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# Energy Taxation in a Small, Open Economy: Efficiency Gains under Political Restraints

**Abstract:**
Welfare analyses of energy taxes typically show that systems with uniform rates perform better than differentiated systems, especially if revenue increases can be recycled via cuts in more distortionary taxes. However, in the practical policy debates, the scope for efficiency gains is traded against industrial concerns. A major explanation to the widespread use of exemptions in energy tax systems has to be sought in the fact that energy-dependent industries tend to constitute powerful lobby groups. Presumably, energy-dependent industries of small, open economies will suffer relatively strongly if taxed, and compensating them will be costly. This CGE study of the case of equalising the Norwegian electricity tax shows that compensating the energy-intensive export industries is surprisingly modest. It is explained by the role of the Nordic electricity market, which is still limited enough to respond to national energy tax reforms. Thus, electricity price reductions partly neutralise the direct impact of the tax on profits. We also examine the effects of different compensation schemes and find significant compensation cost reductions when the scheme is designed to release productivity gains.

**Keywords:** Energy taxes, Electricity markets, Competitiveness, Compensation, CGE models

**JEL classification:** F41; H21: Q43; Q48

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## 1. Introduction

Much of the empirical literature finds that energy tax exemptions and concessions tend to be costly compared to uniform taxation (Böhringer and Rutherford, 1997; Ekins and Speck, 1999; Felder and Schleiniger, 2002; and Bye and Nyborg, 2003). This result is reinforced if also accounting for that the implicit renouncement of tax revenue could be used to cut other, more distortionary taxes; see contributions in Goulder, Parry and Burtraw (1997), Farrow (1999), Fullerton and Metcalf (1998), Parry, Williams and Goulder (1999), and Bovenberg (1999). In spite of these findings, several countries have exempted selected energy-dependent industries from energy taxation. In most cases, a major explanation has to be sought in the fact that these industries constitute powerful lobby-groups. An interesting question arising from this apparent trade-off situation between overall efficiency and industrial distribution arguments, is whether uniform taxation is still welfare enhancing if combined with compensation schemes that alleviate the political pressure from powerful industry interests.

Existing studies of large economies have come to rather optimistic conclusions. In a study of a uniform $CO_2$ tax in the U.S. case, Bovenberg and Goulder (2001) find that the welfare gain is reduced by only a tenth, if the reform is supplied by compensation for profit losses in the American energy industry. Böhringer and Rutherford (1997) find that avoiding lay-offs in the German energy industry is less costly when combining a uniform $CO_2$ tax with wage subsidies to the industry than when using $CO_2$ tax exemptions. In both cases, the energy producers are able to shift most of the $CO_2$ tax burden on to their customers through increases in their producer prices. Thus, after compensation, significant parts of the revenue are still left for cuts in other, distortionary tax wedges. A crucial assumption behind these results is that the regulating country is sufficiently large in the markets for energy products to affect the prices.

However, the smaller, and more open, the country, the more exposed will firms be to externally given world market prices and conditions, and the smaller will be the scope for shifting tax burdens on to demanders or suppliers through price incidences. We examine a case where the Norwegian energy-intensive export sector is included into the electricity tax system. The sector, comprising the three industries producing *Metals*, *Pulp and paper articles*, and *Industrial chemicals*, enjoys several concessional policy measures, including low payroll taxes motivated by its peripheral location, low electricity prices according to favourable long-term power contracts, and exemptions from energy taxes applying to both the consumer tax on electricity and the $CO_2$ tax on process-related emissions. As the sector is first of all consuming energy in the form of electricity this analysis focuses on the electricity tax system. Its electricity consumption constitutes almost 1/3 of the country's total. In the present electricity tax system, all manufacturing industries are exempted, while final consumers, primary industries, and service industries, including transportation and construction, pay a rate of 1.2 Euro-cents/KWh. As the current electricity production is mainly based on hydropower, the expressed arguments for taxing electricity consumption are protection of the waterfall environments, along with revenue rising. It is anticipated that power based on natural gas will turn profitable within the next decades and reinforce the environmental arguments.

As for fossil fuel taxation, previous analyses indicate that the trade-off issue between efficiency and political feasibility is relevant to the Norwegian electricity policies. Bye et al. (1999) find that a more uniform electricity price would improve welfare, but at the expense of the energy-intensive export sector. The sector is politically influential primarily due to its role as the most important generator of export revenues besides the oil and gas sector, as well as to its location. It contributes with between 10-15 percent to the Norwegian total. Its high degree of exposure to internationally given product prices makes the sector highly vulnerable to cost changes. In addition, they buy their input of power in an electricity market that has undergone major liberalising efforts the last decade and is now fully integrated into a Nordic market. Similar processes have taken place in several electricity markets recently, with the Nordic market as a pioneer in many respects (see Wolak, 2000 for a survey). By analysing an introduction of the electricity tax in the manufacturing industries by means of a dynamic, numerical equilibrium model, we find a compensation cost amounting to between 16 and 44 percent of the welfare gain associated with the tax uniformation. The cost depends on the design of the compensation scheme, in particular on the degree of productivity gains released by the scheme. Characteristics of the Norwegian manufacturing industries are consistent with presence of monopolistic competition among firms producing varieties of different characteristics. Given that increasing the number of varieties increases the efficiency value of the good (Dixit and Stiglitz, 1977), compensation costs will be reduced if compensation is offered in a manner that avoids exit of firms from the energy intensive export sector (or encourages entry).

Irrespective of the nature of the compensation scheme, the compensation costs turn out to be surprisingly low and will far from erode the welfare gain of the reform. The main explanation is that there still remains scope for the Norwegian demand and supply impulses to influence the Nordic market prices of electricity. Sensitivity tests show that the role of the electricity market is important. With no flexibility in international trade in electricity, the compensation costs fall to a third, while a hypothetical world market regime with completely externally determined electricity prices leaves little scope for tax incidence and compensation costs more than doubles.

The paper proceeds by presenting the methodological aspects of the analysis in Section 2, including the basic feature of the computable general equilibrium model. Section 3 outlines and explains the results and illustrates their sensitivity to the electricity market openness and the compensation scheme design. Section 4 concludes.

