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Documents

# A CGE model of induced technological change: A detailed model description

Statistics Norway/Research Department

# 1. Introduction

The last two decades have seen the emergence of theoretical growth models in which technological change is endogenously specified. The product-variety model by Romer (1990) and the quality-ladder model by Aghion and Howitt (1992) are both well-known examples. The major policy issues inspiring these developments have been; how can an economy sustain a positive growth rate, and how can innovation policy enhance additional growth? Parallel with these theoretical, macroeconomic approaches, a large amount of microeconometric studies of innovation activities and their effect on productivity and firm performance has developed, Griliches (1988, 1995). With the steady flow of contributions within both these two strands of the literature, the empirical and theoretical foundation for building endogenous technological change into large-scale, empirical models has become gradually better.

The CGE model presented here is motivated by a desire to analyse total welfare effects of innovation policy in a realistic economic and political setting, taking advantage of both the theoretical and the empirical contributions so far. It is inspired by the Romer (1990) approach to productivity change and is applied to the small, open Norwegian economy. This documentation outlines the structure of the model.

The first numerical models with endogenous modelling of the innovation process have already begun to emerge. Diao et al (1999) analyses strategic trade policy and innovation policy within a computable general equilibrium (CGE) model for Japan based on the Romer (1990) model. It concludes that direct Research and Development (R&D) subsidies produce relatively large increases in welfare, capital subsidies produce smaller welfare gains, whilst trade liberalisation has the smallest effect. In principle, trade liberalisation can reduce welfare insofar as production factors are diverted from the R&D sector. Russo (2004) is a Canadian application of the product-variety models of Romer (1990) and Jones (1995) that ranks innovation policies by their effects on R&D and on welfare. Russo (2004) finds that R&D tax credits are the most welfare improving, while a lower capital tax rate and investment tax credits for capital producers have positive but smaller effects on welfare.

Contrary to the theoretical model of Romer (1990) and the empirical application by Diao et al. (1999), our model introduces decreasing returns to scale in the knowledge capital, based on evidence provided in Jones (1995) and Leahy and Neary (1999). We model technological change as results of R&D activities performed by optimising agents. The output of R&D activity is new patents for technological solutions, which are purchased by capital producers in order to supply new varieties of capital equipments. There is monopolistic competition in the capital markets and love of capital variety in

demand, so that productivity in the final goods industries increases with R&D activity as the number of patents, and number of real capital firms producing different capital varieties increases. Besides increasing productivity through the so-called love-of-variety effect in the final goods industry, following Diao (1999), there are external effects of R&D, as knowledge accumulates and enhances the productivity of current R&D activities. The third and last effect is that R&D increases the capacity of domestic production to absorb knowledge spillovers from international trade. Contrary to Russo (2004) we model a small, open economy where export prices are given at the world market. In small, open economies technological progress is inevitably dominated by international processes.

Section 2 presents the structure of the CGE model, section 3 describes the main calibration and parameterisation methods, while section 4 gives some concluding remarks and outlines some planned extensions. The appendices provide more details about the actual implementation and calibration.

# 2. The model

The model is a numerical, intertemporal CGE model with R&D-driven technological change. R&D creates new ideas, and the ideas are used as inputs in the production of new capital varieties. Each new idea produced in the R&D industry creates one and only one new capital variety. Both new capital varieties and the increased stock of ideas/patents contribute to economic growth. Apart from the endogeneity of technological change, the model shares many structural and empirical features with the dynamic version of the MSG6 model developed in Statistics Norway; see Heide et al. (2004) and Bye and Holmøy (1997). The model includes a relatively detailed description of the tax and production structures of the Norwegian economy. In the current description of the model we disregard the exogenous tax system to simplify the presentation. Below we present the model structure for the private industries (section 2.1), the representative consumer behaviour (section 2.2), and the main equilibrium conditions (section 2.3).

## 2.1 Industries

There are 16 private industries and 1 governmental industry in the model; see appendix E for the list of ITC production sectors. Following Romer (1990) the private goods industries can be separated into R&D industries, intermediate goods industries and final goods industries. The latter are, however, not only suppliers of final goods, but also serve as input suppliers to each other. This richer input-output structure is disregarded in the stylised representation.

The model incorporates the small, open economy assumption of given world market prices. It avoids complete specialization both through decreasing returns to scale and through the modelling of trade.

In particular, the home market and the export market are assumed to be segmented through a constant-elasticity-of-transformation (CET) separability between production deliveries to the domestic and the export markets, implying costs of diverting deliveries between the two markets. Domestically produced goods are correspondingly assumed to be imperfect substitutes for imports in the domestic market.

We use the dual approach to the firm's maximization problem. We assume that all firms within the final goods 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. For simplicity, in this presentation of the model, we disregard the input of other intermediaries, only labour, *L*, (measured in efficient man hours) and capital, *K*, are considered as inputs. There are no fixed costs in production.[1]

**2.1.1 Final goods industries**

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

$$(1)\ V_0 = \int_0^{\infty} e^{-rt}\left(\pi_t - P_{Jt}J_t\right)dt\ .$$

$J = \dot{K} + \delta K$ is gross investment, $P_J$ is the price of the investment good and $\delta$ is the depreciation rate. To simplify the exposition we suppress the period term *t* when it is possible. Operating profit is defined as

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

$X^H$ 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))

[1] Except for the intermediate goods industry producing capital varieties, see section 2.1.3.

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

$s$ is the scale elasticity, $0 < s \leq 1$ and $\rho$ is the transformation parameter between deliveries to the domestic and the foreign market. $\tau_i$ is a factor-specific exogenous productivity parameter, $i$=$L,K$. An increase in $\tau_i$ increases the efficient input of factor $i$ and, thus, output. This exogenously determined component of the technological level can vary both with respect to factor and industry. The production technology is given by a nested input factor tree of CES aggregates; see figure 1.

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

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

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

$\sigma$ is the elasticity of substitution between labour and capital and $\delta_L$ is the base year cost share of labour. $P^K$ is the unit price of the machinery composite, consisting of the composite of capital varieties $K_V$ and other machinery $K_O$, (see appendix A, equation (A.2)).

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

(6) $V_0 = \int_0^\infty e^{-rt}\left(\pi_t - P_t^K K_t\right)dt + P_{J0}K_0$.

$P_{J0}K_0$ is the initial value of the capital stock. Equation (6) implies that maximising the present value of the firm is equivalent with maximising $\pi_t - P_t^K K_t$ in each period. By using appropriate substitutions (see appendix B 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 in both 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 is represented by the dual cost functions for the different CES aggregates; see Figure 1 for the nested structure of linear homogeneous CES aggregates. This will determine the different factor shares, which together with total production, determines the use of each input factor. Machinery capital $K$ is defined as a composite of capital varieties $K_V$ and other machinery $K_O$. (We disregard the exogenous technological change terms $\tau_i$)

