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A CGE model for the Icelandic Economy

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Abstract:
This paper presents the first version of a long-term computable general equilibrium model for the Icelandic economy. The model development has been a joint project of the National Economic Institute of Iceland and the Research Department of Statistics Norway. The motivation behind the construction of the model was to enable analysis of the cost of alternative policies for reducing the emissions of greenhouse gases in accordance with the restrictions set forth in the Kyoto protocol. The modelling framework and initial model were provided by the Norwegians while some further development of various parts of the model and the data work were carried out by the Icelanders. The paper describes the main features of the model. It also contains a discussion of some simulation results. First, a baseline scenario is presented. Then the model is used to analyse the impact of different measures (CO_2 taxes, afforestation and land reclamation, CO_2 quota purchases) aimed at reducing emissions of greenhouse gases from the baseline scenario. The baseline scenario does not assume any increase in metal production from current levels. The analysis assumes land reclamation will be recognised as a CO_2 sink. However, it does not take into account the possible effect of Iceland's proposal of largely exempting big projects in small economies that use renewable energy sources from the emission restrictions set forth in the Kyoto protocol. The results suggest that the desired emission reductions cannot be accomplished by CO_2 taxation alone. They further indicate that Iceland could meet the emission restrictions with limited adverse macroeconomic impact by combining taxation with increased afforestation, land reclamation and CO_2 quota purchases.

Keywords:

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1. Introduction

The agreement forged in Kyoto in December 1997 on legally binding emission targets for greenhouse gases (GHG) was open for signing on behalf of the parties to the FCCC until March 16, 1999. Due to the fact that there are still several outstanding issues of importance to Iceland, the Icelandic government decided not to sign the Kyoto protocol by the March 16 deadline. Among these issues are rules on GHG-sinks, quota trade and other flexibility matters. Perhaps most importantly for Iceland, it has not yet been settled if single projects in small countries that lead to an appreciable proportional increase in local emissions will be exempt from inclusion in the emission level.

Extensive preparation took part on Iceland’s behalf before the meeting of the parties to the FCCC in Buenos Aires in November 1998. Economic analysis was part of that preparation. Many important questions relating to the compliance with the Kyoto protocol are inevitably economic: What are the consequences in terms of economic growth, sector composition and other macroeconomic indicators. Given an emissions goal, how do various ways of achieving that goal compare in terms of economic costs?

To answer such questions in a sensible way, it is necessary to have access to a macroeconomic model for the simulation of the economy under different assumptions on GHG-policy. Commitments to reduce GHG-emissions are for the long-term. Therefore, the model must emphasise long-term economic development rather than short- or medium-term fluctuations unless one is very concerned about the transition period and transition cost.

The current macroeconometric model of the National Economic Institute is designed for short- to medium term forecasts (1-5 years) and does not have the necessary sectoral breakup for the estimation of GHG emissions. Thus, it could not be used directly to analyse the issues we are concerned about in this paper, although the experience gained from its construction and use and its database were of help. Therefore, a new model had to be developed, one geared towards long-term simulation (a few decades) and that takes into account the pattern of emissions of GHG in Iceland.

Long-term models have been developed in most industrial countries over the last few years and a model for Iceland could be partially based on that foundation. However, it was inevitable to build a model tailored specifically to the economic structure of Iceland, for it is in many ways very special. The energy-intensive metal production industries, fisheries and transport account for the lion’s share of emissions. Stationary energy use is almost entirely based on renewables (hydro and geothermal), and there are substantial possibilities of CO_2 sequestration through afforestation and land reclamation. These characteristics are distinctly different from those of most other industrialised countries. In 1998, the share of CO_2 in total emissions was 82%, the share of CH_4 was 9%, the share of N_2O 4%, FC 3% and HFC 2%. SF_6 emissions were negligible.

The model presented in this paper allows for various measures to reduce (net) emissions of GHG and enables us to analyze the effect of such measures on different sectors. Special attention is given to sectors that are of the greatest importance in this regard, i.e., transport, fisheries, energy-intensive industries, forestry and land reclamation. The model is disaggregated, which is necessary to make it useful as a tool in policy-making in this field, but nevertheless care is taken to keep it transparent and easy to use. Of course a lot of shortcuts had to be made since an operative version had to be ready in time for the negotiations in Buenos Aires in November of 1998.

From a theoretical point of view, a dynamic, rational expectations, general equilibrium model is the most attractive modelling choice. From a practical point of view, however, an applied general equilibrium model, more related to traditional macroeconomic simulation models, was considered more likely to facilitate the successful outcome of the project, given the time constraints. No estimations of behavioural relations have so far been carried out. Special attention, however, is given to long-term relationships and equilibrium conditions, such that credible conclusions on long-term economic outcomes may be drawn from the use of the model.

A reference model where empirical work has been emphasised is described in Alfsen, Bye and Holmøy (1996). Of course the model developed in this project is smaller and more specialised than the MSG model developed at Statistics Norway, where there is a strong tradition for models of this type, and they are meant to be used as general-purpose tools for economic policy making.

The rest of the paper is organised as follows: Sections 2 through 11 describe the different parts of the model. The general production structure of the model, as well as the sector division and sector-specific considerations, are discussed in section 2. The modelling of private consumption is described in section 3. Section 4 discusses the allocation of investment between different types of capital within the model, whereas sections 5 and 6 describe the determination of demand for different categories of exports and imports, respectively. The modelling of the labour market is discussed in section 7 and factor and output prices are discussed in section 8. Section 9 illustrates the relation between economic activity and emissions of greenhouse gases in the model. The calculation of gross domestic product and various identities pertaining to the government budget are spelled out in sections 10 and 11, respectively. This completes the formal description of the model. Sections 12 through 14 contain a discussion of the results of policy simulations. Section 12 presents the simulation results for a reference (business as usual) scenario. Section 13 considers the impact of measures to restrict the emissions of greenhouse gases to be within the limit stipulated by the Kyoto protocol. Section 14 briefly considers some additional scenarios.

2. Production

The ISM model consists of the 16 production sectors listed below:

Production sectors:

1. Agriculture	AG
2. Fisheries	FI
3. Forestry	FO
4. Land reclamation	LR
5. Fish processing	FP
6. Metal production	MP
7. Other manufacturing	MA
8. Energy – geothermal	EG
9. Electricity – hydroelectric	EH
10. Construction	CN
11. Road transport	TR
12. Air transport	TA
13. Sea transport	TS
14. Post and telecommunications	TP
15. Other services	OS
16. Government services	GS

Production is described by production functions, which can either be of the constant elasticity of substitution (CES) or the Cobb-Douglas variety, depending on the production sector. We assume that output is produced according to a separable CES production function in sectors where oil usage is important or where we have a reasonably good idea about the elasticity of substitution between oil and the other factors of production which form the separable aggregate:

$$(2.1) \qquad Q_i = A_i \left[\mu_i U_i^{-\beta_i} + (1-\mu_i) G_i (E_i, K_i, I_i)^{-\beta_i} \right]^{-\frac{1}{\beta_i}}$$

where

$$(2.2) \qquad G_i(E_i, K_i, I_i) = A_{G,i} E_i^{\alpha i 1} K_i^{\alpha i 2} I_i^{\alpha i 3}$$

where Q_i is gross production, E_i labour employed, K_i capital, U_i dirty energy (oil), and I_i intermediates in sector *i*. A_i is a total factor productivity parameter. The base year value of A_i is calibrated but then it evolves according to assumptions about productivity growth, i.e., it is an exogenous variable in the simulations. In obtaining an estimate for the elasticity of substitution parameter between oil and the aggregate of other input factors, β, for each industry, we use econometric results from a study by Hardarson (1993). The remaining parameters are calibrated using base year data. The parameters in the Cobb-Douglas aggregate of non-oil inputs, α_{ij}, are calibrated to reflect the cost shares in the base year, i.e.