# 2. Method

## 2.1 The design of the analysis

The main question posed in this analysis is whether costs of compensating the Norwegian energy-intensive export sector tend to offset, or even exceed, the welfare potential of an energy tax reform. We answer this by simulating three reform scenarios on a dynamic CGE model for Norway. In the *Reference Reform Scenario* (Scenario 1A) the current electricity tax exemptions of the manufacturing industries are abolished. In two *Full Reform Scenarios* (Scenarios 1B and 1C), the same electricity tax reform is accompanied by compensation schemes designed to neutralise the loss of pure profit rents within the energy-intensive export sector.[1]

The compensation schemes of the two full reform scenarios differ in design. In scenario 1B, we transfer the subsidy lumpsum to those firms remaining in the sector in spite of the tax changes. This corresponds to a case where the lobby groups tend to be dominated by, and to work in the interests of, the largest and most efficient firms. It implies that the subsidies compensate the profit of the sector as a whole. In scenario 1C, the compensation is given as a subsidy to all producers operating in the sector before the tax reform, according to their profit loss. All reform scenarios are changes from a business-as-usual (BAU) scenario. The BAU is

[1] One could argue that profit losses faced by foreign owners can be left out of the Norwegian welfare accounting, and, analogously, that compensation to foreigners should be counted as welfare losses. In the full reform, the foreign profit losses in the energy intensive export sector, and their compensation, offset each other and eliminate the problem.

a 50 years' projection of the Norwegian economy.[2] Policy variables are kept at their (real) 1999 levels, and, in particular, all manufacturing industries are exempted from the electricity tax.

Compared to the BAU scenario, the reference reform in 1A consists of two components:

*i)* *The electricity tax component:* The manufacturing industries are faced by an electricity tax at the same level as the tax already imposed on households and remaining industries.

*ii)* *The electricity tax revenue recycling component:* The revenue is recycled back through a uniform percentage pay roll tax rate decrease for all firms.

In scenario 1B, these reform components are supplied by the simultaneous introduction of a non-distortionary subsidy. Thus, compared to BAU, the reform will also influence through:

*iii)* *The compensation financing component*: The revenue from the electricity tax is shortened in order to finance a subsidy that exactly compensates for the profit losses in the energy-intensive export sector. The joint effect of *ii)* and *iii)* in this scenario thus results in a smaller percentage pay roll tax rate decrease (compared to BAU) than following from *ii)*, alone.

In scenario 1C, where subsidies are handed out to *all* firms operating in BAU, the subsidy will, in itself, hamper exit. Consequently a fourth reform component also generates effects in this scenario:

*iv)* *The compensation subsidy component*: The subsidy wedge has efficiency effects.

The compensation cost constitutes the difference between the welfare results of the full reforms (1B and 1C) and the reference reform (1A).

We measure welfare by the total discounted utility of the household in each period, where utility is an aggregate of material consumption and leisure. We let the welfare effect in scenario 1A, compared to the BAU scenario, serve as a reference for the compensation cost. Note that the difference between the compensation costs in 1C and 1B is the effects from *the compensation subsidy component* in *iv)*. Thus, these scenarios can also be utilised to split the

[2] Most assumptions are in accordance with the Long Term Programme of the Norwegian government; see Norwegian Ministry of Finance (2001).

compensation costs in 1C into *iii) the compensation financing component* and *iv) the compensation subsidy component*.

We supply these scenarios with sensitivity simulations that shed light on the role of the tax incidence in the electricity market. According to our hypothesis, in particular the openness of the electricity market is decisive for the compensation costs in a small, open economy as the Norwegian. We thus test the sensitivity of the results to the degree of the electricity market openness. In the scenarios labelled 2, the *reference* and the *full* energy tax reform, respectively, are simulated within a hypothetical, nationally closed electricity market regime (where trade flows are inflexible), while in scenarios 3 they are simulated in a hypothetical situation with a fully liberalised world market for electricity where prices are exogenous.

## 2.2. Basic features of the computable general equilibrium model

### *2.2.1 General features*

The employed numerical intertemporal general equilibrium model for the Norwegian economy gives a detailed description of the structures of economic policy, production, and consumption in the Norwegian economy. The model has 41 private and 8 governmental production activities, all listed in appendix A, and 26 consumer goods. A more detailed description of the model is found in Bye (2000) and Fæhn and Holmøy (2000).

### *2.2.2. Consumer behaviour*

Consumption, labour supply and savings result from the decisions of an infinitely lived representative, forward-looking consumer, who maximises present value of utility subject to an intertemporal budget constraint (the model of consumer behaviour is described in more detail in appendix B.1). Utility originates from material consumption and leisure consumption, according to an Origo-adjusted Constant Elasticity of Substitution function (OCES); see Bye (2003). The material consumption is allocated across 26 different consumer goods in a nested OCES function (see figure B.2, appendix B); see Wold (1998). The OCES specification allows the income elasticities to vary among goods.

### *2.2.3. Producer behaviour, technology and product markets*

Producer behaviour is generally specified at the firm level. Holmøy and Hægeland (1997) provide a detailed description. The structure of the production technology is represented by a nested tree-structure of CES-aggregates given in figure B.1, appendix B. All factors are completely mobile and malleable[3]. The manager of the firm is assumed to be rational and forward-looking and maximise the present value of the cashflow to owners; see details in Holmøy, Larsen and Vennemo (1993) and Holmøy, Nordén and Strøm (1994).

The domestic market structure is assumed to be "large group case of monopolistic competition", where each firm has some market power in their respective home markets. Markups are calibrated according to empirical analyses that find evidence for markup pricing by Norwegian firms (Klette, 1994 and Bowitz and Cappelen, 2001). Each firm produces a variety of a product that is an imperfect substitute for other varieties of this product (represented by Spence-Dixit-Stiglitz preferences). The elasticity of substitution among the varieties of a product is calibrated to be consistent with the estimated markup ratios.[4]

In the world markets prices are assumed to be unresponsive to domestic demand and supply, and domestic firms have no market power. The export markets and the home markets are assumed segregated, due to firms' adjustment costs of reallocating deliveries between the two markets. Quite analogously, there is imperfect substitution between domestic and imported products according to the Armington hypothesis.

The sector-specific number of firms and varieties is determined by an entry-exit condition, which requires that the after-tax pure profit of the marginal, least efficient firm equals a fixed entry cost. The present value of all future fixed costs represents the necessary investments in entrepreneurship (knowledge, network, risk etc.) in order to enter the industry. The pure rent origins from decreasing returns to scale, as well as the markup on marginal costs in the production for the domestic markets.

The only import and export price that responds to changes in domestic behaviour is the electricity price. The Norwegian electricity market is part of a Nordic, competitive market and domestic supply and demand empirically affect the market price. The sensitivity of the electricity price to Norwegian net import is estimated by using simulated data from a numerical, Nordic electricity market model (NORDMOD); see Aune and Hansen (2004). Johnsen (1998) documents the NORDMOD model. The current Norwegian supply of electricity is based on hydropower. This supply is assumed to grow exogenously, but at a decreasing rate,

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[3] One exception is the production of electricity, see Holmøy, Nordén and Strøm (1994).