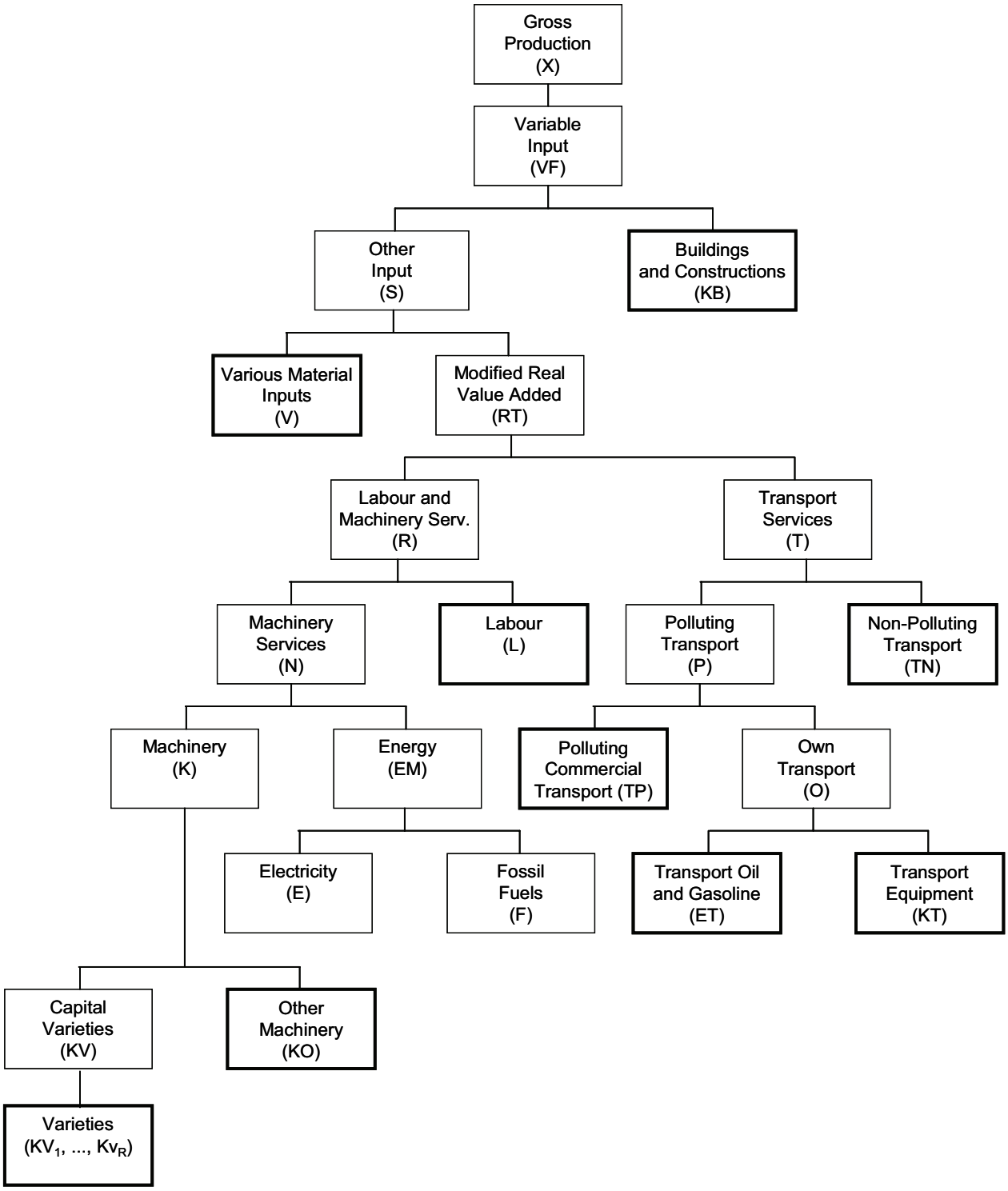
$$(10)\quad K = \left[\delta_{ko}\left(\frac{K_O}{\delta_{ko}}\right)^{\left((\sigma_k-1)/\sigma_k\right)} + (1-\delta_{ko})\left(\frac{K_V}{(1-\delta_{ko})}\right)^{\left((\sigma_k-1)/\sigma_k\right)}\right]^{\left(\sigma_k/(\sigma_k-1)\right)}$$

$\sigma_k$ is the elasticity of substitution between capital varieties and other machinery and $\delta_{ko}$ is the share of other machinery in the machinery capital composite. We assume so-called Spence-Dixit-Stiglitz (love-of variety) preferences for the composite of capital varieties

$$(11)\ K_V = \left[ \sum_{i=1}^{R} \left( K_{Vi} \right)^{(\sigma_{kv}-1)/\sigma_{kv}} \right]^{\sigma_{kv}/(\sigma_{kv}-1)}.$$

$R$ is the accumulated number of capital varieties (number of firms in the capital varieties industry) and $\sigma_{kv}$ is the uniform elasticity of substitution applying to all pairs of capital varieties. More details of the modelling of the machinery capital composite, including the composite of capital varieties, are given in Appendix A.

**Figure 1. The nested structure of the production technology**



### 2.1.2 Production of R&D services

We assume that the R&D industry only delivers production of new patents (ideas) to the domestic market.[2] The production of new ideas 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') $X_R^H = [R]^{s_1}[A]^{s_2}[f(L\tau_L, K\tau_K)]^s$

As for the final goods production, the factor specific exogenous productivity parameters $\tau_i$ capture exogenous factor productivity change. In addition, productivity is enhanced by endogenous *domestic spillovers* from the accumulated stock of knowledge (accumulated stock of patents) $R$, $R = R_{-1} + X_R^H$, that is assumed to be freely accessible by the participants in the R&D industry. $s_1$ denotes the elasticity of domestic spillovers. Also a third productivity component, $A$, is included, representing knowledge *spillovers from abroad*. This is an exogenous productivity parameter that captures the effect on domestic R&D of absorbed new ideas from abroad. $s_2$ is the elasticity of such foreign spillovers. $A$ can also be modelled as dependent on some proxies for openness, e.g. economy-wide trade as in Diao et al (2000).

The production technology is given by the nested CES structure, see Figure 1, with one exception; we assume that the R&D service industries only use other machinery $K_O$ as machinery capital input in the production process, not the differentiated capital variety composite $K_V$.[3]

Equation (3') can be rewritten as

(3''') $\left(X_R^H\right)^{1/s} = (R)^{s_1/s}(A)^{s_2/s} f(L\tau_L, K\tau_K)$.

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

$C = cf(L\tau_L, K\tau_K)$.

[2] The model does not disregard international trade in ideas, but trade in ideas is encompassed in the trade of capital varieties (see 2.1.3).

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

$c$ is the dual price index (unit input cost function) of the CES function. Combining the expression for the variable cost function with equation (3'''), the variable cost function for the representative firm takes the form

$$(4') \quad C = \frac{c}{(R)^{s_1/s}(A)^{s_2/s}}\left[X_R^H\right]^{1/s}.$$

Spillovers from abroad $A$ and domestic spillovers $R$ will both contribute to reduce the costs of production. The dual price index $c$ of the CES-composite of labour and capital input is given by

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

As for the final goods industries the dynamic maximization problem of the firm can be transformed to a sequence of static problems where the firm maximizes

$$(7') \quad \pi' = P_R^H X_R^H - \frac{c}{(R)^{s_1/s}(A)^{s_2/s}}\left(X_R^H\right)^{1/s}$$

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

$$(8') \quad P_R^H = \frac{c}{s(R)^{s_1/s}(A)^{s_2/s}}\left(X_R^H\right)^{\frac{1-s}{s}}.$$

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

### 2.1.3 Production of capital varieties

The firms that produce capital varieties (the so-called intermediate goods industry following the Romer/Diao terminology) buy patents from the R&D industry. We assume that the firms in this intermediate goods industry sell their products on both the domestic and the export market with the same assumptions about separability in the cost structure between deliveries to the domestic and the export market as for the final goods industry. We assume that the firms have market power in the

domestic market, but exhibit no market power in the export market. As for the final goods industries, the export prices are given in the world market and we assume no import of capital varieties.

We assume that the cost structure is identical for all the firms within the capital variety industry. Each firm buys only one patent from the R&D industry and produces only one capital variety. The production technology is given by the nested CES structure, see Figure 1. We assume, as for the R&D industry, that the firms within the capital varieties industry only use other machinery $K_O$ as machinery capital input in the production process.

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

$$(6'') \quad V_{i0} = \int_0^{\infty} e^{-rt}\left(\pi_{it} - P_t^K K_{it}\right)dt - P_{R0}^H + P_{J0}K_{i0}$$

$P_{R0}^H$ is the price of buying one patent from the R&D industry in period 0. The cost of buying a patent is a fixed cost for the firm.

As for the final goods industries the transformation function between input (the technology of production) and output has the separable structure

$$(3'') \quad \left[\left(X_{ki}^H\right)^{\rho} + \left(X_{ki}^W\right)^{\rho}\right]^{1/\rho} = \left[f\left(L_i\tau_L, K_i\tau_K\right)\right]^s .$$

$X_{ki}^H$ 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 $\frac{1}{\rho} = s$ such that the variable cost function is separated into a cost function for export deliveries and a cost function for domestic deliveries.

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

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

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

As for the final goods industries the dynamic maximization problem of the firm can be transformed to a sequence of static problems where 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

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

(9'') $\frac{\partial \pi_i'}{\partial X_{ki}^W} = P_k^W - \frac{c}{s}\left(X_{ki}^W\right)^{\frac{1-s}{s}} = 0$

The domestic demand elasticity for capital variety $X_{ki}^H$ 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 reorganising gives the following monopoly pricing rule for the domestic price of capital variety *i*.

(13) $P_{ki}^H = m_{ki}\frac{c}{s}\left(X_{ki}^H\right)^{\frac{1-s}{s}}$

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

(14) $P_k^W = \frac{c}{s}\left(X_{ki}^W\right)^{\frac{1-s}{s}}$

The composite of capital varieties is used as input in the final goods industries. It can be shown that the demand elasticity is equal to the elasticity of substitution between the different varieties in the capital varieties composite $\sigma_{kv}$, i.e. $\varepsilon_{ki} = \sigma_{kv}$. The mark-up factor in the monopoly pricing rule in equation (13) can then be written as

(15) $m_k = \frac{\varepsilon_k}{\varepsilon_k - 1} = \frac{\sigma_{kv}}{\sigma_{kv} - 1}$ , $\sigma_{kv} > 1$.

The mark-up factor is independent of *i*. Together with the assumption of equal production and cost structure in each firm, and uniform substitution elasticities among varieties, the monopoly pricing rule implies that the price in the domestic market is equal for all the capital varieties, $\overline{P}_k^H = P_{ki}^H$ . Hence, each variety is produced in equal quantity. This implies that the user cost of capital for capital variety *i* is equal for all the varieties, $P_{kvi} = \overline{P}_{kv}$ , and can be written as

(16) $\overline{P}_{kv} = (r + \delta)\overline{P}_k^H - \dot{\overline{P}}_k^H$ .