$$(2.3) \qquad \sum_{j=1}^{3} \alpha_{ij} = 1$$

This insures constant returns to scale in (2.2). The cost shares for labour, intermediates and capital all come from the national accounts. The assumptions of cost minimisation and zero profits imply the following factor demands

$$(2.4) \qquad U_i = \left(\frac{\left[P_{U_i}^{\beta_i} \mu_i \right]^{\frac{1}{1+\beta_i}}}{\left[P_{U_i}^{\beta_i} \mu_i \right]^{\frac{1}{1+\beta_i}} + \left[P_{G_i}^{\beta_i} (1-\mu_i) \right]^{\frac{1}{1+\beta_i}}} \right) \frac{P_{Q_i}}{P_{U_i}} Q_i$$

$$(2.5) \qquad G_i = \left(\frac{\left[P_{G_i}^{\beta_i} (1-\mu_i) \right]^{\frac{1}{1+\beta_i}}}{\left[P_{U_i}^{\beta_i} \mu_i \right]^{\frac{1}{1+\beta_i}} + \left[P_{G_i}^{\beta_i} (1-\mu_i) \right]^{\frac{1}{1+\beta_i}}} \right) \frac{P_{Q_i}}{P_{G_i}} Q_i$$

$$(2.6) \qquad N_{ij} = \alpha_{ij} \frac{P_{G_i}}{P_{ij}} G_i$$

where P_{Qi} is the price index, net of indirect taxes, for gross production in sector *i*, N_{ij} is demand for factor $j = E, K, I$ in sector *i*, and P_{ij} is the price index of factor *j* in sector *i* $\left(j = E, K, I \right)$.

Table 1.1. Sectors with CES production functions

	Elasticity of substitution $\left(\frac{1}{1+\beta}\right)$
Fisheries	0.129
Fish processing	0.166
Other manufacturing	0.166
Road transport	0.238
Air transport	0.129
Sea transport	0.129

Source: Based on estimates in Hardarson (1993)

In the remaining sectors we assume that production functions are of the Cobb-Douglas variety:

(2.7) $$Q_i = A_i E_i^{\alpha i1} K_i^{\alpha i2} U_i^{\alpha i3} I_i^{\alpha 4}$$

We assume constant returns to scale technology so that:

(2.8) $$\sum_{j=1}^{4} \alpha_{ij} = 1.$$

The α_{ij} parameters are calibrated to reflect cost shares in the base year.

Cost minimisation and a zero profit condition imply the following factor demands

(2.9) $$N_{ij} = \alpha_{ij} \frac{P_{Qi}}{P_{ij}} Q_i$$

where N_{ij} is demand for factor $j = E, K, U, I$ in sector *i*, P_{Qi} is the price index, net of indirect taxes, for gross production in sector *i* and P_{ij} is the price index of factor *j* in sector *i* $(j = E, K, U, I)$.

Fisheries
The production in the fisheries sector is based upon the resource base around Iceland. The sector earns a resource rent in addition to traditional profits. This implies that declining prices in the world market for fish or anything production cost increases, do not affect optimal production on the margin. We assume that production in the fisheries sector is exogenous. The factor demands are given by (2.4)-(2.6) with exogenous output Q_{FI} and the term $P_{OFI} \cdot O_{FI}$ in equations (2.4) and (2.5) replaced by $\left(P_{UFI} \cdot U_{FI} + P_{GFI} \cdot G_{FI}\right)$. This change is necessitated by the absence of a mechanism that results in zero long-term profits, namely endogenous output adjustment. Thus, profits may be non-zero in the long run.

Forestry and land reclamation
The forestry sector could become important for Iceland's climate policy. Investment in planting produces negative CO_2 emissions (i.e., CO_2 sequestration) that may be sold domestically and on the international climate gas quota market. In the short, medium or long term (for instance up to 20 years) negative emissions may be sold in the market. In the extra long term (40 years or more), if technical

change solves the climate gas problem, traditional forestry may be profitable. Investment in the forestry sector is assumed to be exogenous.

One of the most attractive options for Iceland regarding CO_2 sequestration is the combination of afforestation and land reclamation. While the Kyoto protocol recognises afforestation for CO_2 sequestration, it is not clear whether the same will apply to land reclamation. Nonetheless, the model includes both forestry and land reclamation sectors and their output is measured in terms of CO_2 sequestration. [1]

CO_2 sequestration relative to 1990 is assumed to be a linear function of the size of areas affected by afforestation and reclamation programs since that time. That is,

$$\text{(2.10)} \qquad \mathrm{CO_2SEQ = CO_2SEQL \times L + CO_2SEQF \times F}$$

where CO_2SEQ is sequestration in CO_2 equivalents, L and F are the number of hectares affected by land reclamation and afforestation, respectively, since 1990. CO_2SEQL and CO_2SEQF are the sequestration rates per hectare a year in land affected by land reclamation and afforestation, respectively. Recent research in connection with Iceland's carbon sequestration initiative indicates that the sequestration rates are somewhat higher than was previously believed. In accordance with latest estimates we assume that CO_2SEQL=2.9 tons CO_2 per hectare per year and CO_2SEQF=6.1 tons CO_2 per hectare per year.[2]

Employment of traditional factors of production in both the forestry and the land reclamation sectors follows planting activity rather than the production level:

$$\text{(2.11)} \qquad N_{FOj} = \alpha_{FOj} H$$

where $N_{FO,j}$ is demand for factor $j = E, K, I, U$ in forestry and H is the size of the current year's addition to forest areas, and,

$$\text{(2.12)} \qquad N_{LRj} = \alpha_{LRj} B$$

where $N_{LR,j}$ is demand for factor $j = E, K, I, U$ in land reclamation and B is the size of current year's additions to areas affected by land reclamation programs.

Metals

Currently there are one ferro-silicon and two aluminium plants in Iceland. Iceland has the potential for producing significant amounts of additional hydroelectric and geothermal energy that is relatively cheap compared to the production cost of electricity in the rest of the world, especially if CO_2 shadow prices are included. Thus, capacity expansion is possible in the energy intensive industrial production.

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[1] Planting in forestry may not be profitable when selling timber is the only option and this possibility is excluded in the first version of the model. A possible extension could be the introduction of a composite good, negative CO_2 and timber. Whether you choose to sell timber or negative CO_2 then should depend upon the profitability of the two options. This could be formalised through a CES distribution function

$$Q_i = (\delta Q_{i1}^{-\sigma} + (1-\delta) Q_{i2}^{-\sigma})^{-\frac{1}{\sigma}} \quad \text{for} \quad i = FO\,.$$

[2] The modelling of sequestration as a linear function of affected areas is in accordance with IPCC guidelines. In reality, however, sequestration varies with the age of trees and plants. The sequestration parameters used are average lifetime sequestration rates. The sequestration rate estimates are obtained from a recent report on Iceland's carbon sequestration initiative (Binding kolefnis í gróðri og jarðvegi, Áfangaskýrsla 1999, Verkefnisstjórn átaks í landgræðslu og skógrækt 1997-2000, August 2000, p. 11)

However, since the establishment of one new metal producing firm with optimal capacity may dramatically increase total capacity, we can not assume smooth expansion of capacity in metal production. Rather any capacity changes will take place in discrete jumps. Thus, we have chosen to assume exogenously determined metal production and exports, while input factor demand follows from the production function (in the same way as in the fisheries sector since output is exogenous).

Government services
Output and investment in the government services sector are exogenous while employment, intermediates and energy use vary linearly with the level of government services, i.e.

$$N_{GS,j} = \alpha_{GS,j} Q_{GS} \tag{2.13}$$

where $N_{GS,j}$ is the demand for factor j $(j = U, E, I)$

Table 1.2. Cost shares in production, 1990-1996

	Employment	Capital	Intermediates	Oil
1. Agriculture	0.0788	0.3859	0.5209	0.0144
2. Fisheries	0.4270	0.2202	0.2736	0.0792
3. Forestry+	0.2500	0.0000	0.7500	0.0000
4. Land reclamation+	0.4667	0.0000	0.5333	0.0000
5. Fish processing	0.1927	0.0946	0.7017	0.0110
6. Metal production	0.1097	0.2000	0.6757	0.0146
7. Other manufacturing	0.2468	0.1048	0.6443	0.0040
8. Energy - geothermal	0.1069	0.5744	0.3160	0.0027
9. Energy - hydro	0.1507	0.3906	0.4558	0.0029
10. Construction	0.1876	0.1386	0.6733	0.0005
11. Road transport	0.2048	0.4042	0.3181	0.0729
12. Air transport	0.2319	0.1431	0.5409	0.0841
13. Sea transport	0.2108	0.1381	0.5993	0.0518
14. Post and telecomm.	0.4035	0.2582	0.3305	0.0078
15. Other services	0.3158	0.2413	0.4402	0.0027
16. Government services	0.5467	0.0262	0.4148	0.0123

+Because of the nature of the available information on costs in forestry and land reclamation, the usage of capital and oil by these sectors is modelled through their purchases of intermediates from other sectors.
* Sources: National Accounts,
Þorbergur Hjalti Jónsson. *Minnspunktar fyrir fund á Orkustofnun 21. mars 1997 um koltvísýringsbindingu í gróðri og jarðvegi,* Memorandum, March 18, 1997.