[4] In order to maximise profits, the firm sets the markup ratio eqal to $\sigma/(\sigma-1)$, where $\sigma$ is the substitution elasticity among varieties.

to represent the limited possibility to develop new hydropower capacity. Along the paths, gas power capacity is introduced as a back- stop technology when the electricity price exceeds the marginal cost of expanding the gas power capacity.

#### *2.2.4. The government*

The government collects taxes, distributes transfers, and purchases goods and services from the industries and abroad. Overall government expenditure is exogenous and increases at a constant rate. The model incorporates a detailed account of the government's revenues and expenditures. In the policy experiments it is required that the nominal deficit and real government spending follow the same path as in the baseline scenario, implying revenue neutrality in each period.

# 3. Results

## 3.1 The Reference Reform: Effects of equalising the electricity tax.

As outlined in Section 2.1, the reference reform consists of two components. Firstly, extending the electricity tax base to include *all* electricity consumption implies a shift in input prices on electricity for all manufacturing industries. Secondly, the additional revenue generated by implementing the reform is recycled back to the economy through uniform percentage cuts in the pay roll tax rates, which affect labour costs in all industries. The direct increase in the input prices of electricity of 1.2 Eurocents/KWh, measured in 1999 real values, represents an electricity price increase in most manufacturing industries of about 30 percent along the path. For the energy-intensive export sector the relative electricity price increase is sharper, as they initially enjoy low electricity prices, partly due to lower distribution costs per KWh, and partly due to favourable, long-term price contracts with the government. These contracts expire in 2010. In the first year, the direct price increase amounts to 60 percent as an average for the energy-intensive export sector, while the increase is 47 percent in the long run (steady state). The revenue recycling implies that the payroll tax rate drops by almost 6 percent in the long run (somewhat more in the earlier periods).

In the long run, the macroeconomic responses to these reform elements can be described by a reduced-form, two-equation presentation of the model. It focuses on two main equilibrium conditions, the labour market equilibrium and the intertemporal constraint on net foreign wealth, which implies that current account must be zero in the long run in order to prevent net wealth from exploding. We refer to Fæhn and Holmøy (2000) for a more comprehensive explanation to the two-equation representation of the CGE model.

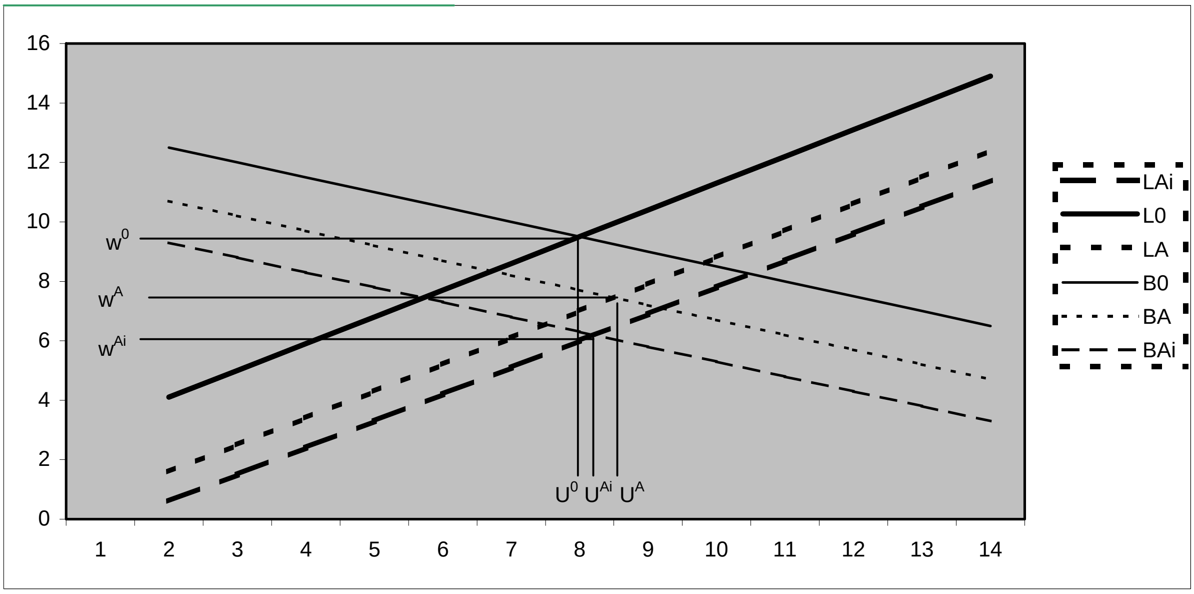
In figure 3.1, the BAU labour market equilibrium is illustrated as an upward sloping locus, $L^0$, in the plane defined by the two variables, the utility level, *U* and the wage rate, *w*. The slope mirrors that an isolated increase in *U* would increase consumption and contribute to excess demand for labour, and that a simultaneous rise in *w* would be necessary in order to restore the labour market equilibrium.The current account restriction is represented as a downward-sloping locus, $B^0$, implying that increased *U*, cet. par., would deteriorate the Norwegian current account through import leakage and would have to be neutralised by improved competitiveness through reduced *w*. The BAU equilibrium is marked in the intersection of the two loci, in ($U^0$,$w^0$).

Effects of the first reference reform component, the electricity tax shifts, are reflected by the intersection point ($U^{Ai}$,$w^{Ai}$) in Figure 3.1. Increasing the electricity tax imposed on manufacturing industries has the direct effect of increasing their marginal costs. The labour market equilibrium is affected by subsequent shifts in both demand and supply. The downscaling of manufacturing output reduces labour demand. Labour supply is reduced, though not to the same scale, along with an increase in domestic prices and a subsequent drop in real wages. All in all, the immediate effect of the tax increase, prior to equilibrium adjustments, is to create unemployment. This is illustrated by the downward shift in the labour market locus to $L^{Ai}$. The interpretation of the downward shift is that for a given U, *w* would have to fall, or equivalently, for a given *w*, *U* would have to rise. A fall in *w* has the effect of discouraging supply and stimulating demand of labour, thus restoring the labour market balance. Accordingly, a rise in *U* would imply higher demand for leisure, which reduces labour supply, as well as higher demand for consumption goods, which raises labour demand.

The other component of the reference reform, the decrease in the payroll tax rates, has the opposite effect on the labour market: Payroll tax reductions stimulate labour demand (more than labour supply) and thus tends to counteract the labour demand deficit and the reactions in *w* and *U*. The effect of this reform component in the labour market is illustrated by the modifying shift from $L^{Ai}$ to $L^A$ in Figure 3.1.