The composite of capital varieties is described by so-called Spence-Dixit-Stiglitz (love-of-variety) preferences, see equation (11) section 2.1.2. The dual unit cost function defining the unit price of the capital varieties composite $P_{kv}$ is given by

(17) $P_{kv} = \left[ \sum_{i=1}^{R} \left( P_{kvi} \right)^{(1-\sigma_{kv})} \right]^{1/(1-\sigma_{kv})}$.

$\sigma_{kv}$ is the elasticity of substitution between the different capital varieties. When the user cost of capital is equal for each capital variety as stated in equation (16), the unit cost price of the capital variety composite $P_{kv}$ can be written as

(18) $P_{kv} = R^{\left(1/(1-\sigma_{kv})\right)} \cdot \overline{P}_{kv}$

By combining equations (1'') and (7'') and using that $P_{J0}K_{i0} = 0$ (there is no production of the marginal firm's variety before entry), in addition to using the fact that profit is equal for all firms, $\pi_{it}^{'} = \overline{\pi}_t^{'}$, the entry/exit condition for each capital variety producing firm is given by

(19) $P_{R0}^H = \int_0^{\infty} e^{-rt} \left( \overline{\pi}^{'}{}_t \right) dt$ .

Firms are entering the capital variety industry until the representative firm's total discounted net profit is equal to the entry costs, i.e. the costs of buying one new idea/patent. In each period new patents are produced and new firms will enter the capital variety industry. Given that a firm has entered the capital variety industry the first order condition in equation (13) determines the price of the capital variety for given marginal costs and domestic demand. The entry/exit condition determines the price of a new

patent in each period.[4] Together with the first order condition for the representative firm in the R&D industry, equation (8'), the production in the R&D industry (number of new patents) is determined.

## 2.2 Consumer behaviour

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

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

given the intertemporal budget constraint

(21) $W_0 = \int_0^{\infty} PD_t d_t e^{-rt} dt$.

$d$ is total material consumption for the representative consumer, $\rho$ is the consumer's rate of time preferences, $PD$ 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 labour income and net transfers). Labour supply is exogenous. We choose a CRRA utility function for the representative consumer[5]. We consider a small open economy where the interest rate is exogenously given from the world market and 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 $\lambda$ (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

(22) $d_t = [\lambda \cdot PD_t]^{-\sigma_d}$.

$\sigma_d$ is the intertemporal elasticity of substitution. Total material consumption $D_t$ is given by

(23) $D_t = d_t (1+n)^t$.

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[4] The implementation of the entry/exit condition in the CGE model is described in more details in Appendix D.

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

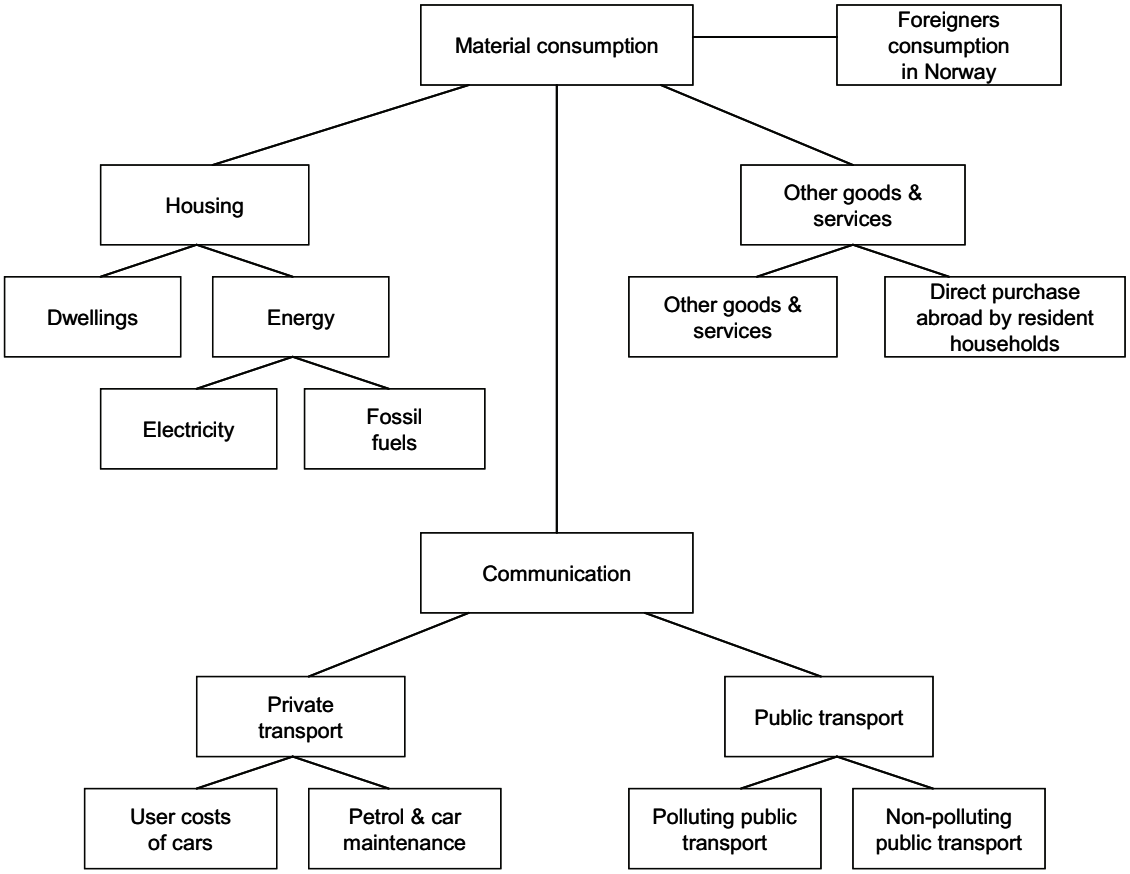
$u(d_t) = \ln d_t$ when $\sigma_d = 1$

*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 2. The demand for consumer good *i*, $D_{it}$, is given by

$$(24)\quad D_{it} = \omega_{i.0}\left(\frac{PD_{jt}}{PD_{it}}\right)^{\sigma_j}\frac{VD_{jt}}{PD_{jt}}$$

$PD_i$ is the price of consumer good *i*, $PD_j$ 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 $\sigma_j$ is the elasticity of substitution between the two consumer goods in CES aggregate *j*, *i*=list of consumer activities, *j*=material consumption composite.

**Figure 2. Material consumption**



## 2.3 Equilibrium conditions

The model is characterized by equilibrium in all product markets and the labour market in each period. 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 Appendix F.

### 2.3.1 Intertemporal equilibrium and long run balanced growth

Intertemporal equilibrium requires fulfilment of the two transversality conditions; Total discounted value of net foreign debt and the total discounted value of real capital, respectively, must both be zero. The model is characterised by a path dependent steady state/balanced growth path solution, see Sen and Turnovsky (1989) and Bye and Holmøy (1992) for theoretical expositions. To ensure a long run balanced growth path (or steady state solution), 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 $g^s$. Each industry must grow 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

$$(25)\quad \frac{D_{t+1}}{D_t} = (1+n)(1+g^s).$$

Using equations (22) and (23) and the intertemporal consumption function in discrete times[6], the relationship between total consumption in two periods can be written as

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

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

(26) $$\frac{D_{t+1}}{D_t} = \left[ \frac{PD_{t+1}}{PD_t} \frac{(1+\rho)}{(1+r)} \right]^{-\sigma_d} (1+n).$$

To reach a long run balanced growth path the rate of inflation, $\frac{PD_{t+1}}{PD_t} = 1+\pi$, must be constant.

Combining equations (25) and (26) gives the following additional condition for a balanced growth path

(27) $$\left[ \frac{(1+\rho)}{(1+r)/(1+\pi)} \right] = (1+g^s)^{-1/\sigma_d}.$$

Equation (27) states that along a balanced growth path the rate of inflation is determined by the growth rate, given the exogenous values of the rate of time preferences and the nominal interest rate.
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 (27) in the following way: In the really long run we assume that the growth rate and the rate of inflation 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 maximising 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 contraint and the transversality condition.[7] Numerically, this transversality condition is taken into account in the following way; λ the marginal utility of wealth in equation (22) 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.

[7] The consumer's budget constraint is given by $\dot{b} = PD_t D_t - \pi_t - w_t L_t + rb_t + \Omega_t$.
b is net foreign debt, $\pi_t$ is net profit by the firms, $w_t L_t$ is labour income and $\Omega_t$ 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 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 empirical findings (Andreassen and Bjertnæs, 2006). We have less empirical foundation for the substitution possibilities within the Machinery composite. Between Capital Varieties and Other Machinery we assume a relatively high substitution elasticity ($\sigma_k$) of 1.5, while the elasticity between the different capital varieties ($\sigma_{kv}$) is expected to be even higher and set to 3.0, giving a mark up factor of 1.5 for the price of capital varieties.

