Rapporter 2008/22

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An innovation and climate policy model with factor-biased technological change

A small, open economy approach

Statistisk sentralbyrå • Statistics Norway
Oslo–Kongsvinger

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ISBN 978-82-537-7381-0 Trykt versjon
ISBN 978-82-537-7382-7 Elektronisk versjon
ISSN 0806-2056

Emne
01.90

Trykk: Statistisk sentralbyrå

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Abstract

This report documents the model structure and empirical implementation procedures of a dynamic computable general equilibrium (CGE) model that includes induced technological change (ITC). The model is developed for analyses of economy-wide welfare and growth impacts of innovation and greenhouse gas abatement policy. It accounts for macroeconomic productivity and productivity growth effects in an realistic economic and political setting, where several simultaneous reallocations take place and interact with each other.

ITC is driven by two separate, economically motivated research and development (R&D) activities. These activities result in new technological solutions that increase the productivity of capital. The first activity develops general patents, while the second is directed towards environmental technological solutions, specified as carbon capture and storage (CCS). These activities result in new technological solutions that increase the productivity of capital. In addition, R&D of one firm increases the productivity of concurrent and future R&D firms, as it contributes to the common knowledge stock of the country. Emissions of the six Kyoto greenhouse gases are modeled in detail. The model describes the Norwegian economy and is designed to address policy challenges of small, open countries, where changes in international trade and competitiveness are crucial for the results of policies, and where knowledge spillovers from abroad dominate the technological development.

Contents

1. Introduction

This report outlines the structure of a dynamic computable general equilibrium (CGE) model designed for climate policy analyses that includes *induced technological change* (ITC). ITC is driven by research and development (R&D). It falls into the tradition of several model developments during the recent decade; see Gillingham et al. (2007) and Wing (2006) for overviews. The new models develop the CGE tradition further by accounting for and explaining progress in energy and abatement technologies. The motivation is to analyze economy-wide welfare effects of the interplay between innovation and abatement policy within a realistic economic and political setting. The modeling of technological change is inspired by pioneering macro models of endogenous growth (Romer, 1990; Aghion and Howitt, 1992), as well as by micro-econometric studies of innovation activities and their effect on productivity (surveyed in Griliches, 1988, 1995). They also stand on the shoulders of the partial bottom-up model tradition, where current and prospective energy technologies are modeled in detail (e.g. the Markal model; see ETSAP, 2004). The major policy questions in climate policy models with ITC are how induced innovation influences costs of emission reductions, and how this affects optimal abatement and innovation policy.

Goulder and Schneider (1999) is one of the pioneer papers that study CO_2 abatement policies in a CGE model where technological change results from R&D investment in different industries. They compare policy implications of having autonomous vs. induced technological change. Another early model is presented in Nordhaus (2002). He introduces an innovation-possibility frontier. Resources devoted to R&D are a fixed proportion of output, but by directing relatively more to energy R&D, the energy-output ratio falls. Popp (2004) and Buonanno et al. (2003) present related models, but where R&D intensity is not fixed. These contributions treat R&D as an input factor; the only difference from other factors is that R&D affects productivity instead of production directly. R&D expenditure accumulates a knowledge stock, which again improves productivity in the economy.

The model we present here describes R&D instead as an economically motivated, resource-consuming activity, inspired by Romer (1990).[1] New ideas arise from R&D performed by optimizing agents. The ideas are patented as new technological solutions, which are purchased by new entrants to the markets for capital equipment. Substitutable varieties of capital equipment are both exported and sold in domestic markets. There is monopolistic competition among the different varieties in the domestic market. The more varieties, the more productive is the capital. Thereby, R&D activity increases the productivity within the final goods producing firms. Besides, R&D of a firm increases the productivity of concurrent and future R&D firms, as it contributes to the common knowledge stock of the country. Based on evidence provided by Jones (1995) we include decreasing returns to scale in the knowledge capital externalities. Along with these processes, we model a large share of the productivity impetus as exogenously driven. Empirical findings suggest that technological change in small, open countries like the Norwegian, to a large extent spills over from abroad (Coe and Helpman, 1995; Keller, 2004).

The model specifies two separate R&D industries, one producing patents that improve productivity of capital in general, and one developing environmental technological solutions, specified as carbon capture and storage (CCS) solutions

[1] Recently, others have introduced CGE models for climate policy analyses that specify profit-maximizing environmental R&D. The model for the Netherlands in Otto et al. (2008) is inspired by the Acemoglu (2002) model of sector-specific investment goods. Otto and Reilly (2007) use a version of the model that specifies carbon capture and storage, as ours. Contrary to ours, these models treat productivity growth as entirely domestically driven.

applicable for gas power generation.[2] The electricity supply is modeled in detail with one renewable power generating industry (hydropower), one emitting industry (gas power) and one gas power industry with reduced CO_2 emissions through CCS. GHG emissions stem from several uses and output activities and include the six Kyoto gases. These sources can be taxed, either by an exogenous rate or by an endogenous rate determined by an exogenous, economy-wide emission target.

Section 2 presents the structure of the CGE model, section 3 describes the main calibration and parameterization methods, while section 4 gives some concluding remarks and outlines some extensions. Appendix A shows derivations of some of the equations in the model. Appendix B gives details on the practical implementations and calibrations, while appendix C presents lists of model sectors and activities.

2. The model

The CGE model is a dynamic growth model with intertemporally optimizing firms and households. The model gives a detailed description of the empirical tax, production and final consumption structures for the small open economy, Norway. Labor is perfectly mobile within the country, but immobile internationally. Other inputs, including investment goods, are internationally traded at given world market prices. Imports are modeled as imperfect substitutes for domestically produced goods (Armington function), while export deliveries are imperfect substitutes for home market deliveries (constant-elasticity of transformation (CET) technology). Both assumptions imply that the trade volumes are dependent of the ratio of domestic to world market prices. The world market prices are exogenous, while the prices in the domestic market are determined by the respective market equilibriums. The interest rate is also externally given.

2.1. Production

The production industries are listed in appendix C.[3] These include 11 final goods industries exclusive of electricity, four industries providing electricity, two R&D industries producing patents, and two industries producing patent-based capital varieties. We present the behavior and market structures of these four categories in the following.

2.1.1. Production of final goods exclusive of electricity[4]

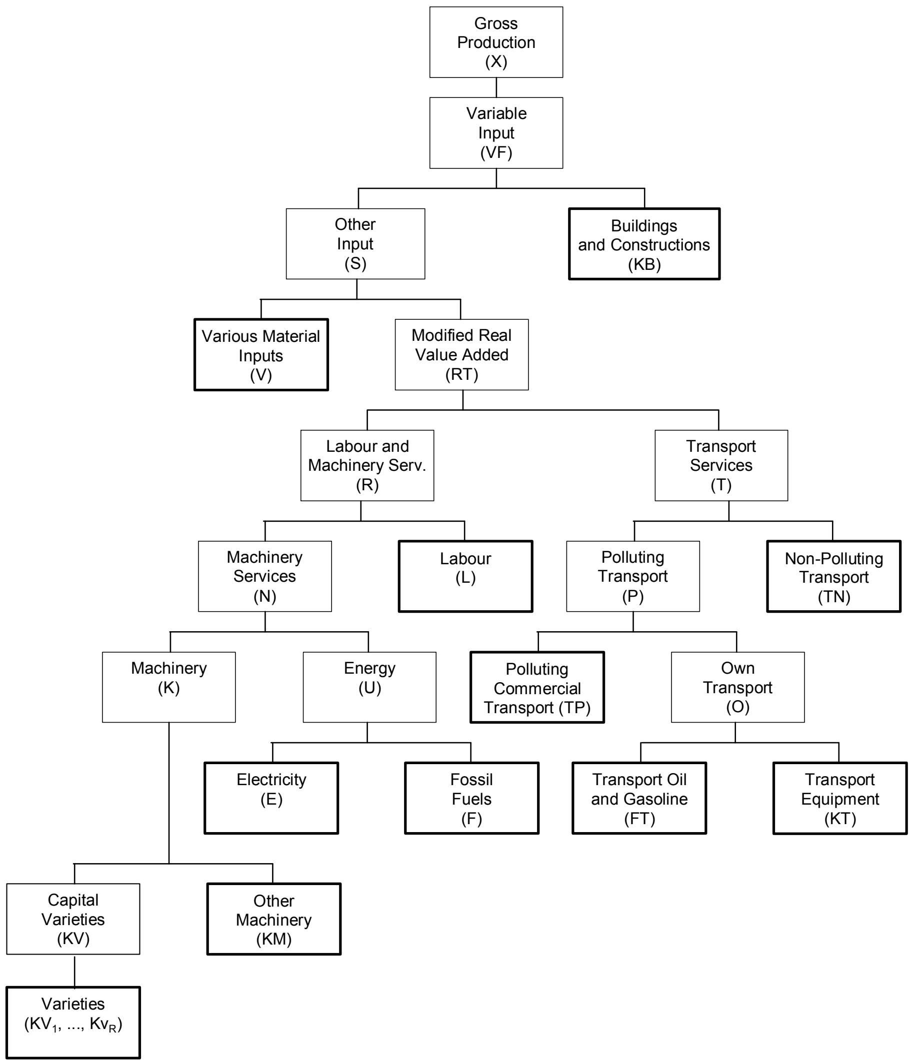
Final goods industry j delivers final products to consumption and export, as well as inputs (intermediates or capital goods) to other industries, in accordance with the empirical input-output structure. Factor inputs of an industry are represented by a nested structure of linearly homogeneous CES aggregates; see Figure 1. In this presentation of the model, we do, for simplicity, disregard intermediates, as well as all other types of capital than machinery, K. There is one type of labor, L, measured in efficient man hours. We assume that all firms within industry j are identical and take the prices as given in the input factor markets and in the final goods markets, both in the home market and at the world market. Each firm has perfect foresight and maximizes the firm's value that is equal to the present value of the after tax cash flow.

[2] An earlier version of the model including only one, general R&D industry and excluding gas power production as well as GHG emissions, is documented in Bye et al. (2006).

[3] There is also a list of production activities, which presents a further disaggregation of the production processes.

[4] Two of the industries are treated exogenously: The central and local governmental sector and The ocean transport, oil and gas exploration and drilling sector.

Figure 1. The nested structure of the production technology



The present value of the representative firm in final goods industry *j* (*j* is suppressed here) in period 0 is given by

$$(1)\quad PV_0 = \int_0^{\infty} e^{-rt}\left(\pi_t - P_t^J J_t\right)dt\,.$$

$J = \dot{K} + \delta K$ is gross investment (in machinery), P^J is the price index of investments, and δ is the depreciation rate. To simplify the exposition we suppress the period term *t* when it is possible. Operating profit π is defined as

$$(2)\quad \pi = P^H X^H + P^W X^W - wL\,.$$

X^H is output delivered to the domestic market, X^W is output delivered to the export market, P^H is the domestic market price, P^W is the exogenous world market price and *w* is the wage rate.

The transformation function between input and output (the technology of production) has the separable structure (see also Heide et al., 2004)

$$(3)\quad \left[\left(X^H\right)^{\theta} + \left(X^W\right)^{\theta}\right]^{1/\theta} = \left[f\left(L\tau, K\tau\right)\right]^s.$$

τ denotes an exogenously developed factor productivity level. It is assumed to be factor and industry neutral and to increase the efficient input of each factor. s is the scale elasticity, $0 < s \leq 1$ and θ is the transformation parameter between deliveries to the domestic and the foreign market. We make a restrictive assumption regarding the relationship between the scale elasticity and the elasticity of transformation in order to obtain a separable structure in the determination of the optimal supply of exports and deliveries to the domestic market. The restriction is given by $1/\theta = s$, see also Holmøy and Hægeland (1997) and Heide et al. (2004). Following this assumption, the variable cost function is additively separable in a cost function for export deliveries and a cost function for domestic deliveries. The variable cost function of the representative firm then takes the form

$$(4)\quad C = c\left[\left(X^W\right)^{1/s} + \left(X^H\right)^{1/s}\right].$$

c is the dual price index (unit cost function) of the CES-composite of labor and capital input given by

$$(5)\quad c = \left[\delta_L\left(\frac{w}{\tau}\right)^{(1-\sigma)} + (1-\delta_L)\left(\frac{P^K}{\tau}\right)^{(1-\sigma)}\right]^{\frac{1}{1-\sigma}}.$$

σ is the elasticity of substitution between labor and capital and δ_L is the base year cost share of labor. P^K is the user cost index of (machinery) capital, K.

Integrating (by parts) equation (1), the present value of the firm can be written as (see appendix A.2 for a detailed description of the calculations)

$$(6)\quad PV_0 = \int_0^\infty e^{-rt}\left(\pi_t - P_t^K K_t\right)dt + P_0^J K_0.$$

$P_0^J K_0$ is the initial value of the capital stock. Equation (6) implies that maximizing the present value of the firm is equivalent to maximizing $\pi_t - P_t^K K_t$ in each period. By using appropriate substitutions (see appendix A.2 for further details), the dynamic maximization problem of the firm can then be transformed to a sequence of static problems where the firm maximizes

$$(7)\quad \pi' = P^H X^H - c\left(X^H\right)^{1/s} + P^W X^W - c\left(X^W\right)^{1/s}$$

w.r.t. X^H and X^W. From the first order conditions of the firm's profit maximization we have the following marginal conditions

$$(8)\quad P^H = \frac{c}{s}\left(X^H\right)^{\frac{1-s}{s}}$$

$$(9)\quad P^W = \frac{c}{s}\left(X^W\right)^{\frac{1-s}{s}}.$$

Equations (8) and (9) state that price must equal marginal costs both in the domestic and the export market. The price on the world market, P^W, is exogenous, while the price in the domestic market, P^H, is determined by equilibrium in the domestic market, given the cost structure.