3. Private consumption

Total consumption in fixed prices follows from the overall budget condition and is determined residually to balance supply and demand

$$CP = Q - I - U - J - (X - M) - CG \tag{3.1}$$

This manner of determining consumption is satisfactory to fulfil the full employment condition in the model.

Total private consumption is divided among the following 9 consumption categories:

1. Food, beverage and tobacco	FOO
2. Clothing and footwear	CLO
3. Rent, fuel and power	REN
4. Furniture and household equipment	FUR
5. Medical health care	MED
6. Public transport and communication	TPU
7. Private transport	TPR
8. Other goods and services	OTH
9. Residents direct purchases abroad	ABR

by a linear expenditure system such that

$$(3.2) \qquad CP_i = \kappa_{i1} + \frac{\kappa_{i2}}{PCP_i}\left(VCP - \sum_j \kappa_{j1} PCP_j\right), \quad i, j = FOO, CLO, REN, ..., ABR$$

where $VCP = \sum_j PCP_j \cdot CP_j$ and PCP_j is the price of consumption category j. This formulation takes into account both income and price effects. The coefficients in the first version of the model are calibrated using some guesstimates of the Engel and direct price elasticities.[3]

3 The guestimates are based upon elasticities in Alfsen, Bye and Holmøy (1996) aggregated to fit the ISM model. The κ_i coefficients follow from the definition of Engel and direct price elasticities in the LES consumer system, i.e. $\kappa_{i2} = \varepsilon_i c_i$ where $c_i = PCP_i{*}CP_i/VCP$, i.e. the budget shares, and $\kappa_{i1} = CP_i \cdot (1 + e_i)/(1 - \kappa_{i2})$, where ε_i is the Engel elasticity for commodity i and e_i is the direct price elasticity .

Table 3.1. Expenditure and direct price elasticities

	Budget shares c_i	Expenditure elasticities ε_i	Direct price elasticities e_i	κ_{i1}	κ_{i2}
1. Food, beverage and tobacco	0.225	0.490	- 0.271	45,373	0.110
2. Clothing and footwear	0.070	0.871	- 0.437	10,054	0.061
3. Rent, fuel and power	0.180	0.953	- 0.742	13,518	0.172
4. Furniture and household equipment	0.074	1.322	- 0.622	7,543	0.098
5. Medical health care	0.021	0.755	- 0.351	2,833	0.016
6. Public transport and comunication	0.023	0.817	- 0.604	2,152	0.019
7. Private transport	0.093	1.268	- 0.609	9,152	0.118
8. Other goods and services	0.239	1.186	- 0.519	36,431	0.284
9. Residents direct purchases abroad	0.074	2.183	- 0.997	60.07	0.161

* In this first version we have just picked elasticities from the Norwegian model MSG-EE - weighted aggregates of relevant consumers groups where the weights are the budget shares - i.e. cf. table 3.16 in Alfsen, Bye and Holmøy (eds.) (1996).

4. Capital formation

In the model real capital is divided between three categories, residential housing, non-residential buildings, and transport and machinery equipment:

Categories of fixed capital formation:

1. Residential housing	H
2. Non-residential buildings	B
3. Transport and machinery equipment	TM
4. Capital in metal production	MP
5. Capital in hydroelectric production	EH

We assume that the capital mix in each sector is constant and the same as the capital mix in the base year.

Gross investment by sector is defined by

(4.1) $$J_{it} = K_{it} - K_{it_{-1}} + D_{it}$$

where capital depreciation is given by

(4.2) $$D_{it} = \delta_i K_{i,t-1}.$$

Investment in residential housing is included in the investment of the other services sector. For simplicity we assume that residential housing is a constant share, φ, of total capital and investment in this sector, i.e.

(4.3) $$J_H = \varphi_H J_{OS}$$

Investment in metal production plants and hydroelectric capacity is also treated separately. As regards other types of capital, we assume that the capital investment mix is the same across sectors and constant over time. Therefore, total investment in non-residential buildings is a fixed fraction of total private investment net of investment in residential housing:

(4.4) $$J_B = \varphi_B \left(J - J_H - J_{MP} - J_{EH} \right)$$

If follows that investment in transport and machinery equipment is

(4.5) $$J_{TM} = (1-\varphi_B)\left(J - J_H - J_{MP} - J_{EH} \right).$$

5. Exports

There are 11 export categories in this version of the model:

1.	Agricultural products	XA
2.	Fish	XF
3.	CO_2 quotas	XT
4.	Fish products	XFP
5.	Metals	XM
6.	Other manufactured products	XO
7.	Energy	XE
8.	Air transport	XTA
9.	Sea transport	XTS
10.	Other services	XS
11.	Non-resident purchases	CPN

Metals and energy exports are assumed to be exogenous and sold at their respective world market prices. CO_2 quotas are also sold at exogenously given world market prices. Non-resident purchases are an exogenous variable in the model. Exports of other commodities are assumed to follow the Armington assumption, that is

(5.1) $$X_i = g_i \left(PX_i / PM_i \right) \quad \text{for } i = A, F, T, \ldots, S, CPN$$

where PX_i is the price index for export commodity *i* and PM_i is the price index for imports (or rather the world market price) of the same commodity. The exact specification in this version of the model is

(5.2) $$\ln X_i = \lambda_1 + \lambda_2 \ln MIX_i + \lambda_3 \ln\left(\frac{PX_i}{PM_i} \right)$$

where *MIX* is an indicator of market conditions, λ_2 is the elasticity of exports with respect to market conditions, and λ_3 is the price elasticity of exports with respect to the ratio of export and import (i.e. world market) prices. The λ_1 coefficient is calibrated using base year data. The *MIX* variables are exogenously determined apart from MIX_{XTA} and MIX_{XTS}, which are determined as follows:

(5.3) $$MIX_{XTA} = XA + XF + XFP + XO + CPN$$

(5.4) $$MIX_{XTS} = XA + XF + XFP + XM + XO$$

The specification of export demand relations in the model is an important consideration as it affects the estimated impact of policies aimed at limiting the emissions of greenhouse gases. In particular, the Armington relations imply that the costs imposed on domestic producers by taxes on oil will be mitigated through improved terms of trade. However, because of the high export price elasticities assumed, these effects are likely to be relatively small.

Table 5.1 Export elasticities

Export category	Elasticity of the market indicator λ_2	Price elasticity λ_3
Agricultural products	1,0	-10
Fish	1,0	-5
CO_2 quotas*	0	∞
Fish processing	1,0	-5
Metals*	0	∞
Other manufactured products	1,0	-10
Energy*	0	∞
Air transport	1,0	-5
Sea transport	1,0	-5
Other services	1,0	-10
Non-resident purchases*	0	0

All the figures are guesstimates at this stage. The constant factor has to be residually determined.

* The quantity of these export categories is exogenous in the model

6. Imports

In the first version of the model there are three import categories[4]

1. Oil imports	MOL
2. Imported intermediate inputs of the MP sector	MIMP
3. All other imports	MNO

[4] In the second version we may use a finer division of imports, e.g.:

1. Metals production	MM
2. Other manufactured products	MOM
3. Services	MS
4. Food, beverage and tobacco	MF
5. Clothing and footwear	MC
6. Furniture and household equipment	MF
7. Cars	MCA
8. Other goods and services	MOG
9. Transport and machinery equipment	MT

Each import item requires us to specify import shares for each intermediate input and final demand categories. Thus, we would have 9 rather than 3 separate equations like equation (6.1), i.e., one for each commodity.