The elasticities of scale ($s$) is equal to 0.83, and fits econometric findings of moderate 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 specialisation patterns for the industry sturcture.[8] This implies that the elasticities of transformation between domestic and foreign deliveries ($\rho$) are equal to 5. The elasticities of substitution between domestic products and imported goods are assumed to be equal to 4. The elasticity of scale related to previous knowledge ($s_1$) is set considerably lower than the elasticity of scale in production, 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).

In the consumer model the intertemporal elasticity of substitution, $\sigma_d$, equals 0.3, cf. Steigum (1993). Econometric estimates of $\sigma_d$ 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 ($\sigma_j$) are all equal to 0.5.

### 3.2 Balanced growth

In an endogenous growth model as this model, special emphasize is put on calibrating the growth path that the model generates. We call this growth path the reference path. Along this reference path, the exogenous growth factors are assumed to grow steadily. In most cases rates are set in accordance with

[8] The relationship between the substitution parameter and the scale elasticity $\rho = 1/s$ is a crucial assumption in the production technology in the model. The larger is the elasticity of scale, the larger is the elasticity of transformation between domestic and foreign deliveries, $\sigma = 1/(1-\rho)$. 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.

the average annual growth estimates in the baseline scenario of Norwegian Ministry of Finance (2004), reporting the governmental long-run economic perspectives (2002 to 2050). In the governmental perspectives, total factor productivity growth is entirely exogenous and valued at 1.0 percent annually. Our model distinguishes between an exogenous and an endogenous component, and in line with empirical findings; see e.g. Coe and Helpman (1995), we ascribe 95% of total factor productivity growth to exogenous diffusion of global technological innovations across Norwegian borders, while the remaining 5% is result of domestic R&D[9]. The latter forms a basis for calibrating the 2002 level of knowledge, $R_0$, which together with the remaining parameters of the model determines the productivity growth generated from domestic knowledge accumulation, see Section 2.1.

World market prices are assumed to increase 1.4 percent annually. This is in the lower range of exogenous price growth estimates in the governmental perspectives. The export price of capital varieties is assumed to rise even more slowly, in line with the domestic price increase of 0.6 percent annually on average. Lower-bound estimates are chosen to let exogenous inflationary impulses be more in line with 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 line with those of the governmental perspectives. The international interest rate is 4 percent throughout the reference path. All policy variables are constant in real terms at their 2002 levels.

In the long run, i.e. 50-70 years from now, the economy reaches stationary growth rates. GDP grows by 1.5 percent annually; consumption grows 0.5 percentage points lower, as net export is increasing more in this period. Exogenous driving factors explain the major part of the growth; about 5 percent is due to the endogenous productivity impacts of domestic innovations. Behind this lies a relatively strong growth in the R&D activity and production of new varieties (3.0 and 2.4 percent annually) that cause productivity to grow within final goods industries. Eventually, in the far future (after about 170 years), all exogenous and endogenous growth mechanisms are cut off. This 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 as described in section 2.3.3.

[9] This lies in the lower bound of estimates for small, open countries like the Norwegian. We choose this, as several mechanisms believed to drive domestic innovations are excluded from the model, like basic, governmental research, endogenous education, learning-by doing and absorptive capacity extension related to R&D.

### 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 $\lambda$.[10] In the very far future (approximately 170 years) all exogenous and 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 170 years beyond) 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 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 $\lambda$ is increased according to a specific procedure. Corresponding reductions in $\lambda$ 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 of small, open countries like Norway. Besides accounting for the firms' internal productivity effects of policies, a macroeconomic approach takes into account how R&D/innovation within firms spill over to other firms/industries and countries, how policies affect resource allocation and factor prices, and also how several policy instruments interplay.

Like several OECD governments, the Norwegian government has recently introduced general tax credits as an instrument for promoting private R&D. There is interest in evaluating the effects of such instruments compared to other, less direct productivity-augmenting policies, for instance provision of infrastructure, or support and stimulation of entrepreneurship, investments or international activities (trade, FDI, research collaboration). Bye et al (2006) analyses the effects of different innovation promoting policies using this model with induced technological change.

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

The model will be extended, and these ambitions have also influenced the design of the present model. In particular, in the prolonging of this project we want to capture the effects of R&D support directed to specific fields of research, with one of the main fields of effort of the Norwegian government as an example, namely the R&D directed towards the energy/environment/climate change nexus. A considerable part of the Norwegian R&D support goes to this field today, and it is expanding.

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# Appendix A - The CES production technology and production of capital varieties

The variable cost function of the representative firm takes the form

(A.1) $C = c \cdot f\left(L\tau_L, K\tau_K\right)$ .

$c$ is the dual price index (unit cost function) of the CES-composite of labour and machinery capital, see equation 5, section 2.1.1.

The unit cost of the machinery capital composite $P^K$ is given by

(A.2) $$P^K = \left[\delta_{ko}\left(\frac{P_{ko}}{\tau_{ko}}\right)^{(1-\sigma_k)} + (1-\delta_{ko})\left(\frac{P_{kv}}{\tau_{kv}}\right)^{(1-\sigma_k)}\right]^{\frac{1}{1-\sigma_k}}$$

$P_{ko}$ is the user cost of other machinery while $P_{kv}$ is the unit cost of the composite of capital varieties. The dual unit cost function that defines the unit price of the capital varieties composite corresponding to the Spence-Dixit-Stiglitz preferences for the composite of capital varieties is then given by

(A.3) $$P_{kv} = \left[\sum_{i=1}^{R}\left(P_{kvi}\right)^{(1-\sigma_{kv})}\right]^{1/(1-\sigma_{kv})}.$$

$P_{kvi}$ is the user cost of capital for capital variety $i$ and $\sigma_{kv}$ 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 $i$.

(A.4) $$K_{Vi} = \frac{\partial C(\cdot)}{\partial P_{kvi}} = c'_{P_{kvi}} \cdot f\left(L, K\right)$$

For convenience we disregard the exogenous technological change terms $\tau_i$. The demand function for capital varieties is then given by

(A.5) $$K_{Vi} = f\left(L, K\right)(1-\delta_L)(1-\delta_{ko})\left(\frac{c}{P^K}\right)^{\sigma}\left(\frac{P^K}{P_{kv}}\right)^{\sigma_k}\left(\frac{P_{kv}}{P_{kvi}}\right)^{\sigma_{kv}}.$$

The partial demand elasticity for capital variety $i$, $\varepsilon_{ki} = -\frac{\partial K_{Vi}}{\partial P_{kvi}}\frac{P_{kvi}}{K_{Vi}} = \sigma_{kv}$ is derived from equation (A.5). This is equal to the domestic demand elasticity for the production of capital variety $i$, defined in section 2.1.3. In this case the substitution elasticity between the capital varieties is equal to the domestic demand elasticity, and the expression for the mark-up factor in the capital varieties industry

is given in equation (15). With a nested CES production technology the mark-up factor only depends on the partial demand/substitution elasticity in the capital varieties composite. 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 unit cost price of the capital variety composite $P_{kv}$ can then be written as

$$\text{(A.6)}\ P_{kv} = R^{\left(1/1-\sigma_{kv}\right)} \cdot \overline{P}_{kv} \ .$$

$\overline{P}_{kv}$ is the user cost of capital of each capital variety. The capital varieties composite is then given by

$$\text{(A.7)}\ K_V = R^{\left(\sigma_{kv}/(\sigma_{kv}-1)\right)} \cdot \overline{K}_V \ .$$

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

Inserting equation (A.6) into equation (A.2) gives the following expression for the unit price of the machinery capital composite

$$\text{(A.8)}\ P^K = \left[ \delta_{ko} \left( \frac{P_{ko}}{\tau_{ko}} \right)^{(1-\sigma_k)} + (1-\delta_{ko}) R^{\left(\frac{1-\sigma_k}{1-\sigma_{kv}}\right)} \left( \frac{\overline{P}_{kv}}{\tau_{kv}} \right)^{(1-\sigma_k)} \right]^{\frac{1}{1-\sigma_k}} .$$

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

$$\text{(A.9)}\ \frac{K_V}{K} = (1-\delta_{ko}) R^{\left(\frac{1-\sigma_k}{1-\sigma_{kv}}\right)} \left( \frac{\overline{P}_{kv} / \tau_{kv}}{P^K} \right)^{-\sigma_k} .$$

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

$$\text{(A.10)}\ \frac{K_O}{K} = \delta_{ko} \left( \frac{P_{ko} / \tau_{ko}}{P^K} \right)^{-\sigma_k} .$$

The gross investment in capital variety *i* (equal to the deliveries of capital variety *i* to the domestic market) is given by

$$\text{(A.11)}\ J_{kvi} = \dot{K}_{Vi} + \delta K_{Vi} = X_{ki}^H \ .$$

# Appendix B - Derivation of the expression for the present value of the firm

The present value of the firm is given by

(B.1) $V_0 = \int_0^{\infty} e^{-rt}(\pi_t - P_{Jt}J_t)dt$

$\pi$ is operating profit given in equation (2) and $J = \dot{K} + \delta K$ is gross investment. In addition we have the following transversality condition $\lim_{t\to\infty} e^{-rt}P_{Jt}K_t \to 0$. Integration (by parts) of equation (B.1) can be done as follows

(B.2) $\int_0^{\infty} e^{-rt}P_{Jt}J_t dt = \int_0^{\infty} e^{-rt}P_{Jt}(\dot{K} + \delta K_t)dt$

Using the formula for partly integration we have

(B.3) $\int_0^{\infty} e^{-rt}P_{Jt}\dot{K}dt = \Big|_0^{\infty} e^{-rt}P_J(t)K(t) - \int_0^{\infty}\left[e^{-rt}(-r)P_{Jt}K_t + e^{-rt}\dot{P}_J K_t\right]dt$ .