The production technology represented in figure 1 implies dual cost functions for the different CES aggregates, which determine the different factor shares. Together with total production, these determine the demand for each input factor. Capital, K, is a composite of two types of machinery capital, one consisting of patent-based varieties, K^V, and one other machinery capital which is homogenous, K^M. When disregarding the exogenous technology variable, τ, we have

$$(10)\; K = \left[\delta_{KM} \left(\frac{K^M}{\delta_{KM}} \right)^{\left((\sigma_K - 1)/\sigma_K \right)} + (1-\delta_{KM}) \left(\frac{K^V}{(1-\delta_{KM})} \right)^{\left((\sigma_K - 1)/\sigma_K \right)} \right]^{\left(\sigma_K / (\sigma_K - 1) \right)}$$

δ_{KM} is the share of K^M in the capital composite. σ_K is the elasticity of substitution between the two types of machinery, K^V and K^M.[5] K^V is, itself, a composite, consisting of capital varieties. It has a CES structure, a so-called Spence-Dixit-Stiglitz (love-of variety) technology

$$(11)\; K^V = \left[\sum_{i=1}^{R} (K_i^V)^{(\sigma_{KV}-1)/\sigma_{KV}} \right]^{\sigma_{KV}/(\sigma_{KV}-1)} .$$

R is the accumulated number of capital varieties (and firms in the variety-producing industry), and σ_{KV} is the uniform elasticity of substitution applying to all pairs of capital varieties.[6] According to equation (11), the effective input of K^V within the final goods industries increases with the number of varieties. This is one important productivity effect stemming from more patented varieties, which is also central in the model of Romer (1990).

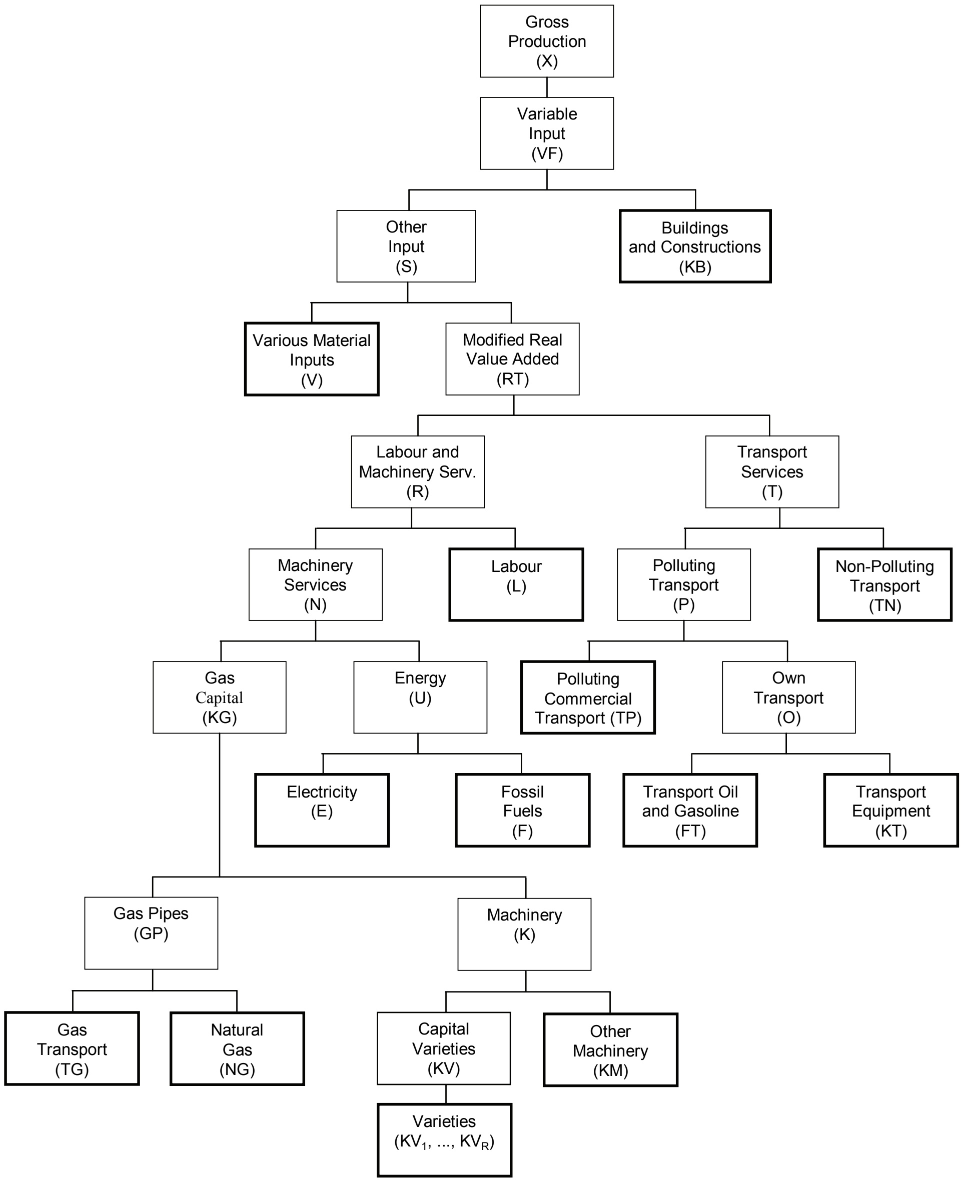
2.1.2. Production of electricity

Electricity is generated in three different production processes (industries), and distributed by a fourth. The three generation processes are based on hydropower, gas power without CCS, and gas power with CCS, respectively. Hydropower production is exogenous and determined by the existing capacities in dams and exploited waterfalls, and the production technology is described by the same nested CES structure as for the final goods industries depicted in Figure 1. The CES structure of factor use in the gas power industries differs, in that gas and gas transport are additional inputs; see Figure 2. At the lowest level in the nested tree, gas-pipes (GP), is defined as a composite of pipes (RT) and gas (NG), with fixed factor shares. Gas-capital (CG) is defined as a standard CES composite of gas-pipes (GP) and the machinery capital composite (K). Both of the gas power industries use capital varieties. There is, however, an important difference. While gas power firms without CCS invest in *general* capital varieties also used in other final goods industries (including the hydropower industry), the gas power industry with CCS uses (only) *environmental* capital varieties. For simplicity this difference is not specified in Figure 2.

[5] The corresponding dual expression for the user cost index of capital, P^K, is presented in appendix A.1, equation (A.3).

[6] The corresponding dual expression for the user cost index of the composite of varieties, P^{KV}, is presented in equation (20). See also appendix A.1.

Figure 2. The nested structure of the production technology for the gas power industries



The behavior of the two gas power industries is based on standard profit maximization as described for the final goods industries in section 2.1.1, and equations (1) to (9) are also valid for the gas power industries. In order to avoid zero production in one of these two industries as the costs of production are not equal, we assume that gas power with and without CCS are close, but not perfect substitutes. We model this as a CES composite, the total gas power composite, with the following composite price index, P^E

$$(12)\quad P^E = \left[{P_{GG}^H}^{(1-\sigma_E)} + {P_{GE}^H}^{(1-\sigma_E)} \right]^{\left(1/(1-\sigma_E)\right)}.$$

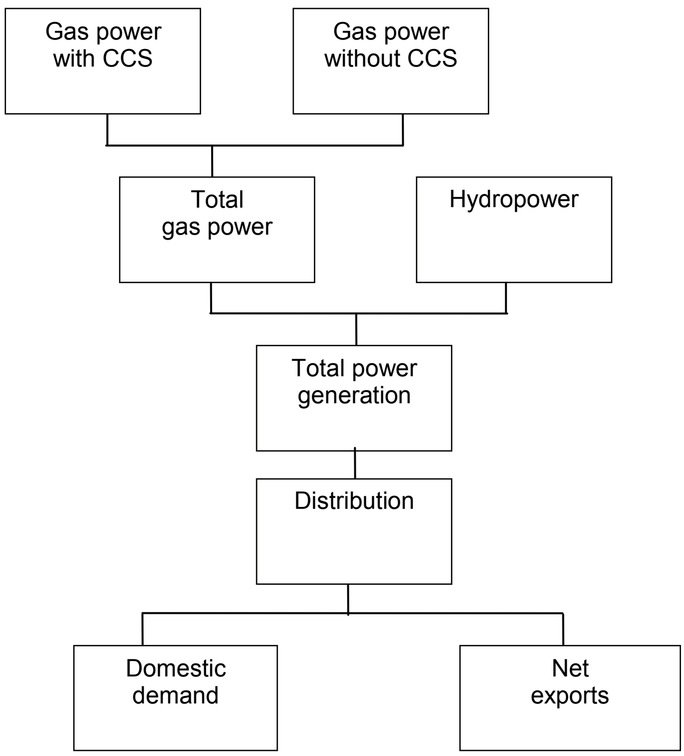
P_{GG}^H is the domestic price of gas power without CCS, determined by the marginal production costs within that industry, while P_{GE}^H is the corresponding cost-determined, domestic price of gas power with CCS. σ_E is the elasticity of substitution between the two kinds of gas power in the total gas power composite. The domestic production of the respective gas power types is determined by

$$(13)\quad X_j = \left[\frac{P^E}{P_j^H}\right]^{\sigma_E} X_G^E,\ j=GG,\ GE,$$

where X_G^E is the demand for the total gas power composite, see Figure 3. This composite, together with the exogenous hydropower production and net import constitutes total electricity demand. Figure 3 illustrates this. The domestic market price for electricity is equal to the composite price of gas power. As expressed in equation (12), it follows from the production costs in the gas power industries. Since the unit cost of production in hydropower is relatively low this industry earns high profits, interpreted as a natural resource rent.

The generated electricity is purchased by a *distribution* industry; see Figure 3, which organizes the market sales to electricity users. This industry is not modelled as the other industries. The output level in the industry is set according to the available amount of electricity. It charges distribution and transmission costs, which are passed on to the users. These may vary among demanders. Export and import activities are also handled by the distribution industry. To simplify the model solution we assume exogenous net import of electricity.

Figure 3. The electricity market



2.1.3. Production of patents

There are two R&D industries, *general* (G) and *environmental* (E). The general R&D industry delivers new patents to domestic firms that wish to enter the industry producing general capital varieties. The environmental R&D industry delivers new patents to domestic firms that wish to enter the industry producing environmental capital varieties. The modeling of the two R&D industries is similar, and we disregard the industry labels G and E in this presentation.

The production of new patents in one time period is given by X_R^H . The transformation function between input and output (the technology of production) mainly has the same structure as for the final goods industries given in equation (3), except that there are only deliveries to the domestic market,

$$(3') \quad X_R^H = [R]^{s_1}\left[f\left(L\tau, K^M\tau\right)\right]^s.$$

The same nested CES production technology as for the final goods industries applies, except that the R&D industry only uses other machinery capital, K^M, as capital input.[7] As for the final goods production, changes in τ capture exogenous productivity change from abroad. Within each R&D industry, there is also another source of productivity change that stems from spillovers from the accumulated, previous and concurrent, patent output of the R&D industry, *R*, so that $R = R_{-1} + X_R^H$. These are freely accessible by all incumbent and potential patent producers within the particular R&D industry, while we assume no spillovers across the two R&D industries. s_1 denotes the elasticity with respect to these spillovers. It is assumed equal in the two industries. The external spillovers from accumulated patents ensure a perpetuated productivity growth process in the R&D industries until it is exhausted according to the decreasing returns assumption.

Equation (3') can be rewritten as

$$(14) \quad (X_R^H)^{1/s} = [R]^{s_1/s} f(L\tau, K^M\tau).$$

The variable cost function (when *f(.)* is a CES-function) is given by

$$(15) \quad C = cf\left(L\tau, K^M\tau\right).$$

c is the dual price index (unit input cost function) of the CES function. By combining equations (15) and (3'), the variable cost function for the representative firm takes the form

$$(4') \quad C = \frac{c}{R^{s_1/s}}\left[X_R^H\right]^{1/s}.$$

Domestic spillovers, *R*, reduce the costs of production. As for the final goods industries, the dual price index, *c*, of the CES-composite of labor and capital input is given by

$$(5') \quad c = \left[\delta_L\left(\frac{w}{\tau}\right)^{(1-\sigma)} + (1-\delta_L)\left(\frac{P^K}{\tau}\right)^{(1-\sigma)}\right]^{\frac{1}{1-\sigma}}.$$

The dynamic maximization problem of the firm can be transformed to a sequence of static problems where the firm maximizes

$$(7') \quad \pi' = P_R^H X_R^H - \frac{c}{R^{s_1/s}}\left(X_R^H\right)^{1/s}$$

w.r.t. X_R^H. From the first order conditions of the firm's profit maximization we get the following marginal condition

[7] This choice is made to avoid cumulative multiplicators of the love-of-variety effect.

$$(8')\quad P_R^H = \frac{c}{sR^{s_1/s}}\left(X_R^H\right)^{\frac{1-s}{s}}.$$

In equilibrium the domestic price of the patent P_R^H equals marginal production costs, since there is free entry into the R&D industries.

2.1.4. Production of capital varieties

As for R&D, there are two industries producing capital varieties, general (*G*) and environmental (*E*), respectively. At the time of entry, a new firm in the general capital varieties industry buys one patent from the general R&D industry at the available market price, P_R^H, and produces one capital variety based on the patent. The general varieties are delivered to all final goods industries, except the gas power industry with CCS. Correspondingly, an entrant into the environmental capital varieties industry buys one patent from the environmental R&D industry. The environmental capital varieties are delivered to the gas power industry with CCS, only. Each variety firm has some degree of market power in the domestic market, but exhibits no market power in the export market. This is a reasonable assumption for a small, open economy. The modeling of the two capital varieties industries is similar, and we disregard the industry labels *G* and *E* in this presentation.

We assume that the cost structure is identical for all the firms within an industry. As for the R&D industries, we exclude input of capital varieties. We allow for deliveries to both the domestic and the export markets with similar separability assumptions between the deliveries as for the final goods industries. Technological change from abroad is accounted for through the τ's. We do not allow for additional productivity growth through import of capital varieties. However, the relatively close substitute, other machinery capital, is imported.