The current account surplus must be zero in the long run (steady state). The electricity tax component of the reference reform has the direct effect of reducing competitiveness, especially that of the highly export-oriented energy-intensive industries. This creates a substantial deficit in the current account prior to equilibrium adjustments. As illustrated by the shift in the current account locus from $B^0$ to $B^{Ai}$, this implies that for a given *U*, *w* would have to fall, or equivalently, for a given *w*, *U* would have to fall in order to fulfil the current account restriction. The reasons are that lower wages restore competitiveness, while lower utility implies lower import leakage in consumption. Both mechanisms improve the trade balance and the current account. The effect on the current account of the simultaneous payroll tax cuts in the reference reform is, as for the labour market, to modify the effects on the current account and the required reactions in *w* and *U*. Thus, a counteracting shift from $B^{Ai}$ to $B^A$ occurs.

**Figure 3.1: The reference reform: Determination of long run utility level and wage rate.**




All in all, the electricity tax shifts are the dominating, and the reference reform implies a 0.7 percent fall in *w* in the steady state in scenario 1A compared to the BAU; see Table 3.1. The net effect on long-run utility is slightly positive: The simulations result in a steady-state increase of 0.08 percent. Such low-scale reactions are expected, as the tax changes in these experiments are modest.

All other steady state changes follow - see Table 3.1. The downscaling of the energy-intensive export sector and the gas power generation has strong implications for the capital demand, as these sectors are highly capital-intensive. Thus, investments fall. Capital stock in the long run drops by 0.38 percent. This, along with a reduction of labour supply of 0.06 percent due to the wage drop, explains the long-run GDP fall of 0.35 percent. This mostly takes place in the energy-intensive export sector, while other industries, including other manufacturing industries, increase their output due to several cost-reducing elements, as payroll tax decreases, wage decreases, reduced user costs of capital, and reductions in the Nordic electricity price. The latter takes place as a consequence of the downscaling of the energy-intensive export sector, which leads to a substantial reduction in electricity demand. Net export of electricity increases, and compared to the BAU scenario, the introduction of gas power is delayed by 5 years (from 2012 to 2017). This reduces the Nordic (pre-tax) price of electricity by between 5 to 10 percent in periods before gas power is introduced. When gas power is introduced, the price is determined by the long-term marginal cost of expanding gas power capacity, and it settles on a virtually constant level similar to the BAU. For all industries, except the energy-intensive export sector, the impacts of the several cost-reducing elements dominate and explain their growth.

**Table 3.1: Effects of the reference reform (1A); changes from the BAU scenario.**

| | **2010** | **2030** | **Steady state** |
|---|---:|---:|---:|
| **GDP** | -0.02 | -0.17 | -0.35 |
| **Real Capital** | -0.10 | -0.45 | -0.38 |
| **Material consumption** | 0.03 | 0.09 | 0.09 |
| **Labour supply** | 0.07 | -0.02 | -0.06 |
| **Utility** | -0.01 | 0.06 | 0.08 |
| **Nominal wage rate to workers** | -0.33 | -0.62 | -0.70 |
| **Price of material consumption** | -0.52 | -0.74 | -0.77 |
| **Export** | -0.87 | -2.22 | -4.20 |
| **Import** | -1.00 | -1.52 | -1.26 |
| **Payroll tax rate** | -5.2? | -7.0? | -5.60 |
| **Pre-tax electricity price** | -6.60 | -1.20 | -1.00 |
| **Electricity price (Metals industry)** | 36.3 | 49.9 | 49.6 |
| **Gross production (Metals industry)** | -14.4 | -21.5 | -27.6 |
| **Pure profit, most efficient firm (Metals industry)** | -17.2 | -25.7 | -32.8 |

The welfare gain of this reference reform, measured as the current value of utility changes in all periods, is 0.04 percent, which is substantially lower than the long-run impact on the utility level. This reflects that a substitution of consumption of leisure, goods and services towards later periods takes place. During the first decade, the utility hardly changes, before it starts increasing gradually. This mirrors that the consumer prices drop less in the earlier periods than in the steady state. The production drop in the energy-intensive export sector is weaker in early periods, due to the drop in the pre-tax price of electricity, implying a weaker downward pressure on wages. Wages has a strong impact on the costs of living, both directly on the price of leisure, and indirectly through prices of goods and services. The dynamics of the electricity price, which show a fall only until gas power is exploited (in 2017), work in the opposite direction, but is not that important in the cost of living index.

Besides the fact that the reform is minor in an economy-wide perspective, the small welfare outcome is due to various allocation effects pulling in opposite directions. The reform implies reductions of two price wedges in the economy, which, in isolation, tend to improve welfare.

The first is the initial electricity price discrimination between different industries; the second is the reduction of the, initially considerable, taxation of real labour income. When comes to the first, approaching an equal electricity price among industries will allocate relatively more electricity input into other industries than the energy-intensive export sector. Besides the initial electricity tax exemptions, there are other reasons why redirecting resources away from the energy-intensive export sector will contribute to improve efficiency. They also enjoy other favourable policy measures, as long-term, concessional electricity contracts, and low pay-roll taxes, based on their peripheral location. In addition, since domestic prices include a mark-up due to monopolistic competition, whereas exports are sold to marginal cost prices, there will be efficiency gains from redirecting deliveries into the imperfectly competitive domestic markets. A reallocation of resources from the heavily export-reliant energy-intensive industries to industries oriented towards the domestic markets has this effect.

Reducing the wedge between the social marginal utility of leisure and the social marginal utility generated by labour also has a potential welfare-enhancing effect. In the Norwegian economy, the initial wedge is substantial and consists of a marginal tax on labour income, approximating 40 percent on average, indirect consumer taxes, including the VAT averaging 22 percent, and the payroll tax, averaging about 13 percent, and a 5 percent mark-up in the domestic industry. A reduced tax wedge will contribute to stimulate employment and improve welfare. Employment increases during the first decade. However, received real wages also respond to other pressures than the pay roll tax reduction, as described above. In the longer run, real wages are almost unaffected and the stimulation of labour supply vanishes and employment actually falls slightly. Irrespective of the net sign, the welfare contribution from the changes in the labour market is of little significance.

Finally, the reform is associated with a modest terms-of-trade loss that pulls the welfare gain downwards. The only international price that responds to domestic behaviour is that of electricity, which drops until 2017, as explained above. As Norway is a net exporter of electricity in the reference reform scenario, this reduces welfare.