Imports of each type are used in final demand activities and as intermediate inputs in production. There is a relation of fixed proportion between each demand category and type of imports. Total imports of each type are then:

(6.1)

$$M_i = \sum_{j \in sector} \alpha_{M_i,j} I_j + \sum_{j \in cons} \alpha_{M_i,j} C_j + \sum_{j \in Inv} \alpha_{M_i,j} J_j + \alpha_{M_i,CG} CG + \alpha_{M_i,DS} DS, \quad i = MOL, MIMP, MNO$$

7. The labour market

The demand for labour is determined by the factor demand equations (2.6) and (2.9), except for the government services sector where it is determined by equation (2.13) and the forestry and land reclamation sectors where demand for labour is determined by equations (2.11) and (2.12), respectively.

The supply of labour *E*, follows population growth (*POP*), and the labour participation rate, *LPRATE*, both of which are exogenously given.

Thus, in equilibrium:

(7.1) $$E = LPRATE * POP = \sum_{i \in sector} E_i \quad \text{for} \quad i = AG, FI, FO, LR, FP, ..., GS$$

8. Factor and output prices

8.1. Labour cost

We assume that the unit labour cost for each sector, w_i, consists of a common total private sector unit cost w, a constant deviation factor ω_i , and a common labour tax rate, t_E, i.e.

(8.1) $$w_i = \omega_i \cdot w \cdot (1 + t_E)$$ [5]

The national accounts contain information on total labour cost, including taxes on labour, TWC_i , and the total labour stock in each sector (in man years) from which we derive total labour unit cost for each sector,

(8.2) $$w_i = \frac{TWC_i}{E_i}$$

Similarly the total private sector unit wage cost is

(8.3) $$w = \frac{TWC}{E}$$

[5] The model also allows different labour tax rates for different sectors.

Iceland's national accounts do not contain figures for labour costs net of taxes. The labour tax rate, t_E, is obtained by dividing the sum of individuals' income taxes and insurance by total salaries. The private sector net wage rates w_{in} then are

$$(8.4) \qquad w_{in} = w_i / (1 + t_E)$$

ω_i is calculated as the ratio between the wage rate in sector i and the average private sector wage rate in the base year. Since labour tax rates are assumed to be the same in all sectors, this implies a stable relation between labour unit costs of different sectors. Differences in unit labour costs across sectors, in a well functioning labour market, may be due to heterogeneity of labour or they may reflect regional differences in residents' utility function.

8.2. The user cost of capital

The user cost of capital in sector *i* is defined as follows:

$$(8.5) \qquad PK_i = (IR_i + \delta_i + t_K) \cdot PJ_i, \quad i = AG, FI, FO, LR, FP, ..., GS$$

where IR_i is the after-tax real rate of return on capital, δ_i is the depreciation rate, t_K is the tax rate on capital, and PJ_i is the price index for investment. As in the case of labour there may be reasons why the rate of return on capital differs across sectors (for instance imperfect capital markets). We assume that these differences are stable from year to year, i.e.

$$(8.6) \qquad IR_i = \rho_i \cdot IR$$

8.3. Energy prices

The price of oil to each sector is determined by the import price of oil and sector-specific taxes. The model allows for CO_2 tax on oil:

$$(8.7) \qquad P_{Ui} = P_{Ui}(1 + t_{Ui}) + TAXCO2U * CO2QEQU_i * a_i$$

where P_U is the import price of oil, t_{ui} is import duty, *TAXCO2U* is a tax per unit of CO_2 emitted, $CO2EQU_i$ are emissions, measured in CO_2 equivalents, per unit of oil used by sector *i*, and a_i indicates the share of domestic emissions in total emissions.

The price of gasoline for private consumption is determined according to equation (8.8):

$$(8.8) \qquad \begin{aligned} PUCP = &\left(PUCPNET + \left(PUCPNET * TUCP\_PER + TUCP\_FIXED\right) * TULEVEL\right) \\ &+ TAXCO2U * CO2EQUCP, \end{aligned}$$

where *PUCPNET* is the import price of gasoline, *TUCP_PER* is an ad valorem tariff on imported gasoline, *TUCP_FIXED* is an import duty per unit of imported gasoline, *TULEVEL* is a variable that varies the level of both of these tax rates simultaneously (normally set equal to 1), *TAXCO2U* is a tax per unit of CO_2 emitted and *CO2EQUCP* are emissions, measured in CO_2, equivalents, per unit of gasoline.

8.4. Prices of intermediate inputs

Prices of intermediate inputs to the sectors depend on the sector-specific composition of the inputs, described by the input-output coefficients, and the output prices (inclusive of taxes) of each product and the import prices of each type of import that make up the intermediate input composite:

(8.9) $$PI_i = \sum_{j \in sector} \gamma_{ij} PQ_j + \sum_{j \in imports} \gamma_{ij} PM_j$$

where PI_i is the price of sector i's intermediate input composite, PQ_j is sector j's output price, PM_j is the price of import category j, and the $\gamma_{ij}s$ are the input-output coefficients.

8.5. Output prices

Generally, each sector's output price is set equal to the average unit cost including taxes, i.e., we impose a zero profit condition.[6] Total production costs are

(8.10) $$TC_i = w_i E_i + P_{Ui} U_i + PK_i K_i + PI_i I_i$$

Then the output price of sector ***i*** is

(8.11) $$PQ_i = \frac{TC_i \cdot (1 + t_{vQ_i})}{Q_i}$$

where t_{vQi} is a tax on sector i.

9. Emissions of greenhouse gases

Emissions of each greenhouse gas j are related to the production of metal, agricultural products, and geothermal energy, as well as private transport, food consumption, residential energy use, and energy use in each production sector:

(9.1) $$GHG_j = \xi_{jMP} QMP + \xi_{jAG} QAG + \xi_{jEG} QEG + \xi_{jTPR} C_{TPR} + \xi_{jFOO} C_{FOO} + \xi_{jREN} C_{REN} + \sum_{i \in sector} \xi_{jU_i} U_i$$

where j takes the values CO_2, CH_4, N_2O, and PFC, and the ξ_{ji}'s are emission coefficients. HFC is an exogenous variable in the model. SF_6 emissions in Iceland are negligible. The emissions of each greenhouse gas j are then converted into CO_2 equivalents, $CL_{CO2,j}$, using gas-specific conversion factors that measure the gases' global warming potential:

(9.2) $$CL_{CO2j} = \theta_j GHG_j$$

where GHG_j is the amount of greenhouse gas j and θ_j is the conversion factor used to convert this amount into CO_2 equivalents.

Total net emissions of greenhouse gases, measured in CO_2 equivalents, are then:

[6] The exceptions to this general rule are output prices of government services (GS) and the sectors for which output is exogenously determined in this model, fisheries (FI), forestry (FO), land reclamation (LR), and metals (MP).

(9.3) $$CL_{CO2} = \sum_j CL_{CO2,j} - CO_2SEQ \quad \text{for} \quad j = CO_2, CH_4, N_2O, PFC, HFC,\ SF_6$$

taking into account sequestration by the forestry and land reclamation sectors (CO_2SEQ).

10. Gross domestic product

The contribution of a sector to gross domestic product, i.e., its value added, in constant prices is defined as gross production minus intermediates and energy

(10.1) $$Y_i = Q_i - I_i - U_i$$

Price indices for value added by sector are constructed by dividing value added in current prices by value added in constant prices

(10.2) $$PY_i = \frac{VQ_i - VI_i - VU_i}{Q_i - I_i - U_I}$$

11. Government budget

The government's income consists of taxes on factor inputs, consumption taxes, taxes on the market value of output, import duties, investment taxes, net interest income, and "profits" of the government production sector. Government expenditures consist of government consumption and investment as well as afforestation and land reclamation expenditures.[7,8]

Total taxes on labour income are

(11.1) $$T_w = \sum_{i \in sector} \frac{t_E w_i E_i}{1 + t_E}$$

while taxes on capital are

(11.2) $$T_K = t_K \sum_{i \in sector} PJ_i \cdot K_i$$

where t_E and t_K are the common labour and capital tax rates, respectively.