The present value of firm *i* in the entry period 0 can be written as

$$(6'')\quad PV_{i0} = \int_0^\infty e^{-rt}\left(\pi_{it} - P_t^K K_{it}\right)dt - P_{R0}^H + P_0^J K_{i0}.$$

The patent price is a sunk cost for the firm. As for the final goods firms, the transformation function between input and output has a constant elasticity

$$(3'')\quad \left[\left(X_{Ki}^H\right)^\theta + \left(X_{Ki}^W\right)^\theta\right]^{1/\theta} = \left[f\left(L_i\tau, K_i^M\tau\right)\right]^s.$$

X_{Ki}^H is the production of capital variety *i* delivered to the domestic market, and X_{Ki}^W is the production of capital variety *i* delivered to the export market. We also assume that $1/\theta = s$. By this, the variable cost function can be separated into a cost function for export deliveries and a cost function for domestic deliveries

$$(4'')\quad C_i = c\left[\left(X_{Ki}^W\right)^{1/s}\right] + c\left[\left(X_{Ki}^H\right)^{1/s}\right].$$

As for the final goods industries, the dual price index (unit input cost function) of the CES-composite of labor and capital input, *c*, is given by

$$(5'')\quad c = \left[\delta_L\left(\frac{w}{\tau}\right)^{(1-\sigma)} + \left(1-\delta_L\right)\left(\frac{P^K}{\tau}\right)^{(1-\sigma)}\right]^{\frac{1}{1-\sigma}}.$$

In each period, the firm maximizes

(7") $\pi_i' = P_{Ki}^H\left(X_{Ki}^H\right)X_{Ki}^H - c\left(X_{Ki}^H\right)^{1/s} + P_K^W X_{Ki}^W - c\left(X_{Ki}^W\right)^{1/s}$

w.r.t. X_{Ki}^H and X_{Ki}^W, given the domestic demand function $P_{Ki}^H\left(X_{Ki}^H\right)$ and the exogenous world market price P_K^W. This gives the following first order conditions

(16) $\frac{\partial \pi_i'}{\partial X_{Ki}^H} = P_{Ki}^{H\prime}\left(X_{Ki}^H\right)X_{Ki}^H + P_{Ki}^H\left(X_{Ki}^H\right) - \frac{c}{s}\left(X_{Ki}^H\right)^{\frac{1-s}{s}} = 0$

(17) $\frac{\partial \pi_i'}{\partial X_{Ki}^W} = P_K^W - \frac{c}{s}\left(X_{Ki}^W\right)^{\frac{1-s}{s}} = 0.$

The domestic demand elasticity for a capital variety is defined as $\varepsilon_{Ki} = -\frac{\partial X_{Ki}^H}{\partial P_{Ki}^H}\frac{P_{Ki}^H}{X_{Ki}^H}$. Inserting this expression into equation (8") and reorganizing, gives the following monopoly pricing rule for the domestic price of capital variety *i*

(8") $P_{Ki}^H = m_{Ki}\frac{c}{s}\left(X_{Ki}^H\right)^{\frac{1-s}{s}}.$

The mark-up factor, m_{Ki}, is $\frac{\varepsilon_{Ki}}{\varepsilon_{Ki}-1}$. For deliveries to the export market, the world market price equals marginal costs

(9") $P_K^W = \frac{c}{s}\left(X_{Ki}^W\right)^{\frac{1-s}{s}}.$

The composite of environmental capital varieties is used as input in the gas power industry with CCS, while the composite of general capital varieties is used as input in the remaining final goods industries. It can be shown that the demand elasticity for a variety, ε_{Ki}, is equal to the elasticity of substitution between the different varieties in its respective composite, σ_{KV}, so that

(18) $m_K = \frac{\sigma_{KV}}{\sigma_{KV}-1}$, $\sigma_{KV} > 1.$

Since σ_{KV} is equal for all pairs of varieties, the mark-up factor is independent of *i*. Together with the assumption of equal production and cost structure in each firm in the industry, the monopoly pricing rule implies that the price in the domestic market is equal for all the capital varieties, $P_{Ki}^H = \overline{P}_K^H$ for all *i*. Hence, each variety is produced in equal quantity. This implies that the user costs of each capital variety *i* produced in the same industry, are equal: $P_i^{KV} = \overline{P}^{KV}$. It can be written as

(19) $\overline{P}^{KV} = (r+\delta)\overline{P}_K^H - \dot{\overline{P}}_K^H,$

where *r* is the interest rate, δ is the depreciation rate and $\dot{\overline{P}}_K^H$ is the capital gains term. As explained in section 2.1.1, the input technology for capital varieties implies love of variety in the final goods industries. This also applies to the environmental capital varieties used in the gas power industry with CCS. The dual user cost index of the composite of varieties, P^{KV} is given by [8]

(20) $P^{KV} = R^{\left(1/(1-\sigma_{KV}) \right)} \cdot \overline{P}^{KV}$.

By combining equations (6'') and (7'') and using that $K_{i0} = 0$ (there is no capital in the marginal variety firm before entry), in addition to using the fact that profit is equal for all firms in an industry, $\pi'_{it} = \overline{\pi}'_t$, the entry condition for a capital variety firm in its respective industry is given by

(21) $P^H_{R0} = \int_0^\infty e^{-rt} \left(\overline{\pi}'_t \right) dt$.

P^H_{R0} is the sunk entry cost of buying one patent from the relevant R&D industry (general or environmental). Firms are entering each capital varieties industry until the representative firm in the industry obtains a total discounted net profit equal to the entry cost. In each period, new patents are produced and new firms will enter the capital varieties industries. Given that a firm has entered, the first order condition in equation (8'') determines the domestic price of the capital variety for given marginal costs and domestic demand. The entry condition determines the price of a new patent in each period.[9] Then, together with the first order condition for the representative firm in each R&D industry in equation (8'), the production in each of the R&D industries (number of new patents in each industry) is determined.

2.2. Consumer behavior

We assume an infinitely lived representative consumer that maximizes the intertemporal utility function

(22) $U_0 = \int_0^\infty u(d_t) e^{-\rho t} dt$,

given the intertemporal budget constraint

(23) $W_0 = \int_0^\infty P^D_t d_t e^{-rt} dt$.

d is total material consumption for the representative consumer, ρ is the consumer's rate of time preferences, P^D is the price index for the material consumption aggregate and r is the nominal interest rate, exogenously given from the world market. The intertemporal budget constraint for the representative consumer sets the present value of consumption expenditure in the current and all future periods equal to total wealth W_0 (current non-human wealth plus the present value of labor income and net transfers). Labor supply is exogenous. We choose a CRRA utility function for the representative consumer[10]. We consider a small open economy where the interest rate is exogenously given from the world market and

[8] Confer appendix A.1 for more details on the user cost index of the composite of capital varieties.

[9] The implementation of the entry condition in the CGE model is described in more detail in appendix B.1.

[10] $u(d_t) = \frac{\sigma_d}{\sigma_d - 1} d^{\left(\frac{\sigma_d - 1}{\sigma_d}\right)}$ when $\sigma_d \neq 1$

$u(d_t) = ln\, d_t$ when $\sigma_d = 1$

we assume that the nominal interest rate equals the consumer's rate of time preference $r = \rho$ for the entire time path. When $r = \rho$, it can be shown that the marginal utility of wealth λ (shadow price associated with financial wealth accumulation) is constant over the entire time path. From the first order conditions of the intertemporal utility maximization the following consumption function is then derived

$$(24) \quad d_t = \left[\lambda \cdot P_t^D\right]^{-\sigma_d} .$$

σ_d is the intertemporal elasticity of substitution. Total material consumption D_t is given by

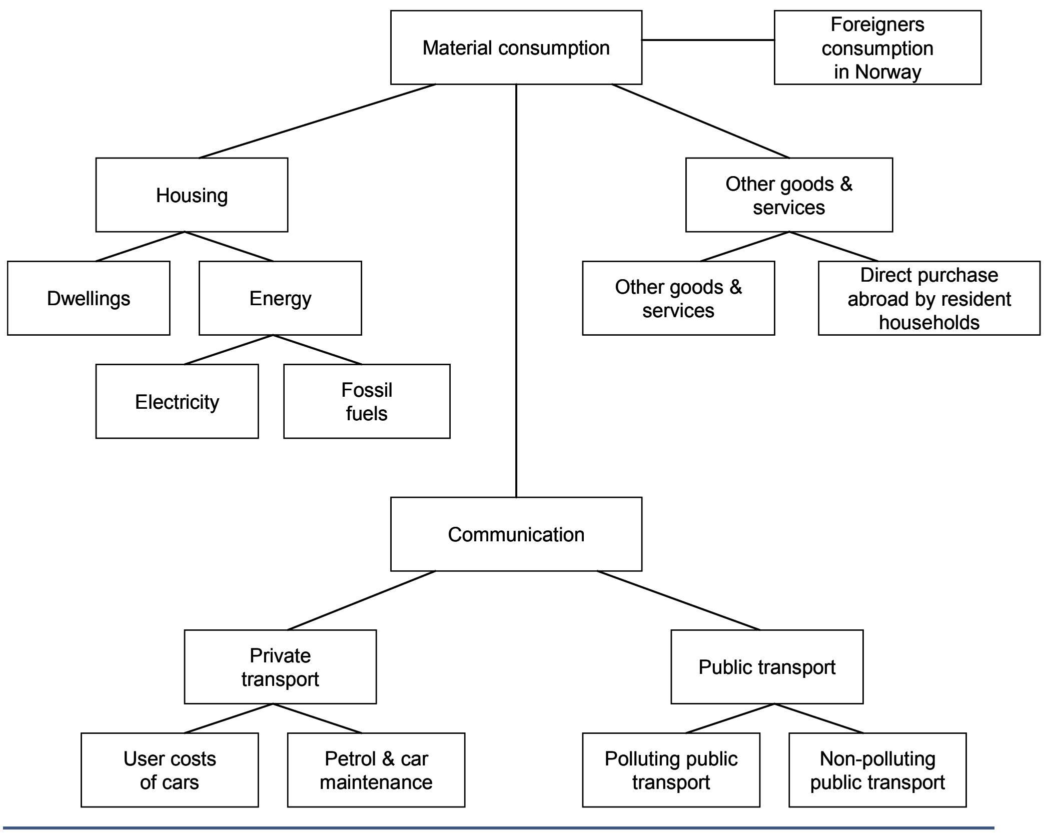
$$(25) \quad D_t = d_t (1+n)^t .$$

n is annual population growth rate. Total material consumption is allocated across 10 different goods and services according to a nested structure of linear homogeneous CES aggregates that is described in detail in Figure 4. The demand for consumer good i, D_{it}, is given by

$$(26) \quad D_{it} = \omega_{i.0} \left(\frac{P_{jt}^D}{P_{it}^D} \right)^{\sigma_j} \frac{VD_{jt}}{P_{jt}^D}$$

P_{it}^D is the price of consumer good i, P_{jt}^D and VD_j are the unit price and total expenditure of the CES aggregate j, respectively. $\omega_{i.0}$ is the budget share of good i in CES aggregate j and σ_j is the elasticity of substitution between the two consumer goods in CES aggregate j, i=list of consumer activities, j=material consumption composite.

Figure 4. Material consumption



2.3. Emissions

The model includes emissions of the six GHGs accounted for in the Kyoto protocol, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), hydrofluorcarbons (HFCs), and perfluorcarbons (PFCs). The emissions are linked to the relevant economic activities at the most disaggregated level possible. These can be factor uses, outputs or consumption goods (activities). Emissions linked to output represent process emissions or emissions from unspecified inputs. The economic activity *j* in period *t*, A_{jt}, is converted into emissions of compound *i*, EM_{jt}^{i}, according to activity and compound specific technical parameters, κ_j^i

(27) $$EM_{jt}^{i} = \varepsilon_{jt}^{i} \kappa_j^i A_{jt}^{i},$$

ε_{jt}^{i} is an exogenous shift parameter allowing for changing emissions per unit of economic activity. Emissions of the six GHGs are converted into CO_2 equivalents by using global warming potential (GWP) weights. The model specifies a uniform price of emission per CO_2 equivalent, which is equivalent to a uniform tax or emission quota price.

2.4. Equilibrium conditions

The model is characterized by equilibrium in each period in all product markets and the labor market. The government collects taxes, distributes transfers and purchases goods and services from the industries and abroad. The model incorporates a detailed account of the government's revenues and expenditures. Direct and indirect taxes, subsidies and transfers follow from the National Accounts; see also the list of indirect taxes and transfers in appendix C.

Intertemporal equilibrium requires fulfillment of two transversality conditions: the limit values of the total discounted values of net foreign debt and of real capital, respectively, must both be zero. The model is characterized by a path dependent steady state/balanced growth path solution; see Sen and Turnovsky (1989) for a theoretical exposition. This implies that both the path and the long-run stationary solution differ between simulated scenarios.

To ensure a long run *balanced growth path*, the following conditions must be fulfilled:

1) The rate of technological change for each input factor in each industry must converge to the same rate, g^s, so that each industry grows at the same rate.
2) The growth in per capita material consumption equals the same rate g^s.
3) The population growth rate is constant.

The rate of technological change is an endogenous variable in these kinds of ITC models. Along the transitional path the growth rate may vary, but in the long run balanced growth path, the growth rate must be constant equal to g^s.

A balanced growth path requires that

(28) $$\frac{D_{t+1}}{D_t} = (1+n)(1+g^s).$$

Using equations (24) and (25) and the intertemporal consumption function in discrete times[11], the relationship between total consumption in two periods can be written as

$$(29)\quad \frac{D_{t+1}}{D_t}=\left[\frac{P_{t+1}^D}{P_t^D}\frac{(1+\rho)}{(1+r)}\right]^{-\sigma_d}(1+n).$$

To reach a long run balanced growth path the rate of price growth, $p=\frac{P_{t+1}^D}{P_t^D}-1$, must be constant. Combining equations (28) and (29) gives the following additional condition for a balanced growth path

$$(30)\quad \left[\frac{(1+\rho)}{(1+r)\big/(1+p)}\right]=(1+g^s)^{-1/\sigma_d}.$$

Equation (30) must be satisfied along a balanced growth path. In order to reach a long run balanced growth path that also satisfies the transversality condition regarding net foreign debt, we implement the constraint given in equation (30) in the following way: In the really long run we assume that the growth rate and the rate of price growth are both equal to zero. This is consistent with the earlier stated assumption that $r=\rho$ at all points in time.

The firms determine their net investments by maximizing total discounted value of each firm, given the transversality condition for the value of real capital. The other transversality condition regarding net foreign debt is fulfilled when the consumer finds its optimal level of material consumption given the intertemporal budget constraint and the transversality condition.[12] Numerically, this transversality condition is taken into account in the following way: λ, the marginal utility of wealth in equation (24), will be constant during a transitional path, and is adjusted to find the optimal path of material consumption that also satisfies the second transversality condition.

