 1.95 | 1.08 | 0.09 |
| 66.67 | 17.43 | 1.30 | 98.37 | 0.73 | 17.55 | 1.48 | 2.43 | 1.42 | 0.11 |
| **Changes in final consumption by commodity (percent)** | | | | | | | | | |
| 16.67 | -0.88 | -0.40 | -6.85 | -0.32 | -0.82 | -0.36 | -0.62 | -0.38 | -0.04 |
| 33.3 | -3.51 | -2.94 | -13.70 | -0.63 | -3.14 | -0.72 | -1.21 | -0.74 | -0.08 |
| 50 | -6.01 | -5.34 | -19.09 | -0.93 | -5.23 | -1.07 | -1.77 | -1.09 | -0.12 |
| 66.67 | -8.38 | -7.62 | -23.49 | -1.21 | -7.15 | -1.41 | -2.31 | -1.42 | -0.16 |
| **Changes in demand for coal by sector (percent)** | | | | | | | | | |
| 16.67 | -10.73 | - | - | -7.78 | -6.55 | - | - | -7.53 | - |
| 33.3 | -20.14 | - | - | -14.91 | -12.89 | - | - | -14.78 | - |
| 50 | -27.53 | - | - | -20.43 | -17.91 | - | - | -20.40 | - |
| 66.67 | -33.52 | - | - | -24.86 | -22.03 | - | - | -24.92 | - |
| **Changes in demand for petroleum by sector (percent)** | | | | | | | | | |
| 16.67 | -2.74 | - | - | -1.21 | -0.14 | -1.35 | -1.41 | -1.36 | -0.52 |
| 33.3 | -5.31 | - | - | -2.35 | -0.53 | -2.63 | -2.74 | -2.64 | -1.00 |
| 50 | -7.72 | - | - | -3.44 | -1.09 | -3.85 | -3.99 | -3.85 | -1.46 |
| 66.67 | -10.00 | - | - | -4.48 | -1.75 | -5.00 | -5.18 | -4.99 | -1.90 |
| **Changes in demand for electricity by sector (percent)** | | | | | | | | | |
| 16.67 | -3.51 | - | - | -1.39 | -2.35 | -1.38 | -1.44 | -1.43 | -0.53 |
| 33.3 | -6.73 | - | - | -2.65 | -4.45 | -2.64 | -2.75 | -2.72 | -1.01 |
| 50 | -9.69 | - | - | -3.81 | -6.36 | -3.82 | -3.97 | -3.92 | -1.45 |
| 66.67 | -12.43 | - | - | -4.88 | -8.11 | -4.93 | -5.10 | -5.03 | -1.87 |
| **Changes in demand for labour by sector (percent)** | | | | | | | | | |
| 16.67 | -0.02 | - | - | 1.02 | -0.01 | -0.41 | -0.54 | 0.01 | 0.15 |
| 33.3 | -2.40 | - | - | 1.02 | -0.03 | -0.82 | -1.05 | 0.03 | 0.29 |
| 50 | -4.66 | - | - | 1.03 | -0.06 | -1.13 | -1.54 | 0.06 | 0.42 |
| 66.67 | -6.81 | - | - | 1.03 | -0.11 | -1.24 | -2.00 | 0.10 | 0.55 |
| **Changes in sectoral activity levels (percent)** | | | | | | | | | |
| 16.67 | -1.79 | - | - | -0.09 | -2.25 | -0.45 | -0.83 | -0.43 | -0.08 |
| 33.3 | -5.85 | - | - | -0.25 | -6.19 | -0.88 | -1.60 | -0.84 | -0.15 |
| 50 | -9.60 | - | - | -0.48 | -9.72 | -1.31 | -2.34 | -1.23 | -0.23 |
| 66.67 | -13.07 | - | - | -0.64 | -12.92 | -1.72 | -3.04 | -1.60 | -0.30 |