## 3.2. The Full Reform: Effects of the compensation

### *3.2.1. The role of the compensation scheme design*

We quantify the costs of compensating the energy-intensive export sector through subsidy transfers equal to the loss of pure profit rents in the sector. The compensation thus aims at maintaining the remuneration of the entrepreneurship within the sector. We investigate the compensation costs in case of two different ways of compensating, differing with respect to their effect on exit and, thus, the external productivity gains.[5] Comparing results between the reference reform in 1A and the two full reform cases reveals that introducing compensation causes the gain in discounted future utility to fall by 44 percent when productivity gains are left out, while the fall is only 16 percent when *love-of-variety* effects are accounted for.

**Table 3.2: Effects of the full reform with lumpsum subsidies (1B); % changes from the BAU scenario.**

| | 2010 | 2030 | Steady state |
|---|---|---|---|
| GDP | -0.06 | -0.24 | -0.64 |
| Real capital | | | |
| Material consumption | -0.03 | 0.01 | -0.10 |
| Labour supply | 0.02 | -0.11 | -0.32 |
| Utility | -0.02 | 0.04 | 0.05 |
| Nominal wage rate to workers | -0.55 | -0.89 | -1.23 |
| Price of material consumption | -0.53 | -0.79 | -0.63 |
| Export | -0.92 | -2.31 | -4.60 |
| Import | -1.05 | -1.58 | -1.32 |
| Payroll tax rate | -2.80 | -4.00 | 2.60 |
| Pre-tax electricity price | -6.60 | -1.20 | -0.90 |
| Electricity price, Metal industry | 36.2 | 49.9 | 49.5 |
| Pure profit, most efficient firm, Metal industry | -17.2 | -25.7 | -33.1 |
| Nb. of firms, Metal industry | -7.12 | -9.57 | -10.7 |
| Gross production, Metal industry | -14.4 | -21.6 | -28.0 |

In scenario 1B the changes in resource allocation and welfare are associated with the financing of the subsidy; see component *iii)* referred to in Section 2.1. Compared to the reference

[5] The model also takes heterogeneity of firms into account, by assuming that the most efficient firms enter the industries first and that the less efficient leaves first in case of contraction. This characteristic counteracts the productivity effects associated with *love-of-variety* somewhat. Possible negative productivity contributions from *creative destruction* (Aghion and Howitt, 1992) are not modelled.

reform (1A), less of the electricity tax revenue can be recycled to the economy via reduced payroll tax. The welfare reduction of reserving revenue for subsidies (with no welfare potential) instead of cutting pay roll taxes, originates first of all from the large difference between the social marginal utility of leisure and the social marginal utility generated by labour in the Norwegian economy. The fall in labour supply in 1B compared to 1A (see Tables 3.2 and 3.1), thus, implies welfare losses that contribute significantly to explain the financing costs.

In scenario 1C, the compensation costs are reduced to 16 percent of the welfare gain. This reflects that the isolated effect of *the compensation subsidy component* in *iv)* is positive and partly offsets *the compensation financing component* in *iii)*, see Section 2.1. The reason is that the only real effects of *the compensation subsidy component* arise from the external productivity gain of hampering exit. The number of firms is maintained at a higher level than in scenario 1B. *Love-of-variety* effects generate a reduction in the producer price index of the energy intensive export sector, which benefits both domestic producers that use products from the energy-intensive export sector as inputs (through productivity increases), and consumers who consume their products as final products (through utility increases). Table 3.2. and 3.3. report some information on the Metal industry, which constitutes the largest of the industries in the energy-intensive export sector. Comparison reveals that while production in the industry is almost unaffected by variations in the compensation scheme, the number of firms are maintained as in BAU in Scenario C, while it falls by 10.7 percents compared to BAU in Scenario B. The number of firms also falls in the other industries within the energy-intensive export sector, though less. An increase in the number of firms in expanding industries is not large enough to offset the productivity gain.

Our estimates illustrate that the distribution of subsidies matters, also when pure efficiency effects are considered. In our case the subsidy should be distributed so as to keep up the number of firms in the industry. We recognise that the optimal scheme will vary from case to case, dependent on what are the potential sources of productivity gains. Economies of scale would, for instance, call for a system able to stimulate large-scale production. Further, given that a *love-of-variety* model is suitable for the actual case, the model parameters must be regarded as uncertain. Comparing scenarios 1B and 1C is thus a useful sensitivity test of the numerical contribution of the *love-of-variety* effect.

**Table 3.3: Effects of the full reform with productivity gains (1C), % changes from the BAU scenario.**

| | 2010 | 2030 | Steady state |
|---|---|---|---|
| GDP | -0.04 | -0.21 | -0.62 |
| Real capital | | | |
| Material consumption | -0.01 | 0.03 | -0.07 |
| Labour supply | 0.02 | -0.11 | -0.33 |
| Utility | -0.01 | 0.05 | 0.06 |
| Wage rate | -0.458 | -0.785 | -1.141 |
| Price, material consumption | -0.47 | -0.67 | -0.57 |
| Export | -0.86 | -2.21 | -4.57 |
| Import | -0.98 | -1.51 | -1.26 |
| Payroll tax rate | -2.80 | -4.00 | 2.60 |
| Pre-tax electricity price | -6.40 | -1.00 | -0.60 |
| Electricity price, Metal industry | 36.6 | 49.9 | 49.6 |
| Pure profit, most efficient firm, Metal industry | 0 | 0 | 0 |
| Nb. of firms, Metal industry | 0 | 0 | 0 |
| Gross production, Metal industry | -13.0 | -20.2 | -27.3 |

Irrespective of the *love-of-variety* contribution, we assess the compensation cost estimates to be relatively small, considering the strong degree of openness of the Norwegian economy. This reflects that the subsidy required, i.e. the profit loss of the energy intensive export sector, is small. Tax incidence effects are the main explanation. True, the possibility to shift taxes on to costumers is very limited for the Norwegian energy-intensive export sector. Export shares are high and export prices are given in the world markets. We identify some effects on prices of domestic deliveries, as well, but these are of little significance, as domestic deliveries constitute only 16 percent[6] of the sector's output.