[11] When formulating the intertemporal utility maximization problem in discrete times, the resulting intertemporal consumption function for the representative consumer is given by

$$d_t=\left[\lambda\cdot P_t^D\left(\frac{1+\rho}{1+r}\right)^t\right]^{-\sigma_d}.$$

[12] The consumer's budget constraint is given by $\dot{b}=P_t^D d_t-\pi_t-w_tL_t+rb_t+\Omega_t$.

b is net foreign debt, π_t is net profit by the firms, w_tL_t is labour income and Ω_t is net taxes paid by the consumer. The long run transversality condition for the net foreign debt b is given by $\lim_{t\to\infty} be^{-rt}dt=0$.

This is the so-called non-Ponzi game condition, ensuring that the economy is on a sustainable path that prevents exploding debt (or wealth).

3. Calibration

3.1. Data and parameters

The model is calibrated to the 2002 Norwegian National Accounts. The elasticities of substitution in the production technology range from 0.15 at the upper part of the nested tree to 0.5 further down in the nested tree structure, see Figure 1, and are consistent with the empirical findings, Andreassen and Bjertnæs (2006). We have less empirical foundation for the substitution possibilities within the composite of variety-capital and ordinary machinery capital. We assume a relatively high substitution elasticity of 1.5, while the elasticity between the different capital varieties is expected to be even higher and set to 5.0, giving a mark-up factor of 1.25 for the domestic price of capital varieties.[13]

The elasticities of scale are equal to 0.83 in all industries, and fit econometric findings of decreasing returns to scale in Norwegian industries (Klette, 1999). The scale elasticity is at the lower end of the estimates by Klette (1999), but is chosen in order to avoid unrealistic industrial specialization patterns.[14] This implies that the elasticities of transformation between domestic and foreign deliveries are equal to 5. The elasticities of substitution between domestic products and imported goods are assumed equal to 4.[15] The elasticity of scale related to previous knowledge is equal to 0.5, in order to ensure decreasing spillover effects of the knowledge base, supported by both theoretical and empirical findings (see Jones, 1995; 1999; Leahy and Neary, 1999).

The specification of the *general* capital varieties industry and the *general* other machinery industry is made by placing the production of relatively technologically advanced process capital in the capital varieties industry, while the rest is placed in the other machinery industry. The rest includes other production of machinery investment goods, technical intermediates, consumer goods and repairs. All imports are categorized as other machinery, as well.

We have generated the base year productions of *environmental* capital varieties on information about the present situation concerning gas power production with CCS. Norway has one gas power plant in operation and one under construction.[16] Several other plants are on the planning board. Neither of the two existing projects has CCS technology. However, their concession rights are conditioned on the implementation of technologies with low GHG emissions, and the plants have

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[13] This is in line with the Jones and Williams (2000) computations that exclude creative destruction (similarly to our model). Numerical specifications of Romer's Cobb Douglas production functions, as in Diao et al. (1999), Lin and Russo (2002), and Steger (2005), result in far larger markups. Markups of 1.5 are nevertheless in the upper bound of econometric estimates (Norrbin, 1993; Basu, 1996). Our main motivation for staying in the upper bound area is that we model industrial R&D as outsourced to a separated R&D industry. Thus, R&D costs are ascribed to this R&D industry, whereas the marginal costs of final industries exclude this part of the costs. This deviates from typical regression of markups, where marginal costs include all observed costs, including industrial R&D costs. Another, more technical, reason for relatively high markups is that the capital varieties represent a relatively small share of machinery capital and thus of total inputs. This, in isolation, drives the markups required to calibrate the model upwards.

[14] Because $\theta = 1/s$, a larger elasticity of scale, will imply a larger elasticity of transformation between domestic and foreign deliveries, $1/(1-\theta)$. If the elasticity of scale is close to 1 (constant returns to scale), the elasticity of transformation will be very high, implying practically no dispersion between domestic and foreign deliveries.

[15] These parameter values correspond to similar parameter values in the MSG6-model, a traditional applied CGE model for the Norwegian economy; see Heide et al (2004).

[16] The plant in operation is on Kårstø. The one under construction is on Mongstad. In addition to these, large enterprises within offshore and processing generate gas power for own use. In the model, this power production is not separated from rest of the production in the respective industries.

timetables for full-scale extraction of CO_2.[17] In the model, two 860 megawatt gas power plants are included, one with CCS and one without CCS. This is 10 percent of the base year production of electricity. The rest is mainly hydropower. The production costs of gas power in our calibration are based on Statoil (2005).[18]

Basically, capital and operating costs are doubled for a CCS plant compared to a non-CCS plant, while use of gas is about 20 percent larger. The substitution elasticity between the two types of gas power is set to 30, implying they are highly substitutable. See appendix B.4 for further details on costs and prices in the gas power industry. The plans to implement CCS technology are joint projects with the government, the energy producers, and the potential suppliers of CCS technology. It is, at present, unsettled how the costs of implementing and developing the technology will be shared among the involved parties. The production of environmental capital varieties in the base year, 2002, is given by the calibrated amount demanded by the gas power industry with CCS technology. Correspondingly, general capital varieties are demanded by the gas power industry without CCS.

Input and output of R&D are not specified in the Norwegian National Accounts. We base our estimates of R&D production and inputs on the R&D-statistics (Statistics Norway, 2004). More details are presented in appendix B.3. In the base year, the share of environmental R&D relative to total R&D production is equal to the share of capital varieties used by the gas power industry with CCS relative to the total production of capital varieties in the economy. By this, we obtain similar firm entry costs as share of production value in the two capital varieties industries. The production in the environmental R&D industry is quite low in the base year, about US$35 million, and is in line with information obtained from the Norwegian Research Council.

The technical parameters that give GHG emissions from factor inputs, output, and consumer activities are taken from Strøm (2007). The emissions sum up to 56.05 million tonnes CO_2-equivalents in the base year, 2002.

In the consumer model the intertemporal elasticity of substitution, σ_d, equals 0.3, cf. Steigum (1993). Econometric estimates of σ_d vary considerably between different sources, and 0.3 is in the lower end of the range of the estimated parameters. The elasticities of substitution between the different commodities in the demand system for material consumption (σ_j) are all equal to 0.5.

3.2. Business as usual path and balanced growth

Along the business as usual (BAU) path the exogenous growth factors are assumed to grow at a constant rate. In most cases rates are set in accordance with the average, annual growth estimates in the baseline scenario of Norwegian Ministry of Finance (2004) that reports the governmental economic perspectives until 2050. In the governmental perspectives, total factor productivity growth is entirely exogenous and valued at, on average, 1.0 percent annually. Our model distinguishes between exogenous and endogenous factor productivity processes. In line with empirical findings; see e.g. Coe and Helpman (1995) and Keller (2004), we ascribe 90 percent of domestic total factor productivity growth to exogenous diffusion of international technological change, while the remaining 10 percent is the result of domestic R&D[19]. The latter forms a basis for calibrating the 2002 level

[17] CCS technology is planned to be operational in 2011 on Kårstø and in 2014 on Mongstad.

[18] Statoil (2005) base their costs on combined cycle power plants with amine based post-combustion separation of CO_2. Reduced energy efficiency, pipeline transport, and storage in geographic formations are included in the costs.

[19] 10 percent from domestic R&D is in the lower bound of estimates for small, open countries like the Norwegian. We have chosen to be in the lower bound since several mechanisms believed to drive

of accumulated patents of the general type, which together with the remaining parameters of the model determines the productivity growth from domestic knowledge accumulation.[20]

Exogenous world market price growth rates are set in the lower range of those in the governmental perspectives. This choice is made to let exogenous inflationary impulses approach the relatively weak internal impulses, which are dampened by the consumption-smoothing features of the model. This provides us with endogenous developments of the delivery ratios between the export and domestic markets that are more in agreement with those of the governmental perspectives. Most world market prices are assumed to increase 1.4 percent annually. The export price developments of the two types of capital varieties constitute an exception. These are linked to the BAU growth in the corresponding domestic prices, to allow for productivity growth abroad in line with the domestic impulses. This results in even lower growth rates in these export prices. The international nominal interest rate is 4 percent. All policy variables are constant in real terms at their 2002 levels.

In the long run, i.e. 60-70 years from now, the economy reaches stationary growth rates. GDP grows by 1.5 percent annually; the consumption growth rate is 0.5 percentage points lower, as net export is increasing more than GDP in this period. The 10 percent contribution from the endogenous productivity impacts of domestic innovations requires a relatively strong growth in R&D production and generation of new varieties, first of all of the more widespread, general types. Both these productions grow about 3 percent annually.

Before 2070, the demand for electricity increases substantially. Most of this is covered by gas power without CCS. Gas power with CCS does not grow, as the production costs are relatively high when the carbon tax faced by the gas power industry without CCS is very low. This leads to low demand for the environmental capital varieties, which again leads to low production in the environmental R&D industry. The low level of investment in environmental R&D yields poor productivity growth in the gas power industry with CCS, and increases the cost difference between power production with and without CCS. Note that gas power without CCS experiences the general productivity growth from general R&D, and that there is no spillover between general and environmental R&D in the model. Emissions rise substantially through the period to 92.0 million tonnes in 2050 and 120.5 million tonnes in 2070. About 16 percent of the increase in emissions comes from the gas power industry. These results are sensitive to the carbon tax assumptions, see Heggedal and Jacobsen (2008).

The endogenous growth is assumed to asymptotically approach zero, according to the decreasing returns assumption. In the far future, we deactivate all growth mechanisms, including all exogenous drivers as imported technical change and growth in world market prices. This cut-off (after about 90 years) is technically motivated, in order to ensure that the economy is on a balanced growth path (steady state) and that this growth path satisfies the transversality conditions described in chapter 2.4.

3.3. Numerical solution

The intertemporal model is solved in a three-step procedure (see also Bye and Holmøy (1997) for more details) implemented in a solution algorithm that works in the following way:

1. The model is simulated contingent on a constant and exogenous trial value of λ.[21] In the far future (approximately 90 years ahead) all exogenous and

domestic innovations are excluded from the model, like basic, governmental research, endogenous education, learning-by doing absorptive capacity extension induced by R&D.

[20] Accumulation of the environmental type of patents is assumed to have the same productivity effect as general capital, confer section 3.1.

endogenous growth elements are set equal to zero, in order to ensure that the economy is on a balanced growth path (steady state).
2. A period *n* (more than 90 years ahead) is found, after which all variables have become sufficiently close to stationarity. *n* is found by checking the growth rates of important growth variables.
3. If the change in the net foreign debt in year *n* is larger than a sufficiently small margin (or equivalently that the future trade surpluses are not large enough to pay back the interests on debt) the value of λ is increased according to a specific procedure. Corresponding reductions in λ are undertaken if the change in net foreign wealth is too large (the future trade deficit is too small compared to the interests on the net foreign wealth). The algorithm then starts up at step 1 again.
4. The solution has been found when the change in net foreign debt is sufficiently small.

4. Concluding remarks

This model is designed for macroeconomic analyses of general innovation policies, specific environmental innovation policies, and GHG emission regulations. Because of its dynamic characteristics, it is also suitable for addressing policy timing issues. Contrary to most of the empirical macroeconomic models with ITC by now, our particular focus is on the policy challenges of small, open countries like Norway, where changes in international trade and competitiveness are crucial for the results of policies, and where knowledge spillovers from abroad dominate the technological development.

Besides accounting for the firms' internal productivity effects of policies, a macroeconomic approach takes into account how R&D activity, and new technology production and investments within firms, spill over to other firms/industries and across borders. In addition, the general modeling allows us to grasp the opportunity costs of redirecting resources through governmental policy, for instance the effects on other innovation activities of giving priority to development or implementation of new energy technology. In the presence of numerous policy instruments and market imperfections, several reallocations may affect macroeconomic productivity and productivity growth. A detailed CGE model is necessary in order to build in the relevant interactions.

Norway has traditionally shown a strong willingness to regulate carbon emissions. The government has recently announced ambitious unilateral goals for GHG reductions. By 2030 the aim is to become carbon neutral. As part of this effort, a considerable share of today's R&D support is directed toward environmental research.[22] Therefore, it is of great interest to analyze how the cost of emissions and emission reductions interact with market failures associated with the innovation and diffusion of new technologies. By using the present model framework, Heggedal and Jacobsen (2008) study the timing and the impact of environmental R&D subsides in presence of political emission restrictions.

There are several potentials for adding new features into the model that are empirically significant and relevant to the effects of innovation policies. First of all, the modeling of knowledge spillovers may be richer. Including spillovers between the general technological development and the environmental specific technological development, or introducing absorption processes of international knowledge spillovers, will influence the effects of governmental policies. Bye,

[21] The model is solved by using a stacked time algorithm in the computer programme TROLL developed by Intex solution Inc., Massachusetts, USA, Hollinger (1996).

[22] The share of the governmental budget of the Norwegian Research Council directed toward environmental research was app. 10 percent in 2003.

Fæhn and Grunfeld (2008) model absorption effects and consequences for innovation policies. A richer modeling of the labor market is another natural path of model extensions. This could include endogenizing supply, distinguishing between skill groups, and introducing education policy and mechanisms through which education affects productivity.

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Appendix A

The model structure in more detail

A.1. Input and output of capital varieties
A representative firm uses a CES-composite of labor and capital input. The variable cost function takes the form

$$\text{(A.1)}\quad C = c \cdot f\left(L\tau, K\tau\right) \quad .$$

where *c*, the dual price index (unit cost function) of the CES-composite, is given by

$$\text{(A.2)}\quad c = \left[\delta_L \left(\frac{w}{\tau} \right)^{(1-\sigma)} + (1-\delta_L)\left(\frac{P^K}{\tau} \right)^{(1-\sigma)} \right]^{\frac{1}{1-\sigma}}$$

as in equation (5) in section 2.1.1. The use of (machinery) capital, *K*, is analogously a CES-composite of two capital types, K^V, consisting of capital varieties, and K^M , which is other machinery (see equation (10)).[23, 24] It has the dual user cost index, P^K

$$\text{(A.3)}\quad P^K = \left[\delta_{KM} \left(\frac{P^{KM}}{\tau} \right)^{(1-\sigma_K)} + \left(1-\delta_{KM}\right)\left(\frac{P^{KV}}{\tau} \right)^{(1-\sigma_K)} \right]^{\frac{1}{1-\sigma_K}} .$$

P^{KM} is the user cost of other machinery while P^{KV} is the user cost index of the composite of capital varieties. According to the Spence-Dixit-Stiglitz technology of K^V, given in equation (11), the dual user cost index of the composite of capital varieties is given by

$$\text{(A.4)}\quad P^{KV} = \left[\sum_{i=1}^{R} \left(P_i^{KV}\right)^{(1-\sigma_{KV})} \right]^{1/(1-\sigma_{KV})} .$$

P_i^{KV} is the user cost of capital variety *i* and σ_{KV} is the elasticity of substitution between the different capital varieties.