Using the transversality condition $\lim_{t\to\infty} e^{-rt}P_{Jt}K_t \to 0$, (B.3) can be written as

(B.3') $\int_0^{\infty} e^{-rt}P_{Jt}\dot{K}dt = -P_J(0)K(0) - \int_0^{\infty}\left[e^{-rt}(-r)P_{Jt}K_t + e^{-rt}\dot{P}_J K_t\right]dt$ .

Inserting (B.3') in (B.2) gives

(B.2') $\int_0^{\infty} e^{-rt}P_{Jt}J_t dt = -P_J(0)K(0) + \int_0^{\infty} e^{-rt}K_t\left[rP_{Jt} + \delta P_{Jt} - \dot{P}_J\right]dt = -P_J(0)K(0) + \int_0^{\infty} e^{-rt}P_t^K K_t dt$ .

$P_t^K = P_{Jt}(r+\delta) - \dot{P}_J$ denotes the user cost of real capital.

Inserting equation (B.2') into equation (B.1) gives the following expression for the present value of the firm

(B.4) $V_0 = \int_0^{\infty} e^{-rt}(\pi_t - P_t^K K_t)dt + P_J(0)K(0)$ .

# Appendix C - The entry/exit condition in the capital varieties industry

The entry/exit condition for the representative firm in the machinery capital variety industry is given by equation (19). This condition can be rewritten in discrete time as follows

(C.1) $P_{R0}^{H} = \sum_{t=0}^{\infty} \frac{1}{(1+r)^{t}} \pi_{it}^{'}$.

Along a stationary path, the interest rate r and the profit are both constant. The entry/exit condition can then be written as (using the formula for a geometric row)

(C.2) $P_{R0}^{H} = \left( \frac{1+r}{r} \right) \overline{\pi}'$.

The price of a new idea/patent is also constant along a stationary path. Due to the small open economy assumption, the interest rate r is exogenous and also assumed to be constant along the whole simulation path. In each time period 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 idea/patent.

The exit/entry condition for the representative firm can be approximated by the following equation

(C.3) $P_{Rt}^{H} = ENT_{t} \left( \frac{1+r}{r} \right) \pi_{ti}^{'}$ .

$$\pi_{ti}^{'} = \left[ P_{k}^{H} X_{ki}^{H} + P_{k}^{W} X_{ki}^{W} - c\left(X_{ki}^{H}\right)^{1/s} - c\left(X_{ki}^{W}\right)^{1/s} \right]$$

$ENT_t$ is a correction variable that takes into account that $\pi_{ti}^{'}$ is not constant along the transitional path towards the stationary solution. To find the value for the correction variable *ENT*, we define a help variable *BENT*

(C.4) $$BENT_T = \frac{\sum_{t=T}^{\infty}\left(\left(\frac{1}{(1+r)^{(t-T)}}\right)\pi_t\right)}{\left(\frac{1+r}{r}\right)\pi_T}.$$

*BENT* measures the relation between the present value of the varying profit from period *T* onwards and the present value of the profit if the profit was constant from period *T* onwards.

We use the following iteration procedure for calculating the *ENT* value:

1. The model is simulated with *ENT*=1 according to the procedure for solving the intertemporal model described in chapter 3.3.
2. $BENT_t$ is calculated and we check whether the new value for $BENT_t$ deviates from the value of $ENT_t$.
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.

# Appendix D - Calibration

## D.1 Calibration of the entry/exit condition for the capital varieties industry and the accumulated stock of patents

We assume decreasing returns to scale in production both within the representative firm in the industry and for the industry as a whole. Since all firms in the capital variety industry are equal and produce the same amount of each capital variety, we assume that the total industry is represented by one representative firm in the base year, i.e. $X_{ki}^H = X_k^H$ and $X_{ki}^W = X_k^W$ and $X_k^H$ and $X_k^W$ is the total industry's deliveries to the domestic and the export market, respectively. This implies that we can transform the number of firms/varieties into the following index that equals 1 in the base year.

(D.1) $\gamma_R = \frac{R_{t-1} + X_{Rt}^H}{R_{.0}}$.

$R_{.0}$ is the base year value of the number of capital varieties. In the base year (t=0) $\gamma_R$=1.
The entry/exit condition (equation (C.3)) determines the number of new varieties (new firms) in the capital variety industry that is equal to the production of new ideas in the R&D industry. The entry/exit condition only applies to the new firms entering the capital variety industry in each period. The only profit that should be included in the entry/exit condition is the share of the total industry's profit that stems from these new firms. Therefore, both the entry/exit condition and the cost functions for the capital variety industry must be formulated at the 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 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.

(D.2) $C_k^H = c\left(\frac{X_k^H}{\gamma_R}\right)^{1/s}\gamma_R$

(D.3) $C_k^W = c\left(\frac{X_k^W}{\gamma_R}\right)^{1/s}\gamma_R$

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

Using the expressions for deliveries from the representative firm, together with equations (D.1)-(D.3), the entry-exit condition in (C.3) can be written as

$$\text{(D.4)}\quad \left(\frac{1+r}{r}\right) ENT\left[P_k^H \frac{X_k^H}{\gamma_R} + P_k^W \frac{X_k^W}{\gamma_R} - c\left(\frac{X_k^H}{\gamma_R}\right)^{1/s} - c\left(\frac{X_k^W}{\gamma_R}\right)^{1/s}\right]\frac{1}{R_{.0}} = P_R^H \,.$$

This entry/exit condition is implemented in the numerical CGE model.

The first-order conditions for profit maximization is given as

$$\text{(D.5)}\quad P_k^H = m\frac{c}{s}\left(\frac{X_k^H}{\gamma_R}\right)^{\left(\frac{1}{s}-1\right)}$$

$$\text{(D.6)}\quad P_k^W = \frac{c}{s}\left(\frac{X_k^W}{\gamma_R}\right)^{\left(\frac{1}{s}-1\right)}$$

(D.5) is the first order condition for deliveries to the home market and (D.6) is the first order condition for deliveries to the export market.

## D.2 Data and calibration of output and input for the R&D industry

### D.2.1 Data

The National Accounts have no separate data for R&D, either as input into production processes or as output from an industry. We have calibrated input and output data for the R&D industry by using input factors (wage costs, other operational costs[11], and investment costs) from the R&D Statistics[12] for the year 2002. We calculate the shares of R&D related activity from the input factors for all the industries

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

[12] 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 is estimated to sector levels. The sectors are in line with the Standard Industrial Classification (SN94). The R&D Statistics are conducted by Statistics Norway. More information can be found on: www.ssb.no -> StatBank -> Industrial Activities -> Technological Indicators -> Research and Development in Norwegian Enterprises

in the model. These shares of input are then reallocated to the R&D industry. Total output of R&D is bought by the capital variety industry.

**Table D.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 |
| 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 | 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 |

### D.2.2 Base year calibration of input and output

We assume that capital letters denote observed National Account variables in the base year and small letters denote calculated variables

$X$ = Gross production

$H$ = Total material inputs

$V$ = Various material inputs

$FT$ = Fuel oils etc

$F$ = Transport oils (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

$\delta_{ij}$ = Share of R&D related input in each industry, industry $j$, input factor $i$.

For each private industry except the R&D industry (industry 38) 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 Account) gross production, $x_j < X_j$ for $j \in PS\backslash\{38\}$ (PS = list of industries).