The main burden shifting takes place on to suppliers of electricity. In periods before gas-power utilisation is profitable, the pre-tax price on electricity is reduced with about 5-10 percent. About 30 percent of the tax burden is shifted on to producers of electricity in these periods. This tax shifting is, however, gradually diminishing along the path. The mechanism turn out to be more or less analogous to the effects in Bovenberg and Goulder (2001). Their result

[6] This refers to the long-run benchmark solution.

depends on the possibility for the energy producers to shift the tax burden on to consumers, ours on the possibility for the energy consumers to shift tax burden on to input suppliers. The effect in Böhringer and Rutherford (1997) is also somewhat similar, though their compensation scheme is different; they use wage subsidies. They find that supplying a uniform $CO_2$ tax in Germany with compensation even tends to *increase* welfare, in other words they identify *negative* compensation costs. Their experimental reform is very different from ours, not least due to the fact that their compensation scheme increases the energy tax rate and thus their recycling effects. (Their reforms are performed for a given economy-wide emission level, while ours have similar tax rates.) Nevertheless, the electricity market is closed in their simulations and tax incidence effects important. We now proceed by analysing the role of the electricity market regime in more detail.

#### *3.3.2 The role of the electricity market openness*

In order to test the sensitivity of the compensation cost results to degrees of tax incidence in the electricity market, we introduce the same reforms in electricity market regimes that are, respectively, more and less open than the current Nordic market. The sensitivity tests are performed for the cases including the *love-of-variety* effects. Scenarios labelled 2 reflect the case of a closed electricity market. Trade flows are inflexible and the electricity price elasticities higher than in the main scenarios 1. In scenarios 3, we simulate the same reforms in an electricity market where prices are externally fixed. This will simulate a hypothetical, fully open electricity market, where profit losses cannot be neutralised by pre-tax electricity price reductions.

The main difference between introducing the electricity tax rate to the energy-intensive export sector in a regime where electricity is not traded abroad (scenarios 2) and in the main regime, when electricity is traded (scenarios 1), is the response in the pre-tax price of electricity in periods before gas-power is utilised. The computations for 2010 are reported in Table 3.4. Since the supply of electricity is fixed before gas-power sets in, the pre-tax price of electricity drops by 13.4 percent in scenarios 2 relative to 1. The accentuated pre-tax electricity price reactions reduce the electricity price increase faced by the energy intensive export sector. In the Metal industry, electricity prices turn out 22.9 percent lower in case 2 than in case 1. Lower costs of taxation borne by the industry imply smaller loss of profit. In the most efficient firm, the pure profit loss falls by 61.0 percent compared to that of case 1. Hence, as anticipated, the revenue needed to compensate for profit losses is lower in a closed electricity market regime than in the Nordic market regime. We find that the necessary compensation cost (in terms of reduction in the welfare gain in the corresponding scenarios without compensation) is 29.0 percent lower in this new regime. Along with a smaller subsidy, more revenue is available for payroll tax reductions. This is socially beneficial, because of the large tax wedge related to labour. However, the lower need for subsidies in this scenario compared to the scenario where electricity is traded abroad, also means a lower stimulation of entry into the energy-intensive export sector and less contribution from positive external effects of entry.

**Table 3.4: Sensitivity of results to degree of electricity market openness, % changes from the main case**

| | Closed market | Fully open market |
|---|---|---|
| 2010:<br>Pre-tax electricity price | -13.4 | 6.5 |
| 2010:<br>Electricity price, Metal industry | -22.9 | 11.9 |
| 2010:<br>Pure profit loss, Metal industry, most efficient firm | -61.0 | 32.2 |
| Compensation cost | -29.0 | 225.0 |

In regime 3, with a hypothetical, fully open world market for electricity, the conclusions are turned around. There will be no scope for tax incidence in the electricity price even in the short run. Thus, compared to the main Nordic market regime in scenario 1, the pre-tax electricity price in 2010 renders 6.5 percent higher. This implies a higher electricity price paid by the energy intensive export sector; for the Metal industry the rise is 11.9 percent compared to the main case. The profit fall in the energy-intensive export sector increases in the early periods; in 2010 by 32.2 percent in the Metal industry. Hence, the revenue needed to compensate for their profit losses is higher compared to in the Nordic market regime. As a result, the compensation cost in the fully open regime is 2.25 times higher than in the Nordic electricity market scenario.

# 4. Conclusions

Given that today's favouring of the energy intensive export sector is an unavoidable part of the Norwegian political surroundings, this analysis shows that there may exist other, less expensive, ways of keeping up profits than exempting the sector for electricity taxes. Equalising the electricity tax and at the same time compensating for the profit losses is welfare improving compared to the current system. The modest costs associated with compensating the energy intensive export sector are surprising, because the sector is highly reliant on prices given externally at the world markets and has little scope for shifting tax burdens on to customers. We do, however, identify a tax shifting on to suppliers of electricity in the Nordic market. The market, though internationalised the last decade, still responds considerably to Norwegian policy changes. Electricity markets are, however, in a process of deregulation and expansion in several areas, and this will tend to increase the political costs of removing energy tax exemptions within several countries.

We also point out the advantage of designing schemes that release possible productivity externalities within the sector. Stimulating entry of new firms may have such effects, either through *love-of-variety* effects, as in our model, or through other productivity-enhancing mechanisms like creative destruction or embodied technological change.

Our study also reveals that the welfare gains of removing the Norwegian electricity tax exemptions are small. This could be an argument for keeping today's system intact. But the system also has other disadvantages: Recently, the Surveillance Authorities of EFTA (ESA) has questioned the legacy of the Norwegian discriminatory practice and claimed that it conflicts with the competition rules of the European Economic Area. We have restricted our analysis to how distributional and efficiency concerns can be combined. The challenges from ESA also arise other questions, as how concerns for practicability and legality can be accounted for. These are the beyond the scope of this study.

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**Appendix A**

**Table A.1: Production Activities in MSG-6**

| MSG-6 Code | Production Activities |
|---|---|
| 11 | Agriculture |
| 12 | Forestry |
| 13 | Fishing |
| 14 | Breeding of Fish |
| 21 | Fish Products |
| 22 | Meat and Dairy Products |
| 16 | Grain, Vegetables, Fruit, Oils, etc. |
| 17 | Beverages and Tobacco |
| 18 | Textiles, wearing Appeal and Footwear |
| 26 | Furniture and Fixtures |
| 27 | Chemical and Mineral Products, incl. Mining and Quarrying |
| 28 | Printing and Publishing |
| 34 | Manufacture of Pulp and Paper Articles |
| 37 | Manufacture of Industrial Chemicals |
| 41 | Gasoline |
| 42A | Diesel Fuel |
| 42B | Heating Fuels, Paraffin, etc. |
| 43 | Manufacture of Metals |
| 46 | Manufacture of Metal Products, Machinery and Equipment |
| 47 | Hired Work and Repairs |
| 48 | Building of Ships |
| 49 | Manufacture and repair of oil drilling rigs and ships, oil production platforms etc. |
| 55 | Construction, excl. of Oil Well Drilling |
| 60 | Ocean Transport - Foreign |
| 63 | Finance and Insurance |
| 66 | Crude Oil |
| 67 | Natural Gas |
| 68 | Services in Oil and Gas Exploration |
| 69 | Pipeline Transport of Oil and Gas |
| 71 | Production of Electricity |
| 72 | Power Net Renting |
| 73 | Sales and Distribution of Electricity |
| 75 | Car and Other Land Transportation |
| 76 | Air Transport |
| 77 | Railroads and Electrical Commuters |
| 78 | Ocean Transport - Domestic |
| 79 | Post and Tele Communication |
| 81 | Wholesale and Retail Trade |
| 83 | Dwelling Services |
| 85 | Other Private Services |
| 89 | Imputed Service Charges from Financial Institutions |
| | Government Input Activities |
| | Central Government |
| 92C | Defense Exclusive of Military Submarines and Aircraft |
| 92U | Military Submarines and Aircraft |
| 93S | Central Government Education and Research |
| 94S | Central Government Health-Care and Veterinary Services etc. |
| 95S | Other Central Government Services |
| | Local Government |
| 93K | Local Government Education and Research |
| 94K | Local Government Health-Care and Veterinary Services etc. |
| 95K | Other Local Government Services |