By using Shepard's lemma on the total cost function (A.1) we derive the demand for capital variety *i*

$$\text{(A.5)}\quad K_i^V = \frac{\partial C(\cdot)}{\partial P_i^{KV}} = c'_{P_i^{KV}} \cdot f\left(L, K\right).$$

For convenience we disregard the exogenous technology variable τ. The demand function for capital varieties is then given by

$$\text{(A.6)}\quad K_i^V = f\left(L, K\right)\left(1-\delta_L\right)\left(1-\delta_{KM}\right)\left(\frac{c}{P^K} \right)^{\sigma} \left(\frac{P^K}{P^{KV}} \right)^{\sigma_K} \left(\frac{P^{KV}}{P_i^{KV}} \right)^{\sigma_{KV}} .$$

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[23] In the case of gas power production with CCS, K_V og K_M are of the environmental type, else they are of the general type.

[24] The R&D industries and capital varieties industries do not use capital varieties as input in the production processes, confer sections 2.1.3 and 2.1.4.

The partial demand elasticity for capital variety i, $\varepsilon_{Ki} = -\frac{\partial K_i^V}{\partial P_i^{KV}} \frac{P_i^{KV}}{K_i^V} = \sigma_{KV}$ is derived from equation (A.6). This is equal to the domestic demand elasticity for the production of capital variety i, defined in section 2.1.4. In this case, the substitution elasticity between any pair of capital varieties is equal to the domestic demand elasticity, and the expression for the mark-up factor in the capital varieties industry is given as in equation (18). With a nested CES production technology, the mark-up factor only depends on the partial demand/substitution elasticity in the composite of capital varieties. The relationship between the mark-up factor in the monopoly pricing rule of the capital varieties and the elasticity of substitution between the different capital varieties, implies that low substitution between the different varieties gives a high mark-up factor, and vice versa. The mark-up factor is independent of i. Together with the assumption of equal production and cost structure in each firm, the monopoly pricing rule implies that the price in the domestic market is equal for all the capital varieties. This implies equal quantity of each variety. The user cost index of the composite of capital varieties, P^{KV}, can then be written

$$\text{(A.7)}\; P^{KV} = R^{\left(1/_{1-\sigma_{KV}}\right)} \cdot \overline{P}^{KV},$$

as in equation (20) in section 2.1.4. $\overline{P}^{KV}$ is the user cost of each capital variety. The capital varieties composite is then given by

$$\text{(A.8)}\; K^V = R^{\left(\sigma_{KV}/_{(\sigma_{KV}-1)}\right)} \cdot \overline{K}^V .$$

$\overline{K}^V$ is the quantity of each capital variety.

Inserting equation (A.7) into equation (A.3) gives the following expression for the price index (user cost index) of the machinery capital composite

$$\text{(A.9)}\; P^K = \left[\delta_{KM}\left(\frac{P^{KM}}{\tau}\right)^{(1-\sigma_K)} + (1-\delta_{KM})R^{\left(\frac{1-\sigma_K}{1-\sigma_{KV}}\right)}\left(\frac{\overline{P}^{KV}}{\tau}\right)^{(1-\sigma_K)}\right]^{\frac{1}{1-\sigma_K}} .$$

The factor share of capital varieties in the machinery capital composite is given by

$$\text{(A.10)}\; \frac{K^V}{K} = (1-\delta_{KM})R^{\left(\frac{1-\sigma_K}{1-\sigma_{KV}}\right)}\left(\frac{\overline{P}^{KV}/\tau}{P^K}\right)^{-\sigma_K} .$$

The corresponding factor share of other machinery in the machinery capital composite is given by

$$\text{(A.11)}\; \frac{K^M}{K} = \delta_{KM}\left(\frac{P^{KM}/\tau}{P^K}\right)^{-\sigma_K} .$$

The gross investment in capital variety i , J_i^{KV} , (equal to the deliveries of capital variety i to the domestic market) is given by

$$\text{(A.12)}\; J_i^{KV} = \dot{K}_i^V + \delta K_i^V = X_{Ki}^H .$$

A.2. Derivation of the expression for the present value of the firm
The present value of the representative firm is given by

$$(A.13)\ V_0 = \int_0^{\infty} e^{-rt}\left(\pi_t - P_t^J J_t\right)dt$$

π is operating profit given in equation (2) and $J = \dot{K} + \delta K$ is gross investment. In addition, we have the following transversality condition

$$\lim_{t\to\infty} e^{-rt} P_t^J K_t \to 0 .$$

Integration (by parts) of equation (A.13) can be done as follows

$$(A.14)\ \int_0^{\infty} e^{-rt} P_t^J J_t dt = \int_0^{\infty} e^{-rt} P_t^J \left(\dot{K} + \delta K_t\right)dt .$$

Using the formula for partly integration, we have

$$(A.15)\ \int_0^{\infty} e^{-rt} P_t^J \dot{K} dt = \Big|_0^{\infty} e^{-rt} P_t^J K_t - \int_0^{\infty} \left[e^{-rt}(-r) P_t^J K_t + e^{-rt} \dot{P}^J K_t\right]dt .$$

Using the transversality condition $\lim_{t\to\infty} e^{-rt} P_t^J K_t \to 0$, (A.15) can be written as

$$(A.15')\ \int_0^{\infty} e^{-rt} P_t^J \dot{K} dt = -P_0^J K_0 - \int_0^{\infty} \left[e^{-rt}(-r) P_t^J K_t + e^{-rt} \dot{P}^J K_t\right]dt .$$

Inserting (A.15') in (A.14) gives

(A.14')

$$\int_0^{\infty} e^{-rt} P_t^J J_t dt = -P_0^J K_0 + \int_0^{\infty} e^{-rt} K_t \left[r P_t^J + \delta P_t^J - \dot{P}^J\right]dt = -P_0^J K_0 + \int_0^{\infty} e^{-rt} P_t^K K_t dt$$

.

$P_t^K = P_t^J (r + \delta) - \dot{P}^J$ denotes the user cost index of capital.

Inserting equation (A.14') into equation (A.13) gives the following expression for the present value of the firm

$$(A.15)\ V_0 = \int_0^{\infty} e^{-rt}\left(\pi_t - P_t^K K_t\right)dt + P_0^J K_0 .$$

Appendix B

Practical implementation and calibration issues

B.1. Implementation of the entry condition in the capital varieties industries
The entry condition for the representative firm in either of the capital varieties industries is given by equation (21). This condition can be rewritten in discrete time and for the random point of time, *T*, as

$$\text{(B.1)} \quad P_{RT}^{H} = \sum_{t=T}^{\infty} \frac{1}{(1+r)^{t-T}} \overline{\pi}_t^{'} .$$

Due to the small, open economy assumption, the interest rate *r* is exogenous. It is assumed constant along the whole simulation path.

Along a stationary path, the profit is constant, which implies that the the price of a new patent is also constant. The entry condition can then be written as (using the formula for a geometric row)

$$\text{(B.2)} \quad P_{R}^{H} = \left(\frac{1+r}{r}\right)\overline{\pi}'$$

In each (random) time period, *T*, there will be entry of new firms until the discounted value of the new firm's profit is equal to the price of the new patent. The entry condition for the representative firm in period *T* can be approximated by the following equation:

$$\text{(B.3)} \quad P_{RT}^{H} = ENT_T\left(\frac{1+r}{r}\right)\overline{\pi}_T^{'} .$$

ENT_T is a correction variable that takes into account that $\overline{\pi}_t^{'}$ is not constant and equal to $\overline{\pi}_T^{'}$ in future periods. To find the value for the correction variable ENT_T, we define a help variable $BENT_T$ for each period:

$$\text{(B.4)} \quad BENT_T = \frac{\sum_{t=T}^{\infty}\left(\left(\frac{1}{(1+r)^{(t-T)}}\right)\overline{\pi}'_t\right)}{\left(\frac{1+r}{r}\right)\overline{\pi}'_T}$$

$BENT_T$ measures the relation between the present value of the varying profit from period *T* onward and the present value of the profit if the profit was constant from period *T* onward. If $ENT_T=BENT_T$ in (B.3), then (B.3) would be identical to (B.1) and thus hold as the true entry condition for period *T*.

In the numerical model, equation (B.3) is implemented. We use the following iteration procedure for determining the *ENT* values that yield the true entry conditions:

1. The model is simulated with a random, exogenous value for ENT_T (e.g. $ENT_T=1$ in every time period, including the transition).
2. $BENT_T$ for each period is calculated recursively, and we check whether the value for $BENT_T$ deviates from the used value, ENT_T .
3. If the value $1\text{-}BENT_T/ENT_T$ is larger than a sufficiently small margin, we set $ENT_T=BENT_T$, and the iteration procedure is repeated from step 1 to step 3.
4. The solution has been found when $1\text{-}BENT_T/ENT_T$ is sufficiently small.

B.2. Calibration of the initial numbers of capital variety firms and patent stocks

We assume decreasing returns to scale in production within each of the firms in the industries producing capital varieties, as well as for the industries as wholes. Since all firms in the respective industry are equal and produce the same amounts, we assume that each industry has one representative firm in the base year. For both the general and the environmental varieties we have $X_{Ki}^{H} = X_{K}^{H}$ and $X_{Ki}^{W} = X_{K}^{W}$, where X_{K}^{H} and X_{K}^{W} are the industry's deliveries to the domestic and the export market, respectively. This implies that we can transform the number of firms/varieties within an industry into the following index that equals 1 in the base year:

(B.5) $$\gamma_{Rt} = \frac{R_{t-1} + X_{Rt}^{H}}{R_0}$$

R_0 is the base year number of capital varieties, which equals the stock of accumulated patents (knowledge base) for the respective type of varieties.

By indexing both stocks (general and environmental) to unity in the base year, an equal growth in the knowledge stocks gives the same productivity increase for general and environmental technology, both in the use of capital varieties and in the production of new patents (i.e. in the two contexts that the knowledge stock index appears in the model). By indexing the knowledge stocks to the same value, we have implicitly assumed that the maturity of the technologies does not matter, and the gains from new patents are the same in the two technologies.

The (un-indexed) levels of the knowledge stocks in the base year, the R_0's, are calibrated in order to meet two criteria. The general stock is set so that the share of total factor productivity growth stemming from domestic innovation processes in the BAU path agrees with empirical findings (see section 3.2). The environmental stock is set to obtain the same growth rate as in the general knowledge stock, when the two gas power industries demand equal amounts of capital varieties. Since it is assumed that the maturity of technology does not matter for productivity, it is also reasonable to assume that the productivity of the CCS technology improves by the same rate as the productivity in gas power production without CCS, given equal uses of capital varieties and, thus, equal demands for R&D services.[25]

The entry condition (equation (B.3)) determines the number of new varieties (new firms) in the capital varieties industry, which is equal to the production of new patents in the R&D industry in the period. The entry condition only applies to the new firms entering the capital varieties industry in each period. The only profit to be included in the entry condition is the share of the total industry's profit that stems from these new (representative) firms. Therefore, both the entry condition and the cost functions for the capital varieties industry must be formulated at the representative firm level. We define output delivered to the home market for the representative firm as $\frac{X_{K}^{H}}{\gamma_{R}}$ and correspondingly output delivered to the export

[25] We use a two-stage loop of simulations to set the environmental knowledge stock:
1. Subsidize gas power with CCS until equal demands for capital varieties are obtained in the two gas power industries.
2. Change the environmental knowledge stock in the base year. If productivity growth is too low in environmental technology, decrease the base year knowledge stock. A reduction in the stock gives higher productivity growth, since new patents have a relatively larger impact on a small stock. Since the stocks are indexed to 1 in the base year, a lower stock does not give lower productivity in the base year.

market for the representative firm as $\frac{X_K^W}{\gamma_R}$. The cost functions that determine the use of inputs in the industry is aggregated over the number of firms, i.e.

(B.6) $$C_K^H = c\left(\frac{X_K^H}{\gamma_R}\right)^{1/s}\gamma_R$$

(B.7) $$C_K^W = c\left(\frac{X_K^W}{\gamma_R}\right)^{1/s}\gamma_R$$

C_K^H and C_K^W is the total production costs for deliveries to the domestic and export market, respectively.

By using the expressions for deliveries from the representative firm, together with equations (B.5)-(B.7) and the maximand expression given in (7"), the entry condition in (B.3) can be written as

(B.8) $$\left(\frac{1+r}{r}\right)ENT\left[P_K^H\frac{X_K^H}{\gamma_R}+P_K^W\frac{X_K^W}{\gamma_R}-c\left(\frac{X_K^H}{\gamma_R}\right)^{1/s}-c\left(\frac{X_K^W}{\gamma_R}\right)^{1/s}\right]\frac{1}{R_{.0}}=P_R^H.$$

This entry condition is implemented in the numerical CGE model.

The first-order conditions for profit maximization is given as

(B.9) $$P_K^H = m_K\frac{c}{s}\left(\frac{X_K^H}{\gamma_R}\right)^{\left(\frac{1}{s}-1\right)}$$

(B.10) $$P_K^W = \frac{c}{s}\left(\frac{X_K^W}{\gamma_R}\right)^{\left(\frac{1}{s}-1\right)}.$$

Equation (B.9) is the first order condition for deliveries to the home market and equation (B.10) is the first order condition for deliveries to the export market.

B.3. Data and calibration of output and input in the R&D industries

The National Accounts have no separate data for R&D, neither as input into production processes, nor as output from industries. We have calibrated input and output data for R&D by using input factors (wage costs, other operational costs[26], and investment costs) from the R&D Statistics[27] for the year 2002. We calculate the shares of R&D related activity from the input factors for all the industries in the model. These shares of input are then reallocated to a separate R&D industry. As a first step, we construct one R&D industry, only, which is split at a later stage. [28]

[26] The R&D services purchased by firms from national institutions, universities, and foreign sources are all added into the operational costs in the respective sectors.

[27] The R&D Statistics is based on surveys from a selection of firms and other entities engaged in R&D. From this, the total R&D input and output in the Norwegian economy are estimated at the sector level. The sectors are in line with the Standard Industrial Classification (SN94). The R&D Statistics are produced by Statistics Norway. More information can be found on: www.ssb.no -> StatBank -> Industrial Activities -> Technological Indicators -> Research and Development in Norwegian Enterprises and Statistics Norway (2004).