For industry 38 we have the following relationships

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

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

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

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

$$=q_{38}$$

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

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

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

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

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

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

$$= x_{38}$$

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

For $j \in PS \setminus \{38\}$ (PS = list of industries) 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. For $j \in PS \setminus \{38\}$ (PS = list of industries) we have

$$x_j + mv_j = X_j$$

Summarizing gross production over all industries (except industry 38) gives the following equation

$$\text{(D.7)} \quad \sum_{j \in PS \setminus \{38\}} X_j = \sum_{j \in PS \setminus \{38\}} x_j + \sum_{j \in PS \setminus \{38\}} mv_j \ .$$

We then add the gross production in industry 38 on both sides in equation (D.7). Since $X_{38}=0$ and $x_{38}>0$, we have the following inequality

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

By assumption the gross production in industry 38 is only delivered to industry 46, and we define the variable *sc46* that is input of commodity 38 in the production of product 46 as $sc_{46}=x_{38}$ . In the base year this calculated production in industry 46, $\bar{x}_{46}$ , is delivered as material input $mv_j$ to all other industries. This implies that in the base year calibration we have the following relationship

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

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

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

The National Account 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 Account gross product Q.

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

To summarize 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 executed 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.

In the numerical simulations the $mv_j$ terms are gradually phased out.

# Appendix E - Sector/Activity Lists

### E.1 The distribution of commodities on ITC commodity/industry 46 and 47

The production in MSG6/MODAG industry 45, Manufacture of Metal Products, Machinery and Equipment, consists mainly of deliveries of MSG6 products 46 and 47 as specified in table E.1. The distribution of the production in MSG6 industry 45 on MSG6 products 46 and 47 is a direct aggregation of National Accounts commodity codes. In contrast, the distribution on ITC (Induced Technological Change) model commodity/industry codes 46 and 47, is not a direct aggregation of National Accounts classifications.

**Table E.1: Production and import of Manufacture of Metal Products, Machinery and Equipment distributed in commodities, MSG6**

| **MSG6 Code** | **Full Name** (Norwegian name in parenthesis) | **Model Database Commodity Code** | **National Accounts Commodity Code** |
|---|---|---|---|
| 46 | Metal Products, Machinery and Equipment (Verkstedprodukter) | 280,297,298,300, 311,318,320,330, 340,356 | 000384,000390,281110-292470, 293210-295620,296012-297210, 300110-311060,312010-341010, 341030-343030,351150,351160, 351210,352010-352040,353010, 353020,354110-355010 |
| 47 | Repair (Leiearbeid og reparasjoner) | 391 | 000371-000375,299992,311092, 351143,351144,351191-351194, 351290,352090,353091 |

In order to simplify the implementation and interpretation of the theoretical model described in section 2, we assume that the ITC industry 38 (R&D industry) only delivers production to ITC industry 46. ITC industry 46 delivers all its production of so-called capital varieties to ITC investment activity 52 (see further down for the definition of this investment activity) that is the investment activity that endogenously influences the productivity in the economy. The distribution of MSG6 commodity 46 and 47 on ITC commodity/industry 46 and 47 is determined by the following:

1. Domestic production of MSG6 commodity 46 (Metal products, Machinery and Equipment) delivered to MSG6 investment activity 50 (machinery) denotes a part of ITC commodity 46. MSG6 investment activity 50 is split into ITC investment activities 52 and 55. ITC investment acitivity 52 consists only of domestic deliveries from ITC industry/commodity 46 and gross profit and transport margins. Gross profit and transport margins (MSG6 and ITC commodity 81) are distributed on ITC-investment activities 52 and 55 in the same relative proportionality as the commodity's share of MSG6 investment acitivity 50. The rest of MSG6 commodity 46 and MSG6 commodity 47 delivered for investment activities is distributed to ITC industry/commodity 47.

2. Domestic production of MSG6 commodity 46 delivered to export is also distributed to ITC commodity 46.
3. ITC industry/commodity 46 consists only of the deliveries specified in 1 and 2. ITC industry 47 consists of MSG6 industry 45 deducted ITC industry 46. The factor input in MSG6 industry 45 is split on ITC industries 46 and 47 according to the relative share of the end deliveries from domestic production of ITC commodities 46 and 47. The share of changes in domestic storage is distributed on the ITC commodities 46 and 47 by the same share as the distribution of production. There are no import, import storage changes or re-export of ITC commodity 46. This is all distributed on ITC commodity 47.
4. Notice that all domestic production and import of MSG6 commodity 46 to material inputs is distributed to ITC commodity 47. This implies that all domestic production of materiel inputs of ITC commodity 47 is produced in ITC industry 47.
5. Notice that all production and imports of repair is distributed to ITC commodity 47 as in MSG6.
6. In addition notice that the correction term $mv_j$ (see appendix D) blows up the gross production term in ITC industry 46. These deliveries are produced in ITC industry 38 (R&D industry) and carried on via ITC commodity 46 and the production input acitvities $mv_j$ , towards the respective receiving industries. This increased production in ITC industry 46 does not influence the relative internal level of total factor input in ITC industries 46 and 47.

Following this description of the distribution of MSG6 products 46 and 47 on ITC commodities/industries 46 and 47, the relationship between ITC production codes and National Accounts commodity codes is described in table E.2. The calibration procedure that takes into account points 1- 6 above, is described in appendix D.

**Table E.2: Production and import of Manufacture of Metal Products, Machinery and Equipment distributed in commodities, ITC model**

| **ITC Code** | **Full Name** (Norwegian name in parenthesis) | **Model Database Commodity Code** | **National Accounts Commodity Code** |
|---|---|---|---|
| 46 | Domestic Produced Deliveries of Metal products, Machinery and Equipment to investment activity 52 and export. (Hjemmeproduserte leveranser av Verkstedsprodukter for Investeringsaktivitet 52 og Eksport) | 280, 297, 298, 300, 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 |
| 47 | Other Metal products, Machinery and Equipment and Repair (Andre verkstedprodukter og leiearbeid og reparasjoner) | | |

## E.2 Aggregation level and variables, Base year 2002

**Document lists**

| | |
|---|---|
| **VA** | List of commodities |
| **PSK** | List of all production sectors |
| **PS** | Production sectors |
| **PP** | Private production sectors |
| **PO** | Government production sectors |
| **KORR** | Sectors collection indirect taxes |
| **PA** | List of production activities |
| **PF** | List of production factors |
| **PSV** | List of input activities |
| **CP** | List of consumption sectors, expenditure, private housholds |
| **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 against Producers |
| **SVX** | Indirect Volume Subsidies Directed against Wholesale and Retail Trade |
| **SPV** | *Ad Valorem* Subsidies Directed against Producers |

## ITC - List of 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 industries"** | | | |
| 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 industry commodities (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 |
| 38* | Research and Development (Forskning og utvikling) | | |

| | | | |
|---|---|---|---|
| 40 | Gasoline etc.<br>(Transportoljer) | 232, 235, 236 | 232001, 232002, 232004, 232017, 232018 |
| 42 | Fuel oils etc<br>(Fyringsoljer) | 234, 237 | 232008, 232014, 232005, 232015 |
| 46** | Metal products, Machinery and Equipment. Domestic produced deliveries to investment activity 52 and export.<br>(Verkstedsprodukter, innenlandsk produksjon, leveranser til investesteringsaktivitet 52 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 |
| 47** | Other Metal products, Machinery and Equipment. Repair.<br>(Andre verkstedprodukter. Leiearbeid og reparasjoner) | | |
| 50 | Ships, Oil Rigs and Oil Production Platforms<br>(Skip, borerigger og oljeplattformer) | 351, 352, 353, 354 | 351121-351133, 351141, 351142,351921-351931, 351941 |
| 55 | Construction<br>(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<br>(Utenriks sjøfart og tjenester tilknyttet utvinning av råolje og naturgass) | 112, 611 | 112011,112012,611013,611014,611022, 611029,611033,713412 |
| 66 | Crude oil<br>(Råolje) | 111 | 111010 |
| 67 | Natural Gas<br>(Naturgass) | 113, 607 | 111020, 603013, 603014 |
| 69 | Oil and Gas Pipeline Transport<br>(Olje og gasstransport med rør) | 608 | 603011, 603012 |
| 71 | Electricity<br>(Elektrisk kraft) | 411- 416 | 401011-401016,401035-401040 |
| 81 | Wholesale and retail Trade<br>(Varehandel) | 509, 609 | 000350,501000,501002,505000,510100, 510900,521100,601029,602429,611027, 634019, 634029 |
| 83 | Dwelling services<br>(Boligtjenester, egen bolig) | 704, 705, 707 | 702011, 704000, 705000 |

**Commodities "Government Production Sectors"**

| | | | |
|---|---|---|---|
| 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 a National Account commodity. The base year calculation of this term is described in appendix D.
** The content in the ITC commodities 46 and 47 are described at the beginning of this appendix.