### B.1 Consumer behavior

In year *t* the representative consumer chooses a path of "utility", *F*, by maximizing intertemporal utility given by

$$\text{(B.1)} \quad U_t = \sum_{s=t}^{\infty} (1+\rho)^{t-s} \frac{\sigma_F}{\sigma_F - 1} F_s^{\frac{\sigma_F - 1}{\sigma_F}}$$

subject to the intertemporal budget constraint, see Bye and Holmøy (1997) for further details. $\sigma_F$ is the intertemporal elasticity of substitution in utility. The intertemporal utility maximization gives the demand for utility

$$\text{(B.2)} \quad F_s = \left[\frac{1 + r(1 - t^D)}{1+\rho}\right]^{\sigma_F t} (\lambda PF_s)^{-\sigma_F},$$

where *r* is the world market interest rate on financial wealth, $t^D$ is the tax rate on capital income, $\lambda$ is the marginal utility of wealth and *PF* is the ideal price index of utility. Utility is a CES-composite of material consumption, *C*, and leisure, *LE*. The corresponding ideal price index is given by

$$\text{(B.3)} \quad PF_s = \left[\alpha_C PC_s^{(1-\sigma_C)} + (1-\alpha_C)\left(\frac{PLE_s}{1+g}\right)^{(1-\sigma_C)}\right]^{\frac{1}{1-\sigma_C}},$$

where *PC* is the price index of material consumption and *PLE* is the price of leisure (net of tax wage rate) measured in efficiency units such as labor, implying that the price of leisure must be adjusted with *g*, the factor augmenting technical change. $\sigma_C$ is the elasticity of substitution between material consumption and leisure, and $\alpha_C$ is the intensity parameter for material consumption. In each period utility is distributed between leisure and material consumption, see Bye (2003) for further details.

### B.2 Intertemporal equilibrium

A necessary condition for reaching a steady state solution is

$$\text{(B.4)} \quad 1 + r(1 - t^D) = (1+\rho)(1+g)^{\frac{1}{\sigma_F}}$$

which is a "razor's edge" condition since *r*, $t^D$, $\rho$ and *g* which determines the long run (steady state) growth rate of the economy, are all considered as exogenous. In the analyses, equation (B.4) is assumed to hold at all points in time.

### B.3 Data and parameters

The model is calibrated to the 1999 national accounts. For the production functions the elasticities of substitution between machinery and energy, the elasticity of substitution between the energy-machinery aggregate and labor and the elasticity of substitution between the modified real value added and various material inputs (see figure B.1.), are adjusted to parameters of a Generalized Leontief (GL) cost function estimated on time-series data from the national accounts, see Alfsen et al (1996). The elasticities of substitution between electricity and fuel oil in the energy aggregate are based on CES-function estimates on time series data by Mysen (1991). Most of these elasticities of substitution are smaller than 1. The elasticities of substitution between non-polluting and polluting transports, and the corresponding elasticities between the modified real value aggregate and various material inputs are set to 0.5, for all industries.

In the model of producer behavior the elasticities of transformation between deliveries to the domestic and foreign market are set equal to 4. The elasticities of scale in different industries are then calibrated to 0.83, given the elasticities of transformation. The elasticities of substitution between domestic products and imported goods are partly based on estimated parameters (see e.g. Svendsen (1990)), but adjusted upwards such that all are around 4. For further details of the calibration of the model of producer behavior, see Holmøy and Hægeland (1997).

In the consumer model the intertemporal elasticity of substitution, $\sigma_F$, equals 0.3, Steigum (1993). Econometric estimates of $\sigma_F$ vary considerably between different sources, and 0.3 is in the lower end of the range of the estimated parameters. The uncompensated wage elasticity of labor supply is 0.1 percent, which is based on estimates of labor supply for married women and men on micro-data by Aaberge, Dagsvik and Strøm (1995). This is consistent with the calibrated elasticity of substitution between material consumption and leisure of 0.6, and the share of leisure in the utility aggregate of 0.4, see also Bye, Holmøy and Strøm (1999) for details. The calibration of the parameters in the complete demand system for material consumption is based on detailed econometric studies using both micro and macro data, see Wold (1998).