[28] For the splitting procedure in step two, confer section 3.1.

Thus, in this first step, we do not distinguish between general and environmental R&D, or the respective categories of capital varieties production and investment. We label the merged R&D industry *38* and the merged capital varieties industry *46* in the following. (When we refer to the list of production industries *PS* in appendix C, industry 38 represents both 38A (general R&D) and 38B (environmental R&D), while industry 46 represents 46A (general capital varieties) and 46B (environmental capital varieties)).

Table B.1 R&D expenditure by Norwegian firms in 2002, in mill NOK, aggregated from the R&D Statistics.

ITC industry	Wage costs	Other operational costs	Capital investments	Total
20	3270.5	2267.7	571.9	6110.1
30	942.8	778.9	181.3	1903.0
32	14.3	13.9	7.6	35.8
33	264.9	157.5	48.2	470.6
45=(46+47)	2224.5	1236.4	204.3	3665.2
50	155.1	103.7	70.8	329.6
55	164.8	45.9	31.0	241.7
60	452.4	835.9	28.3	1316.6
71	70.2	70.7	16.5	157.4
Total	7559.5	5510.6	1159.9	14230.0

We let capital letters denote observed National Accounts variables in the base year and small letters denote calculated variables and define the following variables:

X = Gross production
H = Total material inputs
V = Various material inputs
F = Fuel oils etc.
FT = Gasoline etc.
TP = Polluting transport services
TN = Non-polluting transport services
E = Electricity
Q = Gross product
FD = Capital depreciation
YT = Net indirect taxes
YW = Wage cost
YE = Operating surplus
δ_{ij} = Share of R&D related input in each industry, industry j, input factor i.

For each private industry except the R&D industry (i.e. $j \in PS \setminus \{38\}$, where PS is the list of production sectors given in appendix C), we have the following relationships:

$$ye_j = (1-\delta_{YEj})YE_j$$
$$+yw_j = (1-\delta_{YWj})YW_j$$
$$+yt_j = (1-\delta_{YTj})YT_j$$
$$+fd_j = (1-\delta_{FDj})FD_j$$
$$=q_j$$
$$+v_j = (1-\delta_{Vj})V_j$$
$$+ft_j = (1-\delta_{FTj})FT_j$$
$$+f_j = (1-\delta_{Fj})F_j$$
$$+tp_j = (1-\delta_{TPj})TP_j$$
$$+tn_j = (1-\delta_{TNj})TN_j$$
$$+e_j = (1-\delta_{Ej})E_j$$
$$=x_j$$

This implies that the calculated gross production is smaller than the observed (National Accounts) gross production, $x_j < X_j$ for $j \in PS \backslash \{38\}$.

For the R&D industry ($j=38$) we have the following relationships:

$$ye_{38} = \sum_{j \in PS \backslash \{38\}} \delta_{YEj} YE_j$$

$$+ yw_{38} = \sum_{j \in PS \backslash \{38\}} \delta_{YWj} YW_j$$

$$+ yt_{38} = \sum_{j \in PS \backslash \{38\}} \delta_{YTj} YT_j$$

$$+ fd_{38} = \sum_{j \in PS \backslash \{38\}} \delta_{FDj} FD_j$$

$$= q_{38}$$

$$+ V_{38} = \sum_{j \in PS \backslash \{38\}} \delta_{Vj} V_j$$

$$+ ft_{38} = \sum_{j \in PS \backslash \{38\}} \delta_{FTj} FT_j$$

$$+ f_{38} = \sum_{j \in PS \backslash \{38\}} \delta_{Fj} F_j$$

$$+ tp_{38} = \sum_{j \in PS \backslash \{38\}} \delta_{TPj} TP_j$$

$$+ tn_{38} = \sum_{j \in PS \backslash \{38\}} \delta_{TNj} TN_j$$

$$+ e_{38} = \sum_{j \in PS \backslash \{38\}} \delta_{Ej} E_j$$

$$= x_{38}$$

All input factors summarize to the aggregated observed National Accounts numbers.

For $j \in PS \backslash \{38\}$ we define the following correction term
$X_j - x_j = mv_j$.
This implies that mv_j is total input in R&D related activity in industry j in the base year. Summarizing gross production over all industries (except industry 38) gives the following equation:

$$\text{(B.11)} \quad \sum_{j \in PS \backslash \{38\}} X_j = \sum_{j \in PS \backslash \{38\}} x_j + \sum_{j \in PS \backslash \{38\}} mv_j \; .$$

We then add the gross production in industry 38 on both sides in equation (B.11). Since $X_{38}=0$ and $x_{38}>0$, we have the following inequality:

$$\sum_{j \in PS \backslash \{38\}} X_j + X_{38} < \sum_{j \in PS \backslash \{38\}} x_j + \sum_{j \in PS \backslash \{38\}} mv_j + x_{38} = \bar{x}_{46} \; .$$

By assumption, the gross production in industry 38 is only delivered to industry 46, and we define the variable *sc46* as input of commodity 38 in the production of product 46, i.e. $sc_{46}=x_{38}$. In the base year, this calculated production in industry 46, $\bar{x}_{46}$, is delivered as an input mv_j to all other industries. This ensures that in the base year, inputs originally drawn out of each industry according to their resources devoted to R&D, are eventually returned. These correction flows can be interpreted as base year deliveries of patent-based, technological services from the capital varieties industry to the users of technology. In the numerical simulations, the mv_j terms are gradually phased out. In the base year calibration we have:

$$sc_{46} = x_{38} = \sum_{j \in PS \backslash \{38\}} mv_j \ .$$

Total *calculated* gross production in the economy is then given by

$$x = X + x_{38} + sc_{46} \ .$$

The National Accounts material input, *H,* is given by

$$H = V + FT + F + TP + TN + E \ .$$

Total *calculated* material input *h* is given by

$$h = V + FT + F + TP + TN + E + \sum_j mv_j + sc_{46} \ .$$

h can then be written as

$$h = H + x_{38} + sc_{46} \ .$$

By using the expressions for *x* and *h* we can show that calculated gross product *q* equals the base year National Accounts gross product Q.

$$x - h = Q = q = \sum_j q_j$$

To summarize, by our calibration method we have introduced an R&D industry (industry 38) that only delivers production to the capital varieties industry, industry 46. The calibration is carried out at the industry level, and the product classification and levels do not have to be corrected. The method implies that the National Accounts' description of product *x* activity in the base year is unchanged.

B.4. The price of electricity and the production costs of gas power

The cost structure in the model gives a producer price of electricity delivered from the CCS gas power industry of 0.075 US$/kWh in 2002. From the gas power industry without CCS the price is 0.047 US$/kWh. The producer price of electricity delivered to the market in the calibrated year is 0.03 US$/kWh. To keep production levels in the gas power industries at the calibrated level, their producer prices are subsidized in 2002 with 0.045 US$/kWh and 0.017 US$/kWh, for production with and without CCS, respectively. These subsidies are phased out during the first 10 years. This is compatible with positive and increasing output from the two gas power industries along the path, as the demand for electricity is increasing.

The costs presented here are sensitive to the price of gas. The model is calibrated to a gas price of 0.15 US$/$Sm^3$ in 2002. For a higher gas price, both the gas power industries face higher costs. Though, the cost difference is smaller for a higher gas price, since the gas factor input share is smaller for the CCS plants, confer section 3.1 for more details on cost shares in gas power production with CCS.

Appendix C

Sector/Activity Lists

List index

VA	List of commodities
PSK	List of all production sectors
PS	Production industries
PP	Private production
PO	Government production
KORR	Sectors collecting indirect taxes
PA	List of production activities
PF	List of production factors
PSV	List of input activities
CP	List of consumption sectors, expenditure, private households
G	List of consumption sectors, expenditure, public sector
JR	List of real capital by type
JA	List of investment activities
JS	List of investment sectors
AVG	List of Indirect Taxes and Transfers by Type
PX	Indirect Volume Taxes Collected from Producers
VX	Indirect Volume Taxes Collected from Wholesale and Retail Trade
PV	*Ad Valorem* Taxes Collected From Producers
VV	*Ad Valorem* Taxes Collected from Wholesale and Retail Trade
SPX	Indirect Volume Subsidies Directed to Producers
SVX	Indirect Volume Subsidies Directed to Wholesale and Retail Trade
SPV	*Ad Valorem* Subsidies Directed to Producers

Commodities (VA)

VA Code	Full Name (Norwegian name in parenthesis)	Model Database Commodity Code	National Accounts Commodity Code
Commodities "Non-competing import"			
00	Non-competing import (Ikke-konkurrerende import)	004, 005, 006, 007, 008, 019, 149, 349, 360, 369	005045-005065, 011140,011150, 011170-011191, 011310-011322,011331-011334, 158310, 143011,143013, 293100, 353030, 353053, 341020, 351110
36	Direct purchases abroad by residents household/Foreign residents consumption in Norway (Nordmenns konsum i utlandet/ utlendingers konsum i Norge)	009, 010	005066-005069, 005076-005079
Commodities - Private production			
24	Other commodities and services (Andre produkter og tjenester)	011, 012, 021, 022, 051, 052, 101, 114, 131, 151-160, 170, 180, 190, 201, 202, 220, 231,233, 239, 246, 249, 250, 265, 269, 368, 406, 529, 550, 653, 658, 670, 661, 662, 663, 664, 702 ,703, 800, 851, 852, 853, 900, 901, 902, 950	000379, 011111-011130, 011160, 011192-011224, 011323-011329, 012110-012530, 014001-014005, 015010, 020111-020210, 050011-050050, 050120, 060001-60007, 070001-070006, 101010-103010, 120010-132016,141111, 142210, 143012, 143019-205210, 221110-231000, 232003, 232009, 232010, 232021- 233000, 243010-246640, 251111-268216, 361111-372010, 402000, 403000, 502010, 502030, 527100-555000, 651111-671310, 672010, 701000-702012, 703000, 711010-713411, 714010-726010, 731000-742040, 743010, 744010, 745000, 746010-748410, 801010, 802000, 803010, 804110, 804200, 851110, 851210, 851310, 851413-851419, 852011, 852012, 853110, 853211-853213, 854010, 900010, 900020, 911000-913000, 921110-921130, 921210-923122, 923300-925000, 926000, 927111-927210, 930110-950010
30	Power intensive manufacturers (Kraftintensive industriprodukter)	210, 241, 248, 270	211110-211260, 212110-212515, 241110-241710, 242010, 247000, 271010-275000
32	Polluting transport services (Forurensende transporttjenester)	603, 606, 612, 620, 631, 632, 633	602123, 602130, 602210, 602310-602430, 611011-611025, 611028, 611031, 611032, 621010-622030, 631110, 631210, 632110-632126, 632211, 632215, 632310, 633011, 633012, 634012, 634011, 634020
33	Non-polluting transport services (Ikke-forurensende transporttjenester)	601,605, 640	601010-601025, 602110, 602124, 641111-642030
38A* 38B*	Patents from general research and development (Patenter fra generell forskning og utvikling) Patents from environmental research and development (Patenter fra miljørelatert forskning og utvikling)		
40	Gasoline etc. (Transportoljer)	232, 235, 236	232001, 232002, 232004, 232017, 232018
42	Fuel oils etc (Fyringsoljer)	234, 237	232008, 232014, 232005, 232015

46A**	Capital varieties of machinery for investment activity 52A and export. (Verkstedsprodukter, leveranser til investeringsaktivitet 52A og eksport)	300, 280, 297, 298, 311, 318, 320, 330, 340, 356, 358, 391	000371-000375, 000384,000390, 000990, 281110-292470, 293210-295620, 296012-297210, 299992, 300110-311060, 311092, 312010-341010, 341030-343030, 351143, 351144, 351150, 351160, 351191-351194, 351210, 351290, 352010-352040, 352090, 353010, 353020, 353091, 354110-355010
46B**	Capital varieties of CCS technology for investment activity 52B and export. (Verkstedsprodukter, leveranser til investeringsaktivitet 52B og eksport)		
47**	Other machinery, including metal products, equipment, and repair. (Andre verkstedprodukter, leiearbeid og reparasjoner)		
50	Ships, oil rigs and oil production platforms (Skip, borerigger og oljeplattformer)	351, 352, 353, 354	351121-351133, 351141, 351142,351921- 351931, 351941
55	Construction products (Bygg og anleggsprodukter)	392, 450	000382, 000383, 000385,111050,401051, 401052, 451100-455000,601040,601045, 631045,642040,926010
62	Ocean transport, oil and gas exploration and drilling (Utenriks sjøfart og tjenester tilknyttet utvinning av råolje og naturgass)	112, 611	112011,112012,611013,611014,611022, 611029,611033,713412
66	Crude oil (Råolje)	111	111010
67	Natural gas (Naturgass)	113, 607	111020, 603013, 603014
69	Oil and gas pipeline transport (Olje- og gassrørtransport)	608	603011, 603012
70*,***	Electric Power	411-416	401011-401016, 401035-401040
74***	Electricity distribution and transmission services (Overføring og distribusjon)		
81	Wholesale and retail trade (Varehandel)	509, 609	000350,501000,501002,505000,510100, 510900,521100,601029,602429,611027, 634019, 634029
83	Dwelling services (Boligtjenester, egen bolig)	704, 705, 707	702011, 704000, 705000

Commodities - Government production

90	Paid fees, central and local government, (Innbetalte gebyrer, offentlig forvaltning)	419, 637, 747, 757, 807, 809, 8519, 8529, 8539, 857, 8527, 909, 917, 919	410090, 632271-632275, 632370, 671370, 702071-702092, 730070, 742070,743070, 745070, 751171-751175, 751191-751195, 751271- 751274, 751291-751294, 751371-751378, 751471-751398, 752171-752173, 752271, 752272, 752371, 752372, 752471, 752472, 752570, 752590, 753070, 801070, 801090, 802070, 802090, 803070, 804270, 804290, 851171, 851172, 851191, 851192, 851270, 851290, 851390, 851499, 852070, 852090, 853170, 853190, 853273, 853291, 853293, 854090, 900091-900092, 921170, 923170, 923190, 925170, 925190, 925270, 925290, 925370, 926090, 927290
90G	Consumption and depreciation of capital, Central and local government (Konsum og kapitalslitsprodukter, offentlig forvaltning)	636, 6361, 746, 7461, 756, 7561, 806, 8061, 808, 8081, 8518, 85181, 8526, 85261, 8538, 856, 8561, 85281, 908, 9081, 916, 9161	601060, 601061, 631061, 632061, 632261-632265, 632281-632285, 632360, 671360, 730060, 730061, 742060, 742061,743060, 745060, 745061, 751061-751165, 751181-751185, 751261-751264, 751281-751284, 751361-751368, 751381- 751388, 751461, 751462, 752061, 752161-752163, 752261, 752262, 752361,752362, 752461, 752462, 752560, 752580, 753060, 800061, 800081, 801060, 801080, 802060, 802080, 803060, 804260, 804280, 851061, 851081, 851161, 851162, 851181, 851182, 851260, 851280, 851380, 851489, 852060, 852061, 852080, 852081, 853061, 853081, 853160, 853180, 853263, 853281, 853283, 854080, 854081, 921061, 921081, 921160, 923160, 923180, 925160, 925180, 925260, 925280, 925360, 926080, 927280

* Not based on National Account aggregation. The base year calculations are described in section 2.1.2 and appendix B.3.
** The principles for the splitting into 46A, 46B and 47 are described in section 3.1.
*** Electric power is an aggregate of hydropower (701), gas power without CCS (704) and gaspower with CCS (705). An aggregate of Electric power and Electricity distribution and transmission services also appears in the model, denoted 71. See section 2.1.2 for the structure of the electricity production.