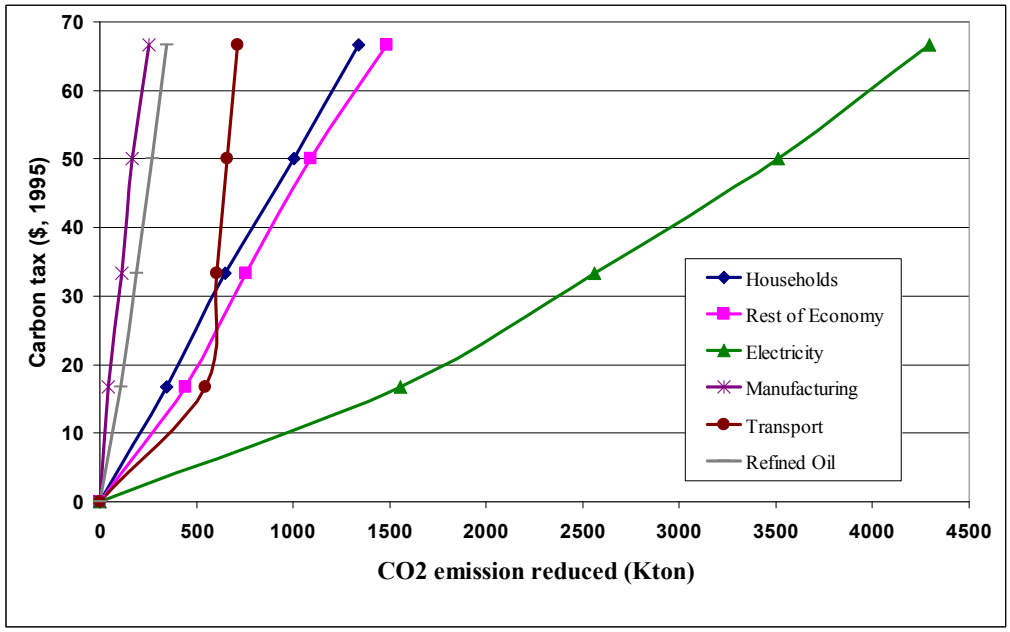



Fig. 1. Sectoral marginal abatement curves (MACs)

Table 3. Aggregate economic impacts of auctioned permits

| Permit price (NIS, 1995) | $CO_2$ emissions (ktons) | $CO_2$ abatement (ktons) | Welfare change from benchmark (%) | GDP change from benchmark (%) | Unemployment rate (%) |
|---|---|---|---|---|---|
| 65.21 | 46,265.6 | 3,482.36 | -0.08 | -0.12 | 5.59 |

percent; see Table 2). The rest of the economy sectors are responsible for about one fifth of the total abatement (440-1480 kton).

*4.2. Auctioned Emission System*

In IGEM, an upstream emissions-trading system, where firms and households require permits to cover the carbon content of fuels they process or use and the market price of permits is passed on into fuel prices, closely resembles the previously simulated carbon tax. The environmental and welfare consequences of a 7 percent emission reduction via an auctioned permits system simulating the Israeli economy to meet potential post-Kyoto targets is shown in Table 3. The trade revenues are collected by the government and fund the simultaneous LT decrease.

If the Israeli economy aims to reduce 7 percent of its $CO_2$ emissions to meet a potential post-2012 target, 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 will reach NIS 65.21 (about US $21^2/_3$ in 1995 prices). Welfare and GDP will decrease by 0.08 and 0.12 percent respectively, while unemployment levels may fall according to the simulation by a considerable 1.3 percent. Correspondingly, an employment double dividend arises in this case too.

*4.3. Sensitivity Analysis*

This section compares some of the results presented above with those obtained when the elasticities of substitution are changed. While the model's results were not greatly

Table 4. Sensitivity of economic indicators to individual changes in the value of the elasticities of substitution between labour–capital and energy composites (compared with the benchmark); 7 percent 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 % |

affected by changes in most of the parameters' values, the most influential elasticities were those that affected the possibilities for energy conservation by substitution for the labour–capital composite. We varied values of LKE elasticity of substitution while keeping the emission reduction target at 7 percent by using the auctioned permits system. In this case, Table 4 shows that as the LKE elasticity of substitution increases, the abatement target can be obtained with lower economic costs. At equilibrium, the auctioned permit price declines, indicating that lower carbon tax is needed to achieve the desired abatement level. Furthermore, for the value of LKE elasticity of substitution equal to 0.5 and higher, not only employment but also welfare and GDP changes are positive. In fact, this simulation shows a (limited) **strong double dividend result**.

## 5. Summary and Discussion

The research presented here expands the academic discussion on climate change mitigation strategies in Israel. The purpose of this study was to determine whether policy makers in Israel could introduce environmental taxation in the form of the $CO_2$ emission tax, without aggravating the problems of unemployment and decrease in welfare. It is particularly relevant following recent negotiations on post-2012 agreement, which is expected to engage all UNFCCC parties in the mutual mitigation effort.