# ITC - Production sectors (PSK)

**PSK**

List of all production sectors

**PSK = PS∪KORR = PP∪PO∪KORR**

**PS** Production sectors

**KORR** Sectors collecting indirect taxes

**PP** Private production sectors

**PO** Public production sectors

| PSK Code | Full Name (Norwegian name in parenthesis) | Model Database Sector Code | National Accounts Sector Code |
|---|---|---|---|
| **PS** | **Production sectors** | | |
| **PP** | **Private production sectors** | | **Type of account 22+23+26** |
| 20 | 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, 23231, 23232, 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, 23231, 23232, 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 |
| 30 | Power intensive indsutry (Kraftintensiv industri) | 23210, 23248, 23270 | 23211-23213, 23241, 23242, 23247, 23271-23275 |
| 32 | Domestic transport, polluting (Innenriks samferdsel, forurensende transport) | 23603, 23606, 23613, 23620, 23631, 23632, 23633 | 23602-23604, 23613, 23620, 23631, 23632, 23633 |
| 33 | (Domestic transport, non-polluting) Innenriks samferdsel, bane- og teletransport | 23601, 23605, 23640 | 23601, 23605, 23641, 23642 |
| 38* | Research and Development (Forskning og utvikling) | | |
| 46** | Metal products, Machinery and Equipment. Domestic Produced Deliveries to Investment Activity 52 and Export. (Verkstedsprodukter. Innenlandske produserte varianter til investeringsaktiviet 52 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 |

| | | | |
|---|---|---|---|
| 47** | Other Metal Products, Machinery and Equipment. 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 |
| 71 | Production of electricity (Produksjon elektrisk kraft) | 23401-23403 | 23401 - 23403 |
| 83 | Dwelling services (Boligtjenester ) | 22704, 22705, 23704 | 22704, 22705, 23704 |
| **PO** | **Government production sectors** | | **Type of account 24+25** |
| 90 | Central and Local Government (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 a National Account industry. The base year calculation of this term is described in appendix D.
** MSG6 industry 45 is split into ITC industry 46 and 47. See the description in the beginning of this appendix

# ITC - 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** | | |
| 2040 | Refining of transport oils (Raffinering av transportoljer) | 23232232, 23232235, 23232236 | **40:** Transport oils |
| 2042 | 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 | Powerintensive industries (Kraftintensiv industri) | 23210, 23248241, 23248248, 23270 | **30:** Powerintensive industry products |
| 32 | Domestic transport, polluting (Innenriks samferdsel, forurensende transport) | 23603, 23606, 23613, 23620, 23631, 23632, 23633 | **32:** Polluting transport services |
| 33 | Domestic transport, non-polluting (Innenriks samferdsel, bane- og teletransport) | 23601, 23605, 23640 | **33:** Non-polluting transport services |
| 38* | Research and Development (Forskning og utvikling) | | **38:** Research and Development |
| 46** | Metal products, Machinery and Equipment. Domestic Produced Deliveries to Investment Activity 52 and Export. (Verkstedsprodukter. Innenlandske produserte varianter til investeringsaktiviet 52 og eksport) | 300, 280, 297, 298, 311, 318, 320, 330, 340, 356, 358, 391 | **46:** Metal products, Machinery and Equipment. Domestic produced deliveries to investment activity 52 and export. |
| 47** | Other Metal Products, Machinery and Equipment. Repair (Andre verkstedprodukter. Leiearbeid og reparasjoner) | | **47:** Other Metal products, Machinery and Equipment. Repair. |

| | | | |
|---|---|---|---|
| 50 | Production of ships and oil platforms<br>(Produksjon av skip og oljeplattformer) | 23351351, 23351998, 23351999, 23352351, 23352998, 23352999 | **50:** Ships, drilling rigs and oil platforms |
| 55 | Construction<br>(Bygg og anlegg) | 22450, 23450 | **55:** Construction |
| 6066 | Production of Crude Oil<br>(Produksjon av råolje) | 23111111 | **66:** Crude oil |
| 6067 | Natural gas<br>(Natural Gas) | 23111113 | **67:** Natural gas |
| 6069 | Pipeline transport<br>(Rørtransport) | 23608608 | **69:** Pipeline Oil- and Gas transport |
| 6099 | Ocean Transport and Other Production in Production of Oil and Gas oil<br>(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 |
| 7171 | Electricity<br>(Elektrisitet) | 23401411, 23401412, 23401413, 23401415, 23401416, 23402, 23403 | **71:** Electricity |
| 7199 | Other Production in Production of Electricity<br>(Øvrig produksjon tilknyttet produksjon av elektrisitet) | 23401999 | **55:** Construction |
| 83 | Dwelling services<br>(Boligtjenester egen bolig) | 22704, 22705, 23704 | **83:** Dwelling services |
| | **Central and Local Government Porduction Activities** | | |
| 90 | Central and Local Government<br>(Offentlig forvaltning) | 24453-24901, 25453-25901 | **90:** Paid fees, Central and Local government |

* Not a National Account industry. The base year calculation of this term is described in appendix D.
** MSG6 industry 45 is split into ITC industry 46 and 47. See the description in the beginning of this appendix.

# ITC - Production Input factors (PF)

| **PF Code** | Name | **ITC Commodity or Capital Code** |
|---|---|---|
| | **Product input**<br>(Produktinnsats) | **ITC Product code ∈ VA** |
| E | Electricity<br>(Elektrisk kraft) | 71 |
| F | Fuel oils etc<br>(Fyringsoljer) | 42 |
| FT | Transport oils (gasoline etc)<br>(Transportoljer) | 40 |
| TN | Non-polluting transport services<br>(Ikke-forurensende transporttjenester) | 33 |
| TP | Polluting transport services<br>(Forurensende transport) | 32 |
| V | Various material inputs<br>(Annen produktinnsats) | VA\{32,33,38,40,42,46,71} |
| MV* | Input of Research and Development, Correction term<br>(Vareinnsats, Forskning og utvikling, korreksjonsledd) | 46 |
| SC* | Input of Research and Development<br>(Kjøp av Forskning og utvikling) | 38 |
| | **List of real capital by type** | **ITC Capital code ∈ JR** |
| KB | Dwellings, Cottages and Non-residential Buildings etc.<br>(Bygningskapital og anlegg) | 11,12 |
| KMO** | Other Machinery, incl. oil drilling rigs and oil platforms<br>(Andre maskiner, oljeutvinnigsplattformer, oljeborerigger m.v.) | 20,55,70 |
| KMV** | Capital Varieties<br>(Kapitalvarianter | 52 |
| KT | Cars<br>(Biler) | 30,40,80 |
| | **Labour** | |
| L | Man hours<br>(Timeverk) | |

* Does not exists in the National Accounts. The base year calculation of these terms are described in appendix D.
** The split into *KMO* and *KMV* is based on the classification in the splitting of MSG6 investment activity 50 in the JR list. Real capital type *KMV* consists of investment activity 52. The rest of Machinery etc. constitutes *KMO*. See the description in the beginning of this appendix.

# ITC - List of input activities (PSV)

| PSV Code | Full Name (Norwegian name in parenthesis) | Material Input Activities (PF Codes) |
|---|---|---|
| | **Input Activities** | |
| | **Industries** | |
| 20 | Production of other commodities and services (Produksjon av andre varer og tjenester) | *F,FT,TN,TP,V,E,MV* |
| 30 | Power intensive industry (Kraftintensiv industri) | *F,FT,TN,TP,V,E,MV* |
| 32 | Domestic transport, polluting (Innenriks samferdsel, forurensende transport) | *F,FT,TN,TP,V,E,MV* |
| 33 | Domestic transport, non-polluting (Innenriks samferdsel, bane- og teletransport) | *F,FT,TN,TP,V,E,MV* |
| 38* | Research and Development (Forskning og utvikling) | *F,FT,TN,TP,V,E* |
| 46** | Other Metal Products, Machinery and Equipment. Repair (Andre verkstedprodukter. Leiearbeid og reparasjoner) | *F,FT,TN,TP,V,E,MV,SC* |
| 47** | Ships, Oil Rigs and Oil Production Platforms (Skip, borerigger og oljeplattformer) | *F,FT,TN,TP,V,E,MV* |
| 50 | Building of ships and oil-platforms (Produksjon av skip 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* |
| 71 | Production of electricity (Produksjon elektrisk kraft) | *F,FT,TN,TP,V,E,MV* |
| 83 | Dwelling services (Boligtjenester) | *TN,V,E* |
| | **Government** | |
| 90 | Central and Local Government (Statlig og kommunal forvaltning) | *F,FT,TN,TP,V,E* |

* Base year material in puts in industry 38 consists of redistributed material inputs from other industries. The base year calculation of this term is described in appendix B.

** MSG6 industry 45 is split into industry 46 and 47 by distributing the input factors proportionally on industry 46 and 47 as for industry 45. See the description in the beginning of this appendix.