Production sectors (PSK)
PSK
List of all production sectors
PSK = PS∪KORR = PP∪PO∪KORR
PS Production industries
KORR Sectors collecting indirect taxes
PP Private production
PO Government production

PSK Code	**Full Name** (Norwegian name in parenthesis)	**Model Database Sector Code**	**National Accounts Sector Code**
PS	**Production industries**		
PP	**Private production**		**Type of account 22+23+26**
20	Production of other commodities and services (Produksjon av andre varer og tjenester)	22011, 22051, 22950, 23011, 23020, 23051, 23052, 23101, 23131, 23151-23160, 23170, 23180, 23190, 23200, 23220, 23249, 23250, 23265, 23269, 23368, 23406, 23509, 23529, 23550, 23653, 23658, 23661-23663, 23669, 23700, 23702, 23800, 23851, 23852, 23853, 23859, 23900, 23901, 26800, 26851-26854, 26901	22010, 22015, 22051, 22950, 23010,23014, 23020, 23051, 23052, 23100, 23120,23130, 23140, 23151-23160, 23170, 23180, 23190, 23201-23204, 23221-23223, 23243-23246, 23250-23266,23361-23363, 23371, 23372, 23404, 23405, 23501-23553, 23651-23659, 23661-23670, 23700-23730, 23741-23748, 23800, 23851-23854, 23859, 23900-23950, 26800, 26851-26854, 26910-26926
40	Petroleum refining (Raffinering av jordolje)	23231,23232	23231,23232
30	Power intensive manufacturing (Kraftintensiv industri)	23210, 23248, 23270	23211-23213, 23241, 23242, 23247, 23271-23275
32	Polluting transport (Innenriks samferdsel, forurensende transport)	23603, 23606, 23613, 23620, 23631, 23632, 23633	23602-23604, 23613, 23620, 23631, 23632, 23633
33	Non-polluting transport, (Innenriks samferdsel, bane- og teletransport)	23601, 23605, 23640	23601, 23605, 23641, 23642
38A*	General research and development (Generell forskning og utvikling)		
38B*	Environmental research and development (Miljørelatert forskning og utvikling)		

46A**	Production of capital varieties of machinery for investment activity 52A and export. (Produksjon av verkstedsprodukter, leveranser til investeringsaktivitet 52A og eksport)	300, 280, 297, 298, 311, 318, 320, 330, 340, 356, 358, 391	000371-000375, 000384,000390, 000990, 281110-292470, 293210-295620, 296012-297210, 299992, 300110-311060, 311092, 312010-341010, 341030-343030, 351143, 351144, 351150, 351160, 351191-351194, 351210, 351290, 352010-352040, 352090, 353010, 353020, 353091, 354110-355010
46B**	Production of capital varieties of CCS technology for investment activity 52B and export. (Verkstedsprodukter, leveranser til investeringsaktivitet 52B og eksport)		
47**	Production of other machinery, including metal products, equipment, and repair. (Andre verkstedprodukter, leiearbeid og reparasjoner)		
50	Ships, oil rigs and oil production platforms (Skip, borerigger og oljeplattformer)	351, 352, 353, 354	351121-351133, 351141, 351142, 351921-351931, 351941
55	Construction, excl. oil well drilling (Bygg og anlegg)	22450, 23450	22452,22454, 23451-23455
60	Ocean transport, oil and gas exploration and drilling (Utenriks sjøfart, olje- og gassvirksomhet)	23111, 23112, 23608, 23611	23111, 23112, 23608, 23611
701	Generation of hydropower (Vannkraftproduksjon)	23401	23401
704*,***	Generation of gas power without CCS (Gasskraftproduksjon uten CCS)		
705*,***	Generation of gas power with CCS (Gasskraftproduksjon med CCS)		
74	Power distribution and transmission (Overføring og distribusjon)	23402,23403	23402,23403
83	Dwelling services (Boligtjenester)	22704, 22705, 23704	22704, 22705, 23704
PO	**Government production**		**Type of account 24+25**
90	Central and local government production (Offentlig forvaltning)	24453-24901, 25453-25901	24453-24921, 25453-25921
KORR	**Sectors collecting indirect taxes**		**Type of account 29**
59	Collection of value added tax (Merverdiavgift)	2951	29501
52	Collection of investment levy (Investeringsavgift)	2952	29502
53	Production taxes (Produktskatter)	2953	29503
54	Production subsidies (Produktsubsidier)	2954	29504

51	Colelction of customs duty (Toll)	2955	29505	
57	Production taxes, import (Produktskatter, import)	2956	29506	
58	Statistical deviation	2958	29900	

* Not based on National Account aggregation. The base year calculations are described in section 2.1.2 and appendix B.3.
** The principles for the splitting into 46A, 46B and 47 are described in section 3.1.
*** 704 and 705 constitute an aggreagate 702, which also appears in the model.

Production Activities (PA)
When there is only one activity in the industry the activity code is the same as the main product code. (ref. 1. column)

PA Code	Full Name (Norwegian name in parenthesis)	Model Database Activity Code	Main Commodity in the Activity (VA Codes)
	Private production activities		
4040	Refining of transport oils (Raffinering av transportoljer)	23232232, 23232235, 23232236	**40:** Gasoline etc.
4099	Refining of fuel oils etc. (Raffinering av fyringsoljer)	23232234, 23232237	**42:** Fuel Oils etc .
2081	Wholesale and retail trade (Varehandel)	23509	**81:** Wholesale and retail trade
2099	Other production of commodities and services (Øvrig produksjon i sektoren andre varer og tjenester)	22051, 22011011, 22011012, 22950, 23011011, 23011012, 23020021, 23020022, 23051, 23052,23151159-23190999, 23101, 23131,23200201, 23200202, 23220, 23231, 23232999, 23249246, 23249249, 23250, 23269, 23368, 23406, 23529, 23550, 23653653-23669999, 23700, 23702, 23800-23859, 23900, 23901, 26800, 26851, 26853, 26854, 26901	**24:** Other products and services
30	Power intensive manufacturing (Kraftintensiv industri)	23210, 23248241, 23248248, 23270	**30:** Power intensive manufacturers
32	Polluting transport (Innenriks samferdsel, forurensende transport)	23603, 23606, 23613, 23620, 23631, 23632, 23633	**32:** Polluting transport services
33	Non-polluting transport, (Innenriks samferdsel, bane- og teletransport)	23601, 23605, 23640	**33:** Non-polluting transport services
38A*	General research and development (Generell forskning og utvikling)		**38A:** Patents from general research and development
38B*	Environmental research and development (Miljørelatert forskning og utvikling)		**38B:** Patents from environmental research and development

46A**	Production of capital varieties of machinery for investment activity 52A and export. (Produksjon av verkstedsprodukter, leveranser til investeringsaktivitet 52A og eksport)	300, 280, 297, 298, 311, 318, 320, 330, 340, 356, 358, 391	**46A:** Capital varieties of machinery for investment activity 52A and export
46B**	Production of capital varieties of CCS technology for investment activity 52B and export. (Verkstedsprodukter, leveranser til investeringsaktivitet 52B og eksport)		**46B:** Capital varieties of CCS technology for investment activity 52B and export
47**	Production of other machinery, including metal products, equipment, and repair. (Andre verkstedprodukter, leiearbeid og reparasjoner)		**47:** Other machinery, including metal products, equipment, and repair
50	Production of ships and oil platforms (Produksjon av skip og oljeplattformer)	23351351, 23351998, 23351999, 23352351, 23352998, 23352999	**50:** Ships, drilling rigs and oil platforms
55	Construction (Bygg og anlegg)	22450, 23450	**55:** Construction
6066	Production of crude Oil (Produksjon av råolje)	23111111	**66:** Crude oil
6067	Natural gas (Natural Gas)	23111113	**67:** Natural gas
6069	Pipeline transport (Rørtransport)	23608608	**69:** Oil and gas pipeline transport
6099	Ocean transport and other output from production of oil and gas (Utenriks sjøfart og øvrig produksjon tilknyttet utvinning av råolje og naturgass)	23111238, 23111391, 23111999, 23112, 23608391, 23608999, 23611	**62:** Ocean transport, oil and gas exploration and drilling
70170	Generation of hydropower (Vannkraftproduksjon)	23401411,23401412, 23401413,23401415, 23401416	**70:** Electric power
70199	Other output in generation of power (Annen produksjon i kraftsektoren)	23401999	**47,55,85**
704*	Generation of gas power without CCS (Gasskraftproduksjon uten CCS)		**70:** Electric power
705*	Generation of gas power with CCS (Gasskraftproduksjon med CCS)		**70:** Electric power

7474	Power distribution and transmission (Overføring og distribusjon av kraft)	23402411,23402412, 23402413,23402415, 23402416,23403411, 23403412,23403413, 23403415,23403416	**74:** Electricity distribution and transmission
7499	Other output in power transmission and distribution (Annen produksjon i overførings og distribusjonssektoren)	23402999,23403999	**47,55,85**
83	Dwelling services (Boligtjenester)	22704, 22705, 23704	**83:** Dwelling services
	Central and local government production activities		
90	Central and local government (Offentlig forvaltning)	24453-24901, 25453-25901	**90:** Paid fees, Central and Local government

* Not based on National Account aggregation. The base year calculations are described in section 2.1.2 and appendix B.3.
** The principles for the splitting into 46A, 46B and 47 are described in section 3.1.

Production Input factors (PF)

PF Code	Name	Commodity or Capital Code
	Product input (Produktinnsats)	**Product code ∈ VA**
E	Electricity (Elektrisk kraft)	71
F	Fuel oils etc. (Fyringsoljer)	42
FT	Gasoline etc. (Transportoljer)	40
TN	Non-polluting transport services (Ikke-forurensende transport)	33
TP	Polluting transport services (Forurensende transport)	32
V	Various material inputs (Annen produktinnsats)	VA\{32,33,38,40,42,46,71, 69,67}
MV*	Patent-based technological input, correction flow (Vareinnsats, forskning og utvikling, korreksjonsledd)	46A, 46B
SC*	Sunk investments in patents (Kjøp av forskning og utvikling)	38
TG	Gas transport (Gasstransport)	69
NG	Natural gas (Naturgass)	67
	List of real capital by type	**Capital code ∈ JR**
KB	Dwellings, cottages and non-residential buildings etc. (Bygningskapital og anlegg)	11,12
KMO**	Other machinery, incl. oil drilling rigs and oil platforms (Andre maskiner, oljeutvinningsplattformer, oljeborerigger m.v.)	20,55,70
KMV**	Capital Varieties (Kapitalvarianter)	52A, 52B
KT	Cars (Biler)	30,40,80
	Labor	
L	Man hours (Timeverk)	

* Does not exist in the National Accounts. The base year calculations are described in appendix B.3.
** The split into *KMO* and *KMV* corresponds to the classification of machinery in the previous lists and of machinery investment activities in the JR list. Real capital type *KMV* consists of investment activities 52A and 52B. The remaining machinery investments (including activity 55) constitute *KMO*. See section 3.1.

Input activities (PSV)

PSV Code	Full Name (Norwegian name in parenthesis)	Material Input Activities (PF Codes)
	Input Activities	
	Private input activities	
20	Production of other commodities and services (Produksjon av andre varer og tjenester)	*F,FT,TN,TP,V,E,MV*
40	Petroleum refining (Raffinering av jordolje)	*F,FT,TN,TP,V,E,MV*
30	Power intensive manufacturing (Kraftintensiv industri)	*F,FT,TN,TP,V,E,MV*
32	Polluting transport (Innenriks samferdsel, forurensende transport)	*F,FT,TN,TP,V,E,MV*
33	Non-polluting transport, (Innenriks samferdsel, bane- og teletransport)	*F,FT,TN,TP,V,E,MV*
38A*	General research and development (Generell forskning og utvikling)	*F,FT,TN,TP,V,E*
38B*	Environmental research and development (Miljørelatert forskning og utvikling)	*F,FT,TN,TP,V,E*
46A**	Production of capital varieties of machinery for investment activity 52A and export. (Produksjon av verkstedsprodukter, leveranser til investeringsaktivitet 52A og eksport)	*F,FT,TN,TP,V,E,MV,SC*
46B**	Production of capital varieties of CCS technology for investment activity 52B and export. (Verkstedsprodukter, leveranser til investeringsaktivitet 52B og eksport)	*F,FT,TN,TP,V,E,MV,SC*
47**	Production of other machinery, including metal products, equipment, and repair. (Andre verkstedprodukter, leiearbeid og reparasjoner)	*F,FT,TN,TP,V,E,MV*
50	Ships, oil rigs and oil production platforms (Skip, borerigger og oljeplattformer)	*F,FT,TN,TP,V,E,MV*
55	Construction, excl. oil well drilling (Bygg og anlegg)	*F,FT,TN,TP,V,E,MV*
60	Ocean transport, oil and gas exploration and drilling (Utenriks sjøfart, olje- og gassvirksomhet)	*F,FT,TN,TP,V,E,MV*
701	Generation of hydropower (Vannkraftproduksjon)	*F,FT,TN,TP,V,E,MV*
704***	Generation of gas power without CCS (Gasskraftproduksjon uten CCS)	*F,FT,TN,TP,V,E,TG,NG*
705***	Generation of gas power with CCS (Gasskraftproduksjon med CCS)	*F,FT,TN,TP,V,E,TG,NG*
74	Power distribution and transmission (overføring og distribusjon)	*F,FT,TN,TP,V,E,MV*
83	Dwelling services (Boligtjenester)	*TN,V,E*
	Government input activities	
90	Central and local government (Statlig og kommunal forvaltning)	*F,FT,TN,TP,V,E*

* Base year inputs in industry 38A and 38B consist of redistributed inputs from other industries. The procedure is described in section 3.1 and appendix B.3.
** The principles for the splitting into 46A, 46B and 47 are described in section 3.1.
*** Not based on National Account aggregation. The base year calculations are described in section 2.1.2.