Similarly, taxes on oil, exclusive of CO_2 taxes, are

(11.3) $$T_U = \sum_{i \in sector} t_{U_i} P_{Ui} U_i + (PUCPNET \cdot TUCP\_PER + TUCP\_FIXED) \cdot TULEVEL \cdot UCP$$

CO_2 taxes are

[7] There are no separate intermediate input taxes. However, intermediate input prices do, of course, reflect taxes levied on sectoral outputs.
[8] Net receipts from sales of CO_2 quotas are included in the government budget equation from 2008 onwards.

$$(11.4) \qquad T_{co2} = TAXCO2U \cdot \sum_{i \in sector \cup cons} CO2EQU_i \cdot a_i \cdot U_i$$

Total consumption taxes are

$$(11.5) \qquad T_C = \sum_{i \in cons} \frac{t_{C_i} P_{C_i} C_i}{1 + t_{C_i}}$$

The consumption tax rates (t_C) are different for different consumption categories.

Sectors may also be subject to a tax on the market value of their output

$$(11.6) \qquad T_{VQ} = \sum_{i \in sector} \frac{t_{VQ_i} P_{Q_i} Q_i}{1 + t_{VQ_i}}$$

In addition the model allows for a unit tax on the output of the metal production sector

$$(11.7) \qquad T_Q = T_{Q_{MP}} = t_{QMP} \cdot Q_{MP}$$

Import duties on non-oil imports sum up to

$$(11.8) \qquad T_{MNO} = \frac{t_{MNOO} P_{MNOO}}{1 + t_{MNOO}} \left(MNO - MNO_{CPTPR} \right) + \frac{t_{MNOCPTPR} P_{MNOCPTPR}}{1 + t_{MNOCPTPR}} MNO_{CPTPR}$$

where we allow for different import duties on products for private road transport ($t_{MNOCPTPR}$), mainly automobiles, and other non-oil imports (t_{MNOO}). $P_{MNOCPTPR}$ and P_{MNOO} are prices (inclusive of import duties) of non-oil imports for private road transport and other non-oil imports, respectively. MNO is the volume of non-oil imports exclusive of imported intermediate goods for the metal producing sector and MNO_{CPTPR} is the amount thereof that is accounted for by private road transport.

Investment taxes are

$$(11.9) \qquad T_J = \sum_{j \in \{H, B, TM\}} \frac{t_j PJ_j J_j}{1 + t_j}$$

Thus, the model allows for different tax rates on different types of investment. These rates are assumed to be the same across sectors.

Government's net interest revenue is

$$(11.10) \qquad NIR = IRGS \cdot NGA(-1)$$

where $IRGS$ is the interest rate on government's net assets and NGA(-1) is government's net assets in the previous year.

The "profits" of the government production sector are denoted by π_{GS}:

$$(11.11) \qquad \pi_{GS} = PO_{GS} Q_{GS} - TC_{GS}$$

In addition the government pays for government consumption (C_G) and investment (J_G) and the cost of forestation (*TCFO*) and land reclamation (*TCLR*). These cost and revenue items result in the following expression for the government budget surplus

$$(11.12)\quad \begin{aligned} &NGB = T_W + T_K + T_U + T_{CO2} + T_C + T_{VQ} + T_{QMP} + T_{MNO} + T_J + NIR + \pi_{GS} \\ &- PC_G \cdot C_G - PJ_G \cdot J_G - TCFO - TCLR \end{aligned}$$

where all taxes are defined net of subsidies.

12. Analysis of a reference scenario

The main purpose of the ISM model is to analyse the economic costs of reducing emissions of GHG to comply with the restrictions set forth in the Kyoto protocol. In order to estimate these costs a reference point is needed. Therefore, we first analyse a "business-as-usual" scenario in which Iceland is not bound by any commitments to reduce emissions. We then compare the outcome of this case to scenarios in which policies are implemented to reduce GHG emissions.

12.1. Assumptions

The most important assumptions of the reference scenario are as follows:

- **Productivity:** Assumed to increase yearly by 1.3% in all sectors. The assumption is based on the yearly average productivity growth in Iceland from 1963-1999.
- **Fish catch**: For the year 2001, we use the same assumption as in the latest macroeconomic forecast of the National Economic Institute (NEI), i.e., it is assumed that the fisch catch declines by 7%. Otherwise, the yearly growth in fish catch is assumed to be as follows:
  2002-2004: 2%
  2005-2015: 2.5%
  2016-2025: no growth.
- **Afforestation and land reclamation**: We assume that the yearly planting and reclamation activity from 2001 onwards equals the realized annual average for the period 1991-1999 exclusive of the 1997-2000 carbon sequestration inititative. That is, we assume that 1,000 hectares are planted with trees annually and that approximately 2500 hectares are affected annually by land reclamation.[9]
- **Government consumption and investment**: Government consumption and investment are assumed to grow by slightly more than 2% annually on average. This translates into approximately 2½ percentage point decrease in the share of government consumption and investment in GDP in the period 2000-2025.
- **Current account:** The current account deficit was ISK 43 billion in 1999 or around 7% of GDP. In our simulations we assume that it gradually decreases to 1.5% of GDP in 2006 and that it remains at that level until the end of the simulation period in 2025. The implication is that the ratio of net foreign debt to GDP will be similar in 2025 as in the beginning of the simulation period.
- **Taxes**: All tax rates remain unchanged throughout the simulation period.
- **Labour force participation**: Historically labour force participation has fluctuated considerably but there has been no overall upward trend in this ratio since the early 1980s. The labour force participation rate is now between 77% and 78%. It is assumed that it remains at that level throughout the simulation period.

[9] If one includes the carbon sequestration initiative the figures are 1,100 ha. and 3,000 ha. for afforestation and land reclamation, respectively.

- **Working-age population**: The Energy Forecast Committee in Iceland has published a detailed forecast regarding population growth in different age categories for each 5-year period from 1995 to 2025. We use this forecast to arrive at our assumptions regarding the growth of the working-age population:
  2000-2005: 1.0%
  2006-2010: 0.7%
  2011-2015: 0.7%
  2016-2025: 0%
- **Export demand (MIX variables)**: We assume a 4% yearly increase in all the MIX variables (see section 5) except MIXS, which we assume will increase by 5% a year.
- **World market prices of exports (except metals)**: We keep this unchanged from year 2000 levels. Ultimately, assumptions regarding exogenous prices determine the price level in the simulations. The good (or goods) for which price is exogenously set throughout the simulation period plays the role of a numeraire.
- **World market prices of metals**: The price of metals varies somewhat but in the long run the real price is little changed from its assumed level in the year 2000.
- **Oil (import) prices**: We assumed this to be the same as in the year 2000.
- **Non-oil import prices**: We keep this unchanged from year 2000 levels.

12.2. Results

Tables 12.1-12.4 contain simulation results for the reference scenario. The model projects almost doubling of GDP from 2000 to 2025, or 2.6% average annual growth. GDP growth is fast to begin with but decreases later in the period as working age population growth slows down. Relatively high levels of investment are forecasted early in the period but a slowdown in economic growth and a relatively slow growth of public investment lowers the share of investment in GDP during the simulation period. The first effect is the well-known accelerator effect. Despite the projected slowdown in investment after the initial spurt, the capital-labour ratio increases throughout the simulation period and is more than twice as big in 2025 than in 2000. This is due to the fact that technical change reduces the price of produced goods, i.e. capital, relative to labour. The reduction in the current account 2001-2006 necessitates fast export growth which comes at the expense of private consumption. From 2007 onwards, however, relatively slow growth in public consumption and investment together with favourable developments in the terms of trade leave room for a relatively fast growth in private consumption.