**Figure B.1. Production technology**

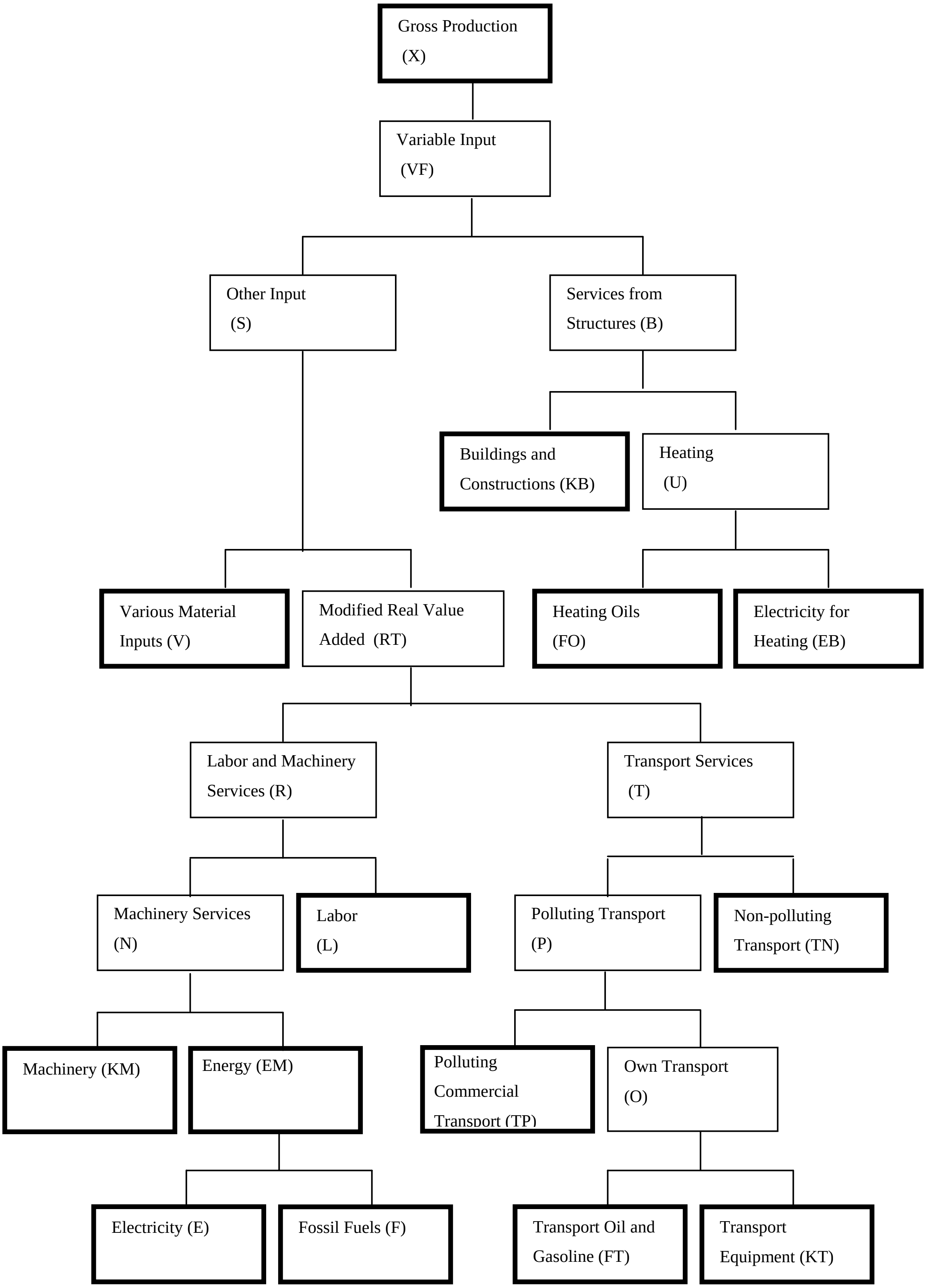
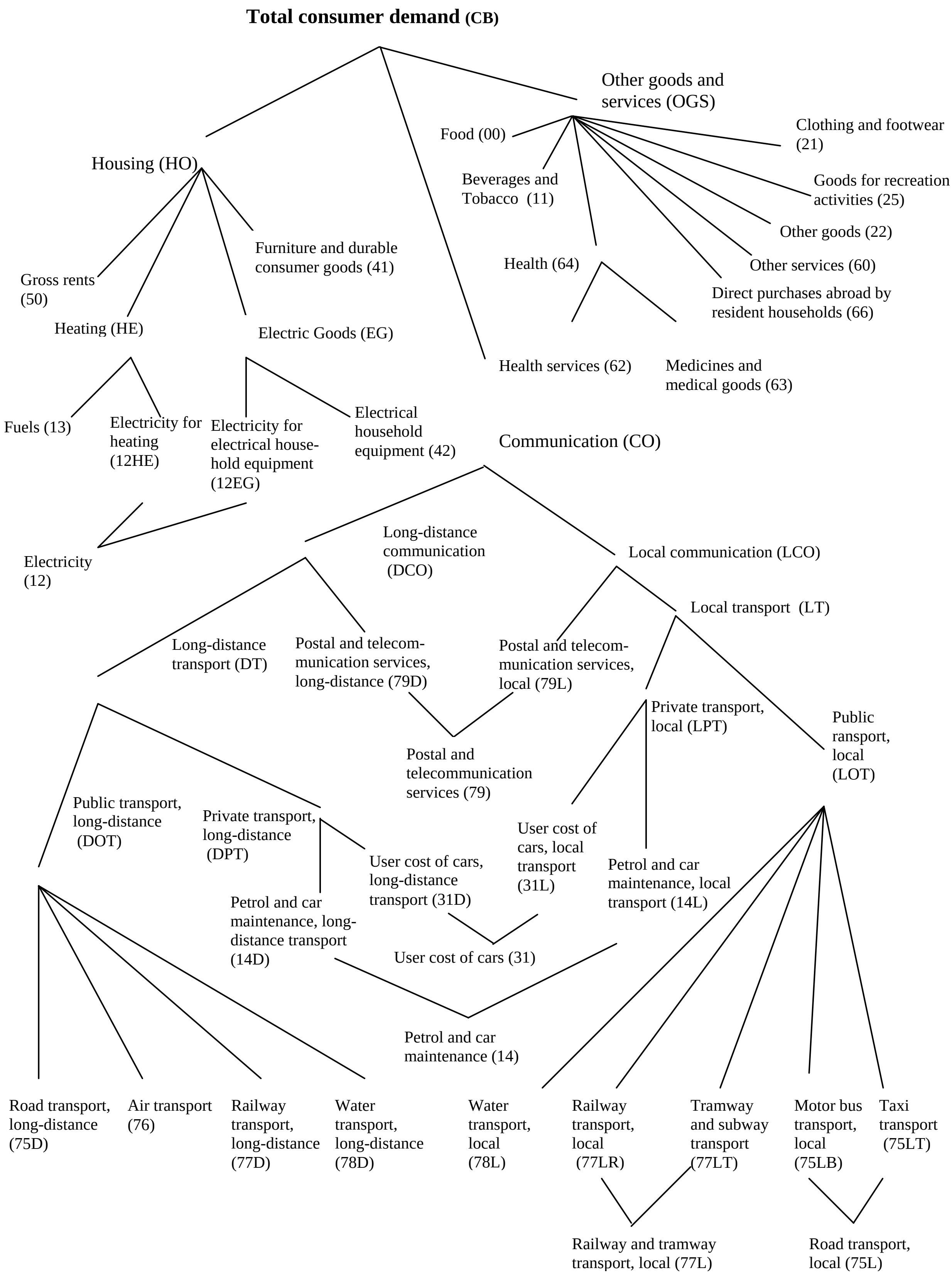


**Figure B.2. Material Consumption**



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