## ITC- List of consumtpion 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 |

## ITC- 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* |

# ITC- List of 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 and 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 |
| 52* | Capital varieties, Machinery. Domestic Produced Deliveries (Kapital varianter, maskiner, innenlands produserte) | 2850, 2879, 2890 | 28510-28580, 28740-28790, 28990 |
| 55* | Other Machinery (Andre maskiner mv. eksl. oljeplattformer) | | |
| 70 | Oil Platforms, Oil Rigs and Ships (Oljeutvinnigsplattformer, oljeborerigger og skip) | 2838 | 28380-28388 |

* MSG6 investment activity 50 is split into ITC investment activities 52 and 55. ITC investment activity 52 consists of ITC commodity 46 and 81 according to the VA list. See the description in the beginning of this appendix.

# ITC- Investment Sectors (JS)

| JS Code | Full Name (Norwegian name in parenthesis) | Model Database Sector Code* | National Accounts Sector Code* |
|---|---|---|---|
| | **Private investment sectors** | | **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, 83231, 83232,83249, 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, 83831,83832, 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 |
| 30 | Power intensive industry (Kraftintensiv industri) | 83210, 83248, 83270 | 83211-83213, 83241, 83242, 83247, 83271-83275 |
| 32 | Domestic transport, polluting (Innenriks samferdsel, forurensende transport) | 83603, 83606, 83613, 83620, 83631, 83632, 83633 | 83602-83604, 83613, 83620, 83631, 83632, 83633 |
| 33 | Domestic transport, non-polluting (Innenriks samferdsel, bane- og teletransport) | 83601, 83605, 83640 | 83601, 83605, 83641, 83642 |
| 38* | Research and Development (Forskning og utvikling) | | |
| 46** | Other Metal Products, Machinery and Equipment. Repair (Andre verkstedprodukter. Leiearbeid og reparasjoner) | 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 |
| 47** | Ships, Oil Rigs and Oil Production Platforms (Skip, borerigger og oljeplattformer) | | |
| 50 | Building of ships and oil-platforms (Produksjon av skip 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 |
| 71 | Production of electricity (Produksjon elektrisk kraft) | 83401-83403 | 83401 - 83403 |
| 83 | Dwelling services (Boligtjenester) | 82704 | 82704 |

| | Central and Local government | | Type of Account 84+85 |
|---|---|---|---|
| 90 | Central and Local Government (Statlig og kommunal forvaltning) | 84453-84901, 85453-85901 | 84453-84921, 85453-85921 |

* Base year investments in industry 38 consists of redistributed investments made by other industries. The base year calculation of this term is described in appendix D.

** Base year investments in MSG6 industry 45 is distributed on ITC industry 46 and 47, relative to the size of the production. See the description in the beginning of this appendix.

# Appendix F - ITC- List of Indirect Taxes and Subsidies (AVG)

**AVG**

List of indirect production taxes and production subsidies by type

**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 Directed against Producers

**SVX** Indirect Volume Subsidies Directed against Wholesale and Retail Trade

**SPV** *Ad Valorem* Subsidies Directed against Producers

| **AVG Code** | **Full Name** (Norwegian name in parenthesis) |
|---|---|
| 225 | Value Added Tax<br>(Merverdiavgift) |
| 231 | Investment levy on New Investment and Material Inputs<br>(Investeringsavgift på nyinvesteringer og vareinnsats) |
| 400 | Customs Duty<br>(Toll) |
| **PX** | **Indirect Volume Taxes Collected from Producers** |
| 312 | Excise on Chocolate and Sweets<br>(Sjokolade- og sukkeravgift) |
| 321 | Excise on Non-Alcoholic Beverages<br>(Avgift på alkoholfrie drikkevarer) |
| 322 | Excise on Beer<br>(Avgift på øl) |
| 331 | Excise on Tobacco<br>(Tobakksavgift) |
| 342 | Tax on Use of Electric Energy<br>(Avgift på forbruk av elektrisk kraft ) |
| 344 | Tax on Use of Coal and Coke<br>(avgift på forbruk av kull og koks) |
| 351 | Tax on cars etc.<br>(Avgift på transportmidler) |
| 363 | Tax on boat engines<br>(Avgift på båtmotorer) |
| 374 | Tax on environmental hazardous batteries<br>(Avgift på miljøskadelige batterier) |
| 368 | Tax on packing, beer<br>(Emballasjeavgift øl) |
| 369 | Tax on packing, non-alcoholic beverages<br>(Emballasjeavgift på alkoholfrie drikkevarer) |
| 376 | Taxes in the telecom industry area<br>(Avgifter i telesektoren) |
| 377 | Tax on Recording Tapes and Video Cassetttes<br>(Avgift på lydbånd og videokasetter) |
| 379 | Tax on Charter Flights<br>(Charteravgift) |

| VX | Indirect Volume Taxes Collected from Wholesale and Retail Trade |
|---|---|
| 325 | Tax on purchase of wine and spirits<br>(Avgift på brennevin og vin, mengdeavgift) |
| 343 | Tax on mineral oil<br>(Avgift på mineralolje opphører 1.1.1999) |
| 345 | Tax on autodiesel<br>(Autodieselavgift) |
| 346 | Tax on mineral oil<br>(Mineraloljeavgift (grunnavgift på fyringsolje) ) |
| 347 | Tax on grease oil<br>(Avgift på smøreolje) |
| 352 | Tax on motor vehicles<br>(Motorvognavgift oppkrevd i varehandelsleddet ) |
| 361 | Tax on gasoline<br>(Avgift på bensin) |
| 364 | CO2-tax<br>(CO2-avgift ) |
| 365 | Tax on sulphur<br>(Svovelavgift ) |
| 367 | Tax on packing, wine and spirits<br>(Emballasjeavgift på brennevin og vin) |
| **PV** | ***Ad Valorem* Taxes Collected From Producers** |
| 372 | Special Duty on Radio and Television<br>(Avgift på radio- og fjernsynsmateriell m.v.) |
| 373 | Tax on Cosmetics<br>(Avgift på kosmetikk) |
| 375 | Tax on Pharmaceutical Products<br>(Avgift på farmasøytiske spesialpreparater) |
| 381 | Surplus of Norwegian Pools Limited<br>(Overskott i Norsk Tipping A/S) |
| 382 | Excise on Race-Tracks<br>(Totalisatoravgift) |
| 383 | Tax on Lotteries<br>(Lotteriavgift) |
| 385 | Tax on Document (property)<br>(Dokumentavgift) |
| 391 | Export Duties on Fish and Fish Products, volume taxes<br>(Utførselsavgift på fisk og fiskeprodukter, volumavgifter) |
| **VV** | ***Ad Valorem* Taxes Collected from Wholesale and Retail Trade** |
| 311 | Tax on Fish etc. for Price Regulation<br>(Avgift på fisk m.v. for prisregulering) |
| 324 | Purchase Tax on Spirits and Wine<br>(Omsetningsavgift på brennevin og vin, verdiavgift) |
| 326 | Surplus of the Norwegian Wine and Spirit Monopoly<br>(Overskudd i A/S Vinmonopolet) |
| 392 | Export Duties on Fish and Fish Products, *ad valorem* taxes<br>(Utførselsavgift på fisk og fiskeprodukter, verdiavgifter) |
| **SPX** | **Indirect Volume Subsidies Directed against Producers** |
| 612 | Consumer Subsidies on Milk and Milk Products<br>(Forbrukersusidier på melk og melkeprodukter) |
| 632 | Regional Subsidies on Milk<br>(Distriktstilskudd på melk) |
| 691 | Regional Production Subsidies on Grain<br>(Geografisk produksjonstilskudd for korn) |
| 693 | Regional Subsidies to North Norway for Potato Raising<br>(Distriktstilskudd for Nord-Norge til potetdyrking) |

| | |
|---|---|
| 694 | Subsidies on Beef and Mutton<br>(Tilskudd til storfe og sauekjøtt) |
| 696 | Subsidies for Early Slaughtering of Sows<br>(Tilskudd til førtidsslakting av purker) |
| 697 | Regional Subsidies on Fuits, Berries and Vegetables<br>(Distrikts- og kvalitetstilskudd på frukt, bær og grønnsaker) |
| 698 | Contract Support on Eggs<br>(Kontraktstilskudd på egg) |
| 699 | Subsidies for Early Slaughtering of Hens<br>(Godtgjørelse for førtidsslakt av høner) |
| **SVX** | **Indirect Volume Subsidies Directed against Wholesale and Retail Trade** |
| 610 | Compensation of Value Added Tax on Food<br>(Kompensasjon for merverdiavgift på matvarer) |
| 614 | Other Consumer Subsidies on Food<br>(Andre pristilskudd, matvarer) |
| 616 | Support by the Price Directory Fund<br>(Tilskott over prisdirektoratets fond) |
| 619 | Consumer subsidies on milk and milk products and compensation for VAT on milk, cheese and meat, from 2001<br>(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<br>(Forbrukersubsidier på brensel og drivstoff, varehandel) |
| **SPV** | ***Ad Valorem* Subsidies Directed against Producers** |
| 671 | Subsidies for Education<br>(Subsidier til utdanning) |
| 672 | Subsidies for Research<br>(Subsidier til forskning) |

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