To bring about the reduction in the current account deficit by the year 2006, domestic prices have to fall relative to foreign prices. Thus, there is around 3% deterioration in the terms of trade from 2000 to 2006. Once the current account balance target has been reached, strong growth in the demand for Icelandic export products gradually improves the terms of trade. Consequently, the terms of trade are slightly better in 2025 than in 2000. Export prices of fish products increase substantially in the same period or by 12-15% relative to other export prices. This can be explained by the twin assumptions of strong demand growth and supply side constraints. The improvement in the terms of trade from 2007 onwards means that the volume of imports can grow faster than the volume of exports without violating the assumption regarding the current account deficit.

Emissions of GHG increase by approximately 27% in the period 2000-2025. The assumed increases in productivity, which result, among other things, in a lower oil consumption per unit of production, cause the growth in emissions to be considerably lower than the growth in GDP. Road transport accounts for about 40% of the increase in emissions, and fisheries and heavy industry about 15% and 13%, respectively. The remaining 30% is accounted for by various sources. Despite their fast growth, the air and sea transport sectors account for less than 2% of the increase in emissions as only domestic emissions count towards the limits set forth in the Kyoto protocol.

It is important to note that our assumptions regarding HFC emissions from 2011 onwards are considerably lower than the official forecast by the Environmental and Food Agency of Iceland. According to the Montreal agreement, the fishing fleet is required to phase out ozone-depleting HCFC for refrigeration and freezing purposes in the period 2004-2025. In the official forecast a substantial part of the post-2005 growth in HFC emissions is due to the assumption that the fishing fleet will satisfy the requirements of the Montreal agreement by converting to HFC equipment. Here, however, we assume that there will be widespread conversion to ammonia equipment.

Annual sequestration of GHG was 137 thousand tons of CO_2 greater in 1999 than in 1990. The stated official goal of 100 thousand ton increase in annual sequestration by the year 2000 has, thus, already been exceeded. This is due to an upward revision in estimates of sequestration per hectare. Our assumptions regarding afforestation and land reclamation imply that by 2012 annual sequestration of CO_2 will be approximately 320 thousand ton greater than in the reference year 1990 and 460 thousand ton greater by 2025. Nonetheless, sequestration does not keep up with the increase in emissions. According to the Kyoto protocol, net emissions in Iceland in 2008-2012 can exceed 1990 levels by 10%. Net emissions refer to emissions less sequestration by recognized means. We have assumed that land reclamation's contribution to sequestration will be recognized, but this may or may not be the case.[10] The model simulation indicates that net emissions will exceed the limit set by the Kyoto protocol by almost 300 thousand tons in 2008-2012. If we assume that allowable net emissions will not be increased further emissions will exceed stipulated levels by 500 thousand tons in 2025. Given the model's sequestration rate assumption in afforestation of 6.1 ton CO_2 per ha, it would take a forest of more than 80,000 ha in order to sequester the excess net emissions of GHG. For comparison, plans for Sudurlandsskogar, the current major forestation project in the southern part of Iceland, are for approximately 25,000 ha of forested areas in the next 40 years.

Table 12.1. Simulation Results for a Few Important Economic Variables - Reference Scenario. ***Volume Indices and Average Annual % Change***

Period	GDP		Private consumption		Investment		Exports		Imports		Terms of Trade	
	V	%	V	%	V	%	V	%	V	%	V	%
2000	100.0		100.0		100.0		100.0		100.0		100.0	
2012	147.2	*3.3*	131.3	*2.3*	160.3	*4.0*	187.9	*5.4*	158.3	*3.9*	98.8	*-0.1*
2025	190.7	*2.0*	179.8	*2.5*	183.8	*1.1*	247.9	*2.2*	212.2	*2.3*	100.6	*0.2*

V=Volume index
%=Average annual % change (from previous year in table)

Table 12.2. Simulated Production Values for Selected Sectors (Gross Production) - Reference Scenario. ***Volume Indices and Average Annual % Change***

Period	Fisheries		Fish Processing		Metal Production		Other Mfg.		Road Transport		Air Transport		Sea Transport		Other Services	
	V	%	V	%	V	%	V	%	V	%	V	%	V	%	V	%
2000	100.0		100.0		100.0		100.0		100.0		100.0		100.0		100.0	
2012	120.2	*1.5*	106.4	*0.5*	113.8	*1.1*	272.0	*8.7*	155.3	*3.7*	161.1	*4.1*	166.9	*4.4*	154.2	*3.7*
2025	129.5	*0.6*	113.5	*0.5*	113.8	*0.0*	395.8	*2.9*	218.9	*2.7*	197.8	*1.6*	219.2	*2.1*	212.4	*2.5*

V=Volume index
%=Average annual % change (from previous year in table)

[10] In our simulation ,average annual sequestration due to land reclamation in 2008-2012 is approximately 160 thousand tons CO_2.

Table 12.3. Emissions and Sequestration of GHG – Simulation Results in Reference Scenario. *CO_2 Equivalents and Average Annual % Change*

Period	Emissions		Sequestration		Net emissions in excess of 1990 level + 10%
	tht	%	tht	%	tht
2000	3,277		160		-92
2008-2012	**3,793**	***1.5***	**293**	***6.2***	**291**
2025	4,169	*0.6*	459	*3.0*	502

tht = CO_2 equivalents in thousands of tons
% = Average annual % change (from previous year/period in table)

Table 12.4. Emissions by Activity – Simulation Results in Reference Scenario. *CO_2 Equivalents and Shares of Total Emissions*

Period	Fisheries		Metal Prod.		Other Mfg.*		Air Transport		Sea Transport		Road Transport**		Other	
	tht	sh	tht	sh	tht	sh	tht	sh	tht	sh	tht	sh	tht	sh
2000	767	23.4	803	24.5	283	8.6	22	0.7	16	0.5	659	20.1	727	22.2
2012	908	23.4	920	23.7	321	8.3	29	0.8	22	0.6	827	21.3	855	22.0
2025	904	21.7	920	22.1	347	8.3	30	0.7	24	0.6	1,031	24.7	914	21.9

* All manufacturing apart from metal production (includes fish processing)
** This figure does not only refer to the "road transport" production sector. It also includes private automobile use and estimated oil consumption of vehicles owned by other sectors.
tht = CO_2 equivalents in thousands of tons
sh = % share of total emissions

13. Possible Policy Responses

The model suggests that in a business-as-usual scenario GHG emissions in excess of sequestration will be significantly above the maximum level stipulated by the Kyoto agreement. Various policy options are available to prevent such an outcome. Among these options are CO_2 taxes and increased afforestation and land reclamation. Additionally, international markets for CO_2 quotas may be established where countries with excess CO_2 quotas can trade with those experiencing deficit. In this section, we use the ISM model to address each of these possibilities.

13.1. CO_2 Taxes

Virtually all endogenously determined emissions in the model stem from the use of oil. One possible policy tool to combat excess emissions is to impose a CO_2 tax on oil. We assume that taxation starts in 2008, the first year of the commitment period of the Kyoto protocol. It should be noted at the outset that the substitution elasticities of the production functions reflect long-term flexibility in production. Therefore, it is possible that taxation might have to start, and the associated costs borne, prior to 2008 for the oil tax to obtain the necessary emission reductions.

Table 13.1. Necessary CO_2 Tax. ***ISK thousands per ton***

2008	15
2009	18
2010	19
2011	24
2012	28
2016	37
2020	37
2025	40

Table 13.1 illustrates the CO_2 tax that is necessary according to the model to keep GHG emissions within the level stipulated by the Kyoto protocol from 2008 onwards. From the very start the required taxes are extremely high. For example, the tax level in 2008 implies a 135-200% increase in fuel prices to the production sectors compared to the baseline scenario. The tax levels in the latter half of the simulation period imply 4-6 fold increases in fuel prices. In our simulations the output of the fisheries sector is exogenous. Given such a high CO_2 tax, this is hardly a realistic assumption without a major income transfer scheme. According to the simulations, GDP and consumption would be about 1.1% lower in 2025 than in the baseline scenario. However, with the tax levels imposed the credibility of the simulations may be questionable.