Here the IGEM model of the Israeli economy was upgraded, to study the effects of green tax reforms on environmental quality, the economic burden of the tax system and, ultimately the level of unemployment. The model incorporated a few key aspects on the labour market. First, it contemplated the possibility of involuntary unemployment at equilibrium. Second, the wage and unemployment rates were determined endogenously. The mitigation policy implied $16⅔ to $66⅔ tax per ton of carbon or simulated the 7 percent emission reduction via the auctioned permits system and the revenues were directed to cut the labour tax.

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

The major limitation of the analysis is the age of the data base. For this reason simulation

results showing a double dividend should be taken as an indication of what may be possible, not as irrefutable proof.

Nevertheless, on general economic grounds a strong case can be made to support revenue-neutral emission tax policies as a singular tool of choice for achieving better environmental quality and a lower inefficiency level (in welfare or unemployment) for the Israeli economy.

## Notes

[1] Assumption: 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).

[2] New Israel Sheqel, the Israeli currency.

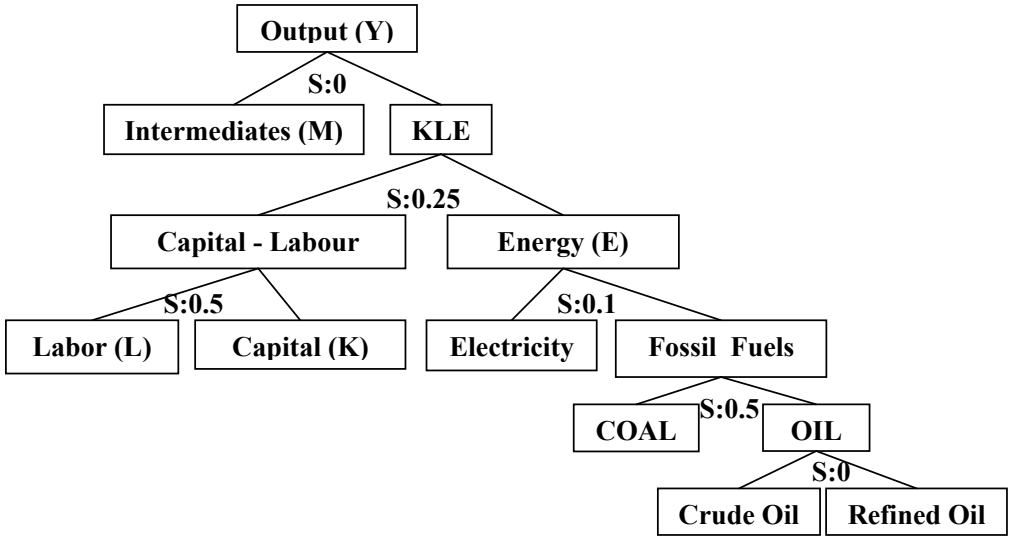
## APPENDIX A Sectors and Commodities in the SAM

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 A therefore gives descriptions of commodities only.

Table A. Commodities in the SAM and the IGEM

| 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 B Nesting Structure of the Production Function**

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# Оценка экономических эффектов изменения климата при помощи моделей вычисляемого общего равновесия с применением децентрализованных рыночных инструментов

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*Представленное исследование призвано количественно измерить последствия следования целевым ориентирам соглашений после 2012 г. для экономики Израиля. Применена модель вычисляемого общего равновесия (CGE) израильской экономики, называемая IGEM. В данной статье авторы расширяют ранее разработанную модель IGEM для нахождения потенциала двойной выгоды (выгоды, полученной от рабочей силы) для случаев повышения доходов от сборов за выбросы $CO_2$ за счет снижения существующих ставок оплаты труда. Дана оценка эффективности децентрализованных экономических стимулов сокращения выбросов $CO^2$, таких как налоги на выброс углерода и распределяемые через механизм аукционов разрешения на выбросы, в контексте их влияния на уровень безработицы и экономическое благосостояние. Анализ показал, что двойная выгода может стать достижимой целью для экономик, подобных израильской. Используемый в статье подход, связанный с применением моделей вычисляемого общего равновесия, должен способствовать конструктивному обсуждению политики в области в окружающей среды в Израиле.*

*Ключевые слова: изменения климата, вычисляемое общее равновесие, двойная выгода, политика в области охраны окружающей среды, Израиль.*