Consumption sectors (CP)

CP Code	Full Name (Norwegian name in parenthesis)	Model Database Sector Code	National Accounts Sector Code
			Type of Account 61+68+69
10	Other goods and services (Andre varer og tjenester)	62A1, 62A21, 62A22, 62B11- 62B13, 62B2, 62B3, 62C1, 62C2, 62E11-E62, 62F3, 62F11, 62F13, 62G5, 62H2, 62I1- 62I6, 62J0, 62K0, 62L3- 62L6, 6640, 6662, 6671, 6694, 6696	A11-A22, B11-B31, C11-C22, E11-E61, F11-F31, H21, I11- I54, L12- L32, G23, G24, G36, I15-I61, J11-J51, K11-K21, L11-L71, 66F00, 66I40, 66J00, 66L41, 66L70
12	Electricity (Elektrisitet)	62D5	D51
13	Fuels (Brensler og fjernvarme)	62D52-62D54	D52-D54
14	Petrol and car maintenance (Driftsutgifter til egne transportmidler)	62G2, 62G3	G21, G22
30	Purchase of cars etc. (Kjøp av egne transportmidler)	62G1	G11,G12
32	Public transport, polluting (Offentlige transportmidler, fururensende transport)	62G311,62G313, 62G321, 62G323, 62G324	Part of 61G31 and 61G32
33	Public transport, non-polluting (Offentlige transportmidler, ikke-forurensende transport)	62G312, 62G322, 62H3	Part of 61G31 and 61G32 61H11, 61H31
50	Gross Rents (Bolig)	62D11-62D22, 62D3, 62D4	D11- D22, D31, D32,D41
66	Direct purchases abroad by resident households (Nordmenns konsum i utlandet)	62L8	L91
70	Foreigners consumption in Norway (Utlendingers konsum i Norge)	62L9	L92

Consumer expenditure, Central and Local Government (G)

G Code	Full Name (Norwegian name in parenthesis)	Model Database Sector Code	National Accounts Sector Code
			Type of Account 64+65
90	Consumer expenditure, Central and Local Government (Konsumutgifter, statlig og kommunal forvaltning)	6402, 6404, 6405, 6406, 6504, 6505, 6506	64A*- 64H*, 65A*- 65H*

Real capital by type (JR)

JR Code	Full Name (Norwegian name in parenthesis)	Model Database Sector Code	National Accounts Sector Code
			Type of Account 28
11	Dwellings, cottages, non-residential buildings, etc. (Bolig, fritids- og driftsbygg med mer.)	2810, 2820,2831, 2860	28111-28195, 28210-28270, 28301-28318, 28330-28348, 28610, 28650
12	Power constructions (Kraftanlegg)	28321, 28322, 28328	28321, 28322, 28328
20	Oil constructions etc (Oljeanlegg mv.)	2837, 2839, 2871	28370, 28378, 28390, 28398, 28710, 28718
30	Ships, fishing boats etc. (Skip, fiskebåter mv.)	2841	28410
40	Cars etc. (Biler mv.)	2843	28431-28434, 28440
80	Aircrafts and helicopters (Fly og helikoptre)	2842	28420
52A*	Capital varieties of machinery, domestically produced	2850, 2879, 2890	28510-28580, 28740-28790, 28990
52B*	Capital varieties of CCS technology, domestically produced		
55*	Other machinery (Andre maskiner mv. eksl. oljeplattformer)		
70	Oil Platforms, Oil Rigs and Ships (Oljeutvinnigsplattformer, oljeborerigger og skip)	2838	28380-28388

* The split into 52A, 52B and 55 is based on the classification of machinery in previous lists; see section 3.1. Investment activities 52A and 52B consist of commodities 46A and 46B, respectively, as well as shares of commodity 81 (according to the base year input-output data and relative sizes of 52A, 52B and 55).

Investment industries (JS)

JS Code	Full Name (Norwegian name in parenthesis)	Model Database Sector Code*	National Accounts Sector Code*
	Private investment industries		**Type of Account 82+83+86**
20	Production of other commodities and services (Produksjon av andre varer og tjenester)	83011, 83020, 83051,83052, 83101, 83131, 83151-83160, 83170, 83180, 83190,83200, 83220,83249, 83250, 83265, 83269,83368, 83406, 83509, 83529,83550, 83653, 83658, 83661-83663, 83669, 83700, 83702,83800, 83851, 83852, 83853,83859, 83900, 83901, 86800,86851-86854, 86901	83010, 83014, 83020, 83051,83052, 83100, 83120, 83130, 83140,83151-83160, 83170, 83180, 83190,83201-83204, 83221-83223, 83243-83246, 83250-83266,83361-83363, 83371, 83372, 83404,83405, 83501-83553,83651-83659, 83661-83670, 83700-83730, 83741-83748, 83800, 83851-83854, 83859,83900-83950, 86800, 86851-86854, 86910-86926
40	Petroleum refining (Raffinering av jordolje)	83231,83232	83231,83232
30	Power intensive manufacturing (Kraftintensiv industri)	83210, 83248, 83270	83211-83213, 83241, 83242, 83247, 83271-83275
32	Polluting transport (Innenriks samferdsel, forurensende transport)	83603, 83606, 83613, 83620, 83631, 83632, 83633	83602-83604, 83613, 83620, 83631, 83632, 83633
33	Non-polluting transport, (Innenriks samferdsel, bane- og teletransport)	83601, 83605, 83640	83601, 83605, 83641, 83642
38A*	General research and development (Generell forskning og utvikling)		
38B*	Environmental research and development (Miljørelatert forskning og utvikling)		
46A**	Production of capital varieties of machinery for investment activity 52A and export. (Produksjon av verkstedsprodukter, leveranser til investeringsaktivitet 52A og eksport)	300, 280, 297, 298, 311, 318, 320, 330, 340, 356, 358, 391	000371-000375, 000384,000390, 000990, 281110-292470, 293210-295620, 296012-297210, 299992, 300110-311060, 311092, 312010-341010, 341030-343030, 351143, 351144, 351150, 351160, 351191-351194, 351210, 351290, 352010-352040, 352090, 353010, 353020, 353091, 354110-355010
46B**	Production of capital varieties of CCS technology for investment activity 52B and export. (Verkstedsprodukter, leveranser til investeringsaktivitet 52B og eksport)		
47**	Production of other machinery, including metal products, equipment, and repair. (Andre verkstedprodukter, leiearbeid og reparasjoner)		
50	Ships, oil rigs and oil production platforms (Skip, borerigger og oljeplattformer)	83351, 83352	83351, 83352
55	Construction, excl. oil well drilling (Bygg og anlegg)	82450, 83450	82452, 83451-83455

60	Ocean transport, oil and gas exploration and drilling (Utenriks sjøfart, olje- og gassvirksomhet)	83111, 83112, 83608, 83611	83111, 83112, 83608, 83611
701	Generation of hydropower (Vannkraftproduksjon)	83401	83401
704***	Generation of gas power without CCS (Gasskraftproduksjon uten CCS)		
705***	Generation of gas power with CCS (Gasskraftproduksjon med CCS)		
74	Power distribution and transmission (Overføring og distribusjon)	83402,83403	83402,83403
83	Dwelling services (Boligtjenester)	82704	82704
	Central and local government investment industries		
90	Central and local government (Statlig og kommunal forvaltning)	84453-84901, 85453-85901	84453-84921, 85453-85921

* Base year investments in industry 38 consist of redistributed investments from other industries. The procedure is described in appendix B.3.
** The principles for the splitting into 46A, 46B and 47 are described in section 3.1.
*** Not based on National Account aggregation. The base year calculations are described in section 2.1.2.

Indirect Taxes and Subsidies (AVG)

AVG = PX∪SPX∪VX∪SVX∪PV∪SPV∪VV

PX Indirect Volume Taxes Collected from Producers

VX Indirect Volume Taxes Collected from Wholesale and Retail Trade

PV *Ad Valorem* Taxes Collected From Producers

VV *Ad Valorem* Taxes Collected from Wholesale and Retail Trade

SPX Indirect Volume Subsidies to Directed Producers

SVX Indirect Volume Subsidies to Directed a Wholesale and Retail Trade

SPV *Ad Valorem* Subsidies to to Directed Producers

AVG Code	**Full Name** (Norwegian name in parenthesis)
225	Value Added Tax (Merverdiavgift)
231	Investment levy on New Investment and Material Inputs (Investeringsavgift på nyinvesteringer og vareinnsats)
400	Customs Duty (Toll)
PX	**Indirect Volume Taxes Collected from Producers**
312	Excise Tax on Chocolate and Sweets (Sjokolade- og sukkeravgift)
321	Excise Tax on Non-Alcoholic Beverages (Avgift på alkoholfrie drikkevarer)
322	Excise Tax on Beer (Avgift på øl)
331	Excise Tax on Tobacco (Tobakksavgift)
342	Tax on Use of Electric Energy (Avgift på forbruk av elektrisk kraft)
344	Tax on Use of Coal and Coke (avgift på forbruk av kull og koks)
351	Tax on cars etc. (Avgift på transportmidler)
363	Tax on boat engines (Avgift på båtmotorer)
374	Tax on environmentally hazardous batteries (Avgift på miljøskadelige batterier)
368	Tax on packing, beer (Emballasjeavgift øl)
369	Tax on packing, non-alcoholic beverages (Emballasjeavgift på alkoholfrie drikkevarer)
376	Taxes in the telecom industry area (Avgifter i telesektoren)
377	Tax on Recording Tapes and Video Cassetttes (Avgift på lydbånd og videokasetter)
379	Tax on Charter Flights (Charteravgift)
VX	**Indirect Volume Taxes Collected from Wholesale and Retail Trade**
325	Tax on purchase of wine and spirits (Avgift på brennevin og vin, mengdeavgift)
343	Tax on mineral oil (Avgift på mineralolje opphører 1.1.1999)
345	Tax on autodiesel (Autodieselavgift)
346	Tax on mineral oil (Mineraloljeavgift (grunnavgift på fyringsolje))
347	Tax on grease oil (Avgift på smøreolje)

352	Tax on motor vehicles (Motorvognavgift oppkrevd i varehandelsleddet)
361	Tax on gasoline (Avgift på bensin)
364	CO_2 tax (CO_2-avgift)
365	Tax on sulphur (Svovelavgift)
367	Tax on packing, wine and spirits (Emballasjeavgift på brennevin og vin)
PV	***Ad Valorem* Taxes Collected From Producers**
372	Special Duty on Radio and Television (Avgift på radio- og fjernsynsmateriell m.v.)
373	Tax on Cosmetics (Avgift på kosmetikk)
375	Tax on Pharmaceutical Products (Avgift på farmasøytiske spesialpreparater)
381	Surplus of Norwegian Pools Limited (Overskott i Norsk Tipping A/S)
382	Excise Tax on Race-Tracks (Totalisatoravgift)
383	Tax on Lotteries (Lotteriavgift)
385	Tax on Document (property) (Dokumentavgift)
391	Export Duties on Fish and Fish Products, volume taxes (Utførselsavgift på fisk og fiskeprodukter, volumavgifter)
VV	***Ad Valorem* Taxes Collected from Wholesale and Retail Trade**
311	Tax on Fish etc. for Price Regulation (Avgift på fisk m.v. for prisregulering)
324	Purchase Tax on Spirits and Wine (Omsetningsavgift på brennevin og vin, verdiavgift)
326	Surplus of the Norwegian Wine and Spirit Monopoly (Overskudd i A/S Vinmonopolet)
392	Export Duties on Fish and Fish Products, *ad valorem* taxes (Utførselsavgift på fisk og fiskeprodukter, verdiavgifter)
SPX	**Indirect Volume Subsidies Directed to Producers**
612	Consumer Subsidies on Milk and Milk Products (Forbrukersusidier på melk og melkeprodukter)
632	Regional Subsidies on Milk (Distriktstilskudd på melk)
691	Regional Production Subsidies on Grain (Geografisk produksjonstilskudd for korn)
693	Regional Subsidies to North Norway for Potato Raising (Distriktstilskudd for Nord-Norge til potetdyrking)
694	Subsidies on Beef and Mutton (Tilskudd til storfe og sauekjøtt)
696	Subsidies for Early Slaughtering of Sows (Tilskudd til førtidsslakting av purker)
697	Regional Subsidies on Fruits, Berries and Vegetables (Distrikts- og kvalitetstilskudd på frukt, bær og grønnsaker)
698	Contract Support on Eggs (Kontraktstilskudd på egg)
699	Subsidies for Early Slaughtering of Hens (Godtgjørelse for førtidsslakt av høner)
SVX	**Indirect Volume Subsidies Directed to Wholesale and Retail Trade**
610	Compensation of Value Added Tax on Food (Kompensasjon for merverdiavgift på matvarer)
614	Other Consumer Subsidies on Food (Andre pristilskudd, matvarer)
616	Support by the Price Directory Fund (Tilskott over prisdirektoratets fond)

619	Consumer subsidies on milk and milk products and compensation for VAT on milk, cheese and meat, from 2001 (Forbrukersusidier på melk og melkeprodukter,produsent og Merverdiavgiftskompensasjon på melk, ost, kjøtt , oppkrevd i varehandelsleddet (ny 2001))
622	Consumer subsidies on fuel oils and tranport oils (Forbrukersubsidier på brensel og drivstoff, varehandel)
SPV	***Ad Valorem* Subsidies Directed to Producers**
671	Subsidies for Education (Subsidier til utdanning)
672	Subsidies for Institutes (Subsidier til institutter)