13.2. Increased Afforestation, Land Reclamation Efforts and International Markets for CO_2 Quotas

It seems clear from the previous section that a CO_2 tax alone is not a realistic option to decrease emissions sufficiently from the baseline scenario. Current sequestration rate estimates, abundance of available land and cost considerations suggest that increased afforestation and land reclamation may be an attractive alternative.[11] Cost figures from the carbon sequestration initiative imply that the cost per CO_2 ton sequestered is between ISK 800 and ISK 1,200 in net present value terms.[12] In particular, the revised sequestration rates have made afforestation a considerably more attractive option than previously believed, although the cost of sequestration is still lower in land reclamation. If international markets for CO_2 quotas were established Iceland would also have the option of trading in these markets. Projections of likely CO_2 quota prices vary widely but most estimates are in the range ISK 1,000 to ISK 5,000 per ton.[13] In this paper we assume a price of ISK 2,000.

Model simulations were run assuming 2,200 hectares will be planted with trees and 9,000 hectares will be seeded and fertilized each year from 2002 onwards. These assumptions imply a twofold increase in the rate of afforestation and threefold increase in land reclamation compared to 1991-1999 averages. According to the Soil Conservation Service of Iceland a threefold increase in the rate of areas reclaimed could definitely be achieved. A twofold increase in the rate of afforestation should also be within the confines of reality. In fact, Arnór Snorrason of the Iceland Forest Service outlines a somewhat more ambitious plan in a newspaper article and considers it a modest one.[14] Using cost

[11] According to a recent report on Iceland's carbon sequestration initiative only "…about 1.4% of Iceland is wooded, but potentially 25% could be covered with forests and woodlands." (Binding kolefnis í gróðri og jarðvegi, Áfangaskýrsla 1999, Verkefnisstjórn átaks í landgræðslu og skógrækt 1997-2000, Ágúst 2000.)
[12] These estimates are obtained using a real rate of interest of 5%.
[13] See, "Yfirlit um efnahagslega þætti er varða aðgerðir til að takmarka eða draga úr losun gróðurhúsalofttegunda og aðild Íslands að Rammasamningi S.þ. um loftslagsbreytingar - unnið af
ráðgjafanefnd um efnahagslega þætti samninga um minnkun á losun gróðurhúsalofttegunda", April 21, 1999.
[14] Arnór Snorrason, *Möguleikar skógræktar til að binda koltvísýring*, Morgunblaðið, February 1, 1998, p. 30.

figures from the carbon sequestration initiative our assumptions imply total yearly afforestation and land reclamation costs of approximately ISK 700 million.

Increased afforestation and land reclamation go a long way towards eliminating excess net emissions by 2008-2012 as can be seen in Table 13.2. If we assume that allowable net emissions will not be increased further from those stipulated by the Kyoto agreement for 2008-2012, excess emissions will be eliminated by 2018 and Iceland will have a surplus of 130 thousand tons in 2025. To bridge the gap until 2018, a modest CO_2 tax could be imposed. Simulations suggest that a tax of less than ISK 2,000 per ton CO_2 would suffice in the first commitment period 2008-2012 (see Table 13.3). GDP and private consumption are 0.1-0.2% lower than in the baseline scenario during the simulation period.

Table 13.2. Emissions and Sequestration of GHG – Increased Afforestation and Land Reclamation but no CO_2 Tax. ***CO_2 Equivalents and Average Annual % Change***

Period	Emissions		Sequestration		Net emissions in excess of 1990 level + 10%
	tht	%	tht	%	tht
2000	3,277		160		-92
2008-2012	**3,790**	***1.5***	**529**	***12.7***	**53**
2025	4,167	*0.6*	1,089	*3.0*	-130

tht = CO_2 equivalents in thousands of tons
% = Average annual % change (from previous year/period in table)

Table 13.3. Necessary CO_2 Tax. ***ISK thousands per ton***

2008	1.6
2009	1.8
2010	1.3
2011	2.0
2012	2.0
2013	2.2
2014	2.1
2015	2.0
2016	1.4
2017	0.7
2018	0.1
2019	0

If international markets for CO_2 quotas become a reality, Iceland could also satisfy the restrictions set forth in the Kyoto protocol by quota purchases until 2018. After 2018, however, Iceland would have a surplus of CO_2 quotas that it could sell at the world market price. In our simulations we have assumed a world market price of ISK 2,000 per ton CO_2 and a tax on CO_2 emissions equal to the world market price. Private consumption during the simulation period is on average around 0.1% lower than in the baseline scenario. The reduction in consumption is relatively great at first but because of revenues from CO_2 quota sales, consumption in the two scenarios is virtually the same in 2025. Due to the assumption that the world market price of CO_2 quotas is greater than the cost of sequestration, the consumption level will ultimately exceed that of the baseline scenario.

14. Some Other Possible Scenarios

In our analysis above we departed from the official forecast of the Environmental and Food Agency of Iceland regarding HFC emissions. This forecast is a few years old and is currently being updated. Although it is in all likelihood somewhat too high with respect to HFC emissions, it is worth analysing briefly the implications of such a "worst case" scenario.

Table 14.1. Emissions and Sequestration of GHG – Amended Baseline Scenario: HFC Emissions According to Official Forecasts. ***CO_2 Equivalents and Average Annual % Change***

Period	Emissions		Sequestration		Net emissions in excess of 1990 level + 10%
	tht	%	tht	%	tht
2000	3,277		160		-92
2008-2012	**3,801**	***1.5***	**293**	***6.2***	**300**
2025	4,491	*1.1*	459	*3.0*	824

tht = CO_2 equivalents in thousands of tons
% = Average annual % change (from previous year/period in table)

In the previous simulations we followed the official forecast for HFC emissions through 2010 so most of the divergence from the baseline scenario occurs after the first commitment period. On average emissions in 2008-2012 are only about 22 thousand ton of CO_2 equivalents greater than in the baseline scenario. By 2025, however, the difference is 324 thousand tons. Most of this increase is attributable to the fisheries sector. Increased afforestation and land reclamation do not manage to eliminate the deficit during the simulation period unlike in the previous analysis. Excess net emissions are slightly over 60 thousand tons of CO_2 annually in 2008-2012 and about 190 thousand tons in 2025. Table 14.2 gives the CO_2 tax necessary to reduce emissions to the levels stipulated by the Kyoto agreement (given an increase in afforestation and land reclamation).

Table 14.2. Necessary CO_2 Tax. ***ISK thousands per ton***

2008	1.6
2009	1.8
2010	1.3
2011	2.5
2012	3.1
2015	5.2
2020	4.8
2025	6.4

While taxation together with increased sequestration may be a realistic option for reducing emissions sufficiently through the first commitment period, additional measures would probably be called for later on. The CO_2 tax rate in 2012 translates into an increase in fuel prices to the production sectors by around ISK 8 (USD 0.1) per liter, the tax rate in 2015 to an increase of ISK 14 (USD 0.15) per liter, and the tax rate in 2025 to an increase of ISK 17 per liter. Even if tax rates of this magnitude are viable they probably put an unnecessary burden on the production sectors. An economically efficient tax rate in the presence of international CO_2 quota markets is equal to the world market price of CO_2 quotas, and equal to the cost of sequestration in the absence of such markets. In spite of the CO_2 tax the macroeconomic impact of the measures to limit emissions would be relatively small. Private consumption would be approximately 0.1% lower than in the baseline scenario on average during the simulation period. Likewise, the impact on the production of individual sectors is small. For example, the output of the transport sectors is decreased by around 0.5%. The CO_2 tax leads to a 190 thousand ton reduction in emissions in 2025 when compared to the baseline scenario. Table 14.3 shows how that reduction is distributed among various activities. The production of the fisheries sector is exogenous by assumption (and so is its HFC use) so the reduction in emissions is caused solely by measures to increase fuel efficiency in response to higher prices.

Table 14.3. Reduction in emissions (thousands of ton CO_2) as a result of CO_2 tax: Comparison with the baseline scenario in 2025

Road transport	93
Fisheries	54
Other manufacuring	14
Other	31
Total	**192**

There are several other developments, apart from potentially greater use of HFC in the fisheries sector, that could significantly alter the picture presented in section 13. First, Iceland has proposed that a special consideration be given to big projects in small economies that use renewable energy sources. If agreed to, the proposal would exempt a large fraction of the emissions from aluminium and ferrosilicon capacity built since 1990 from the Kyoto agreement. It would also make new aluminium smelters possible without exceeding these emission restrictions. Emissions from aluminium and ferrosilicon capacity already in use or under construction that would qualify for this exemption are in excess of 500 thousand tons CO_2 equivalents. Under the proposal approximately 400 thousand tons would be exempt. Thus, if the proposal is agreed to, Iceland would be well within its emission limit in 2008-2012 in all of the scenarios presented above, or close to 150 thousand tons of CO_2 within the limit in the baseline scenario and approximately 350-400 thousand tons within the limit with the additional afforestation and land reclamation efforts described above.

Additional aluminium smelters would also change the picture presented so far. A little over 2 tons of CO_2 equivalents are emitted per ton of aluminium produced so that, for example, a 240 thousand ton aluminium smelter would result in Iceland being approximately 750 thousand tons of CO_2 over its emission limit in 2008-2012 in the baseline scenario and 500 thousand tons over the limit with increased afforestation and land reclamation effort. Iceland's proposal dramatically alters the situation. A new 300 thousand ton aluminium smelter could be accommodated within Iceland's emission limits for 2008-2012. With an increased afforestation and land reclamation effort like that described above, close to 800 thousand ton aluminium production on top of that in the baseline scenario could be accommodated.[15] Finally, as is evident from the effect of CO_2 taxation in the scenarios presented above, long-term trends in oil prices may significantly affect emissions, and, thus, the force with which other measures need to be implemented if Iceland signs the Kyoto protocol.

[15] Low PFC emission rates would increase the aluminium production that could be accomodated.

References

Alfsen, K.H., T. Bye and E. Holmøy (eds.): MSG-EE: An Applied General Equilibrium Model for Energy and Environmental Analyses. *Social and Economic Studies* no. 96, Statistics Norway, 1996.

Fimmti viðauki við aðalsamning milli Ríkisstjórnar Íslands og Alusuisse-Lonza Holding Ltd., fylgiskjal við lög nr 155/1995 um lagagildi viðaukasamnings milli ríkisstjórnar Íslands og Alusuisse-Lonza Holding Ltd. um álbræðslu við Straumsvík, *Stjórnartíðindi*, vol. 2, 1995, pp. 800-828.

Cappelen, Å., R. Choudhury, P. R. Johansen and K. Magnusen. The Selection Model of Saudi Arabia. Revised Version 1998. *Documnets no. 98/6*, Statistics Norway, 1998

Baldurson, Friðrik. *Project proposal: An economic model for Iceland to be used for estimation of the economic effects of reductions in greenhouse gas emissions*. Memorandum, National Economic Institute, Iceland, 1998.

Energy Information Administration, *Short-Term Energy Outlook*, Table 4. U.S. Energy Prices, October 1998, www.eia.doe.gov/emeu/steo/pub/4tab.html

Harðarson, Yngvi. *CO_2 afgift og olieforbrug i Island*, 1993.

International Energy Agency, *World Energy Prospects to 2020: Paper prepared for the G8 Energy Ministers' Meeting Moscow 31 March – 1 April 1998*, <www.iea.org/g8/world/index.htm>

Jónsson, Þorbergur Hjalti. *Minnspunktar fyrir fund á Orkustofnun 21. mars 1997 um koltvísýringsbindingu í gróðri og jarðvegi,* Memorandum, March 18 1997.

Jónsson, Þ.H., and Úlfur Óskarsson. Skógrækt og landgræðsla til að nema koltvísýring úr andrúmslofti. *Skógræktarritið 1996*, Skógræktarfélag Íslands, 1996.

Landbúnaðarráðuneytið (Ministry of Agriculture), verkefnastjórn, *Átak í landgræðslu og skógrækt til ársins 2000: Stöðuskýrsla* 1997, May 1998.

Orkuspárnefnd (Energy Forecast Committee), *Eldsneytisspá 1995-2025*, Orkustofnun (National Energy Authority of Iceland), 1995.

Snorrason, Arnór. Möguleikar skógræktar til að binda koltvísýring, *Morgunblaðið*, February 1, 1998, p. 30.

Suðurlandsskógar, Kostnaðaráætlun Suðurlandsskóga, Fylgiskjal III með frumvarpi til laga um Suðurlandsskóga, nr. 93/1997.

Umhverfisráðuneytið (Ministry for the Environment). *Second Status Report for Iceland pursuant to the United Nations Framework Convention on Climate Change,* Reykjavík, 1997.

Verkefnisstjórn átaks í landgræðslu og skógrækt 1997-2000. *Binding kolefnis í gróðri og jarðvegi, Áfangaskýrsla 1999*, August 2000.

Vilhjálmsson, Jón, *Töflur um eldsneytisnotkun Íslendinga árin 1980-1997*.

World Coal Institue. *The Six Greenhouse Gases*, February 25, 1998, <www.wci-coal.com/clnews3.htm>.

Yfirlit um efnahagslega þætti er varða aðgerðir til að takmarka eða draga úr losun gróðurhúsalofttegunda og aðild Íslands að Rammasamningi S.þ. um loftslagsbreytingar, unnið af ráðgjafanefnd um efnahagslega þætti samninga um minnkun á losun gróðurhúsalofttegunda, April 21, 1999.

Appendix 1: Main Data Sources

Eysteinsson, Þröstur (Skógrækt ríkisins (Iceland Forest Service)): Tafla með upplýsingum um áætlaðan hektarafjölda nýrrar skógræktar 1980-1999 (unpublished).

Hagstofa Íslands (Statistics Iceland), *Hagtíðindi,* various issues.

Hollustuvernd (Environmental and Food Agency of Iceland): Various tables with information on the emissions of greenhouse gases, 1990-1998, and forecasts to 2025.

Ríkisbókhald, Unpublished tax data.

Seðlabanki Íslands (Central Bank of Iceland), *Hagtölur Mánaðarins*, various issues.

Þjóðhagsstofnun (National Economic Institute). Various publications including: *Þjóðhagsreikningar* (National Accounts), *Sögulegt yfirlit hagtalna 1945-1998* (Historical Statistics 1945-1998), *Búskapur hins opinbera*, *Atvinnuvegaskýrslur*, *Ársreikningaskýrslur*, and unpublished data tables.

Appendix 2: Definitions of production sectors

The input-output table relies to a large extent on an input-output table constructed at the National Economic Institute (NEI) for the year 1992. Data for production sectors has been aggregated to conform with the sector division of the model. Table A.1 below documents how each production sector in the model corresponds to the data given in the original input-output table.

Table A.1. Definitions of Production Sectors

Production sector in model	**Corresponding Information in original Input-Output Table** **(Industry number within parentheses)**
Agriculture (AG)	Agriculture (11)
Fisheries (FI)	Fishing and Whaling (13)
Fish Processing (FP)	Fish Processing (30)
Metal Processing (MP)	Manufacture of aluminium and ferro-silicone (37)
Other Manufacturing (MA)	Manufacture of food and beverages excl. fish processing (31) + Manufacture of textiles, wearing apparel and leather products (32) + Manufacture of wood and wood products including furniture (33) + Manufacture of paper and paper products, printing and publishing (34) + Manufacture of chemicals and plastic products (35) + Manufacture of non-metallic mineral products (36) + Manufacture of fabricated metal products, machinery and equipment (38) + Other manufacturing industries (39)
Energy- Hydro (EH)	Electricity supply (511)
Energy – Geothermal (EG)	Hot water supply (513)
Construction	Construction (50)
Road Transport	Scheduled passenger land transport (712) + Other passenger land transport (713) + Fright transport by road (714)
Air Transport	Air transport of passengers and freight (717) + Supporting services to air transport (718)
Sea Transport	Ocean transport (715) + Operation of harbours and lighthouses (716)
Post and Telecommunication	Post and telecommunication services (72)
Other Services	Water supply (42) + Wholesale trade and commission broking (61) + Retail trade (62) + Restaurants and hotels (63) + Travel agency services (719) + Storage and warehousing (720) + Financial institutions (81) + Insurance (82) + Real estate and business services (83) + Market services of health (93) + Recreation and cultural services (94) + Personal and household services (95) + Producers of private non-profit services to households (99)

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