Overall and regional economic impacts of an area-wide heavy vehicle duty: Comparing the results of an Input-Output and a CGE Analysis

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Abstract: Many European countries have heavy vehicle duties in place on their primary road network. Only Switzerland introduced its heavy vehicle duty system *nationwide* from the beginning, however, parallel with a significant increase in maximum loads. No other European country has expanded its heavy vehicle duty to the secondary road network yet, but such an expansion is discussed in many countries (e.g. in France, Austria, Slovenia, Czech Republic). We analyse such an expansion and quantify the transport and economic impacts nationwide as well as their differentiation a peripheral region within a country.

The economic analysis builds on a transport reaction model supplying the adjustments of freight transport activities by sector. A computable general equilibrium model is developed, based on detailed sectoral freight transport intensities. Freight transport is taxed sectorally differentiated using freight transport expenditure results from the above transport reaction analysis.

For three scenarios of expanding the heavy vehicle duty to the secondary road network the CGE analysis quantifies sectoral shifts in production (with -3.5% strongest in the sector “stones and earth”) and prices (strongest with +2% in the very same sector), as well as overall economic impacts, particularly on GDP and employment. These macroeconomic impacts depend crucially on the choice of revenue use. The larger the share that is used for a general tax relief, the better are macroeconomic implications. When all revenues beyond system costs are spent on tax reductions, and the duty rate is high enough, we get net positive employment and GDP effects.

In a pure input-output analysis sectoral price impacts are found higher at a factor of up to 1.5 than in the CGE analysis. Using the former, we can restrict the impact on the consumer price index of an equal duty rate expansion from the primary to the secondary road network to below 0.2%.

It is relevant to look at the impacts on particular regions of such a policy. We analyse one peripheral region. We find that while it is not the sectors of highest economic importance hit by the duty, still those sectors hit are more important in peripheral regions (up to the twofold share in value added) and simultaneously show stronger production price impact, as due to non-availability they did not use the primary road network in peripheral regions earlier.

In terms of social indication we find a slight tendency for poorer households to be over-proportionally hit, as especially the housing sector is hit by higher construction costs, and housing expenditure makes up for a higher share in consumption for the poor.

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1. Introduction

The instrument of a heavy vehicle kilometre based tax is widely used in Europe, but charged almost exclusively on the primary road network so far. To avoid re-routing to the secondary road network truck bans have been implemented at sections particularly exposed to that risk. Yet, as the heavy vehicle duty tax is a comparatively popular instrument in public opinion and as trucks come up only for a particularly small share of the costs they cause on the secondary road network, the expansion of the heavy vehicle duty tax to a nationwide system is a crucial political issue in many countries.

For this policy discussion there is need for clarification on a number of questions:

- would the impact on truck mileage be of any significance at all, given that road transport on the secondary network could be rather inelastic?
- which economic sectors would be hit particularly in economic terms?
- are there any macroeconomic impacts of significance to be expected as a consequence?
- as peripheral regions are proportionally more dependent on the secondary road network, how much more significant are sectoral or overall economic impacts in these regions?

We develop a nationwide CGE model to analyse the macroeconomic impacts here. It is coupled to a freight transport reaction analysis by sector. From the latter we take tax adjusted vehicle kilometres by sector and type of road network. Acknowledging the vehicle tax adjusted freight transport prices we derive the implicit tax on freight transport, differentiated by sector. This implicit tax rate rises with the sector´s share of intermediate input transport on the secondary road network, transport intensity of value added, and lack of substitution options.

While this analysis gives the medium-term and long-term impacts, for the quantification of short term impacts we employ an input-output analysis for an upper bound of sectoral production cost implications.

We also use a regionally differentiated analysis of economic activities and related transport flows to quantify the impacts for a representative peripheral region. This analysis will point out the degree of regional imbalance in the effects of such an instrument.

The issue we focus on here, the expansion of an existing lorry tax to a nationwide system, concerns the secondary road network, which is hardly relevant for transit transport and only of small relevance for export and import transport. Therefore, foreign trade aspects are of less relevance here. Foreign trade induced impacts are of significant relevance, however, when a heavy vehicle duty tax is introduced in a country from scratch. They have been analysed in this context in detail in Steininger (2002).

The present paper is structured as follows. Section 2 presents the CGE model. In section 3 three scenarios for the expansion of the heavy vehicle duty tax are defined and results of the transport reaction analysis are reported for each. Section 4 uses these as inputs in its macroeconomic analysis and reports the results of the CGE analysis. In section 5 these results are compared with those of a short term oriented input-output analysis, before section 6 analysis regional differentiation of impacts. A final section summarizes the main conclusions.

2. The CGE model

We present a comparative static small open economy Computable General Equilibrium (CGE) Model, which maps the national economy based on data of 2003. The model addresses the economic effects resulting from an introduction of a nationwide kilometer-based heavy vehicle duty. We test the introduction of the heavy vehicle duty tax in the reference year, i.e. we compare the actual economic data of 2003 with the situation had a vehicle duty tax been implemented earlier to have become fully effective in 2003 already. Thus we avoid assumptions on future sectoral development differentiation. In the following, production, foreign trade, consumption, labour market and heavy vehicle duty specifications are discussed.

2.1 Production

Production within the economy is characterised by profit maximizing and cost minimizing behaviour and is disaggregated into 37 sectors. A nested production function, which is hierarchically structured, is used to describe the production in each sector. (Figure 1)

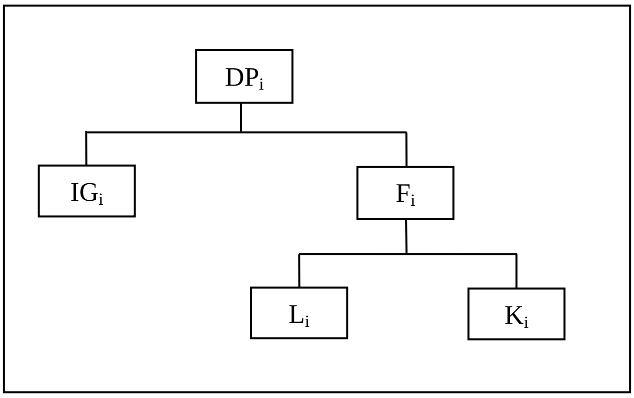

Figure 1. Nested production function

On the top level, domestic production (*DP_i*) is modelled by a Leontief production function (equ.1). This implies that the factors of production are used in a fixed proportion and substitution is not possible.

$$(1) \qquad DP_i = \min[\frac{F_i}{a_i}, \frac{IG_i}{b_i}] \qquad \forall i = 1,...,37$$

Production inputs for each sector i = 1,…,37 include the production factor aggregate F_i (capital and labour) as well as domestic intermediate inputs (IG_i). The Leontief input coefficients – a_i and b_i – describe the minimal required amount per input factor to produce one unit of output.

On the lower level of the nested production function, the required production factor aggregate F_i is assumed to be produced by a CES (constant elasticity of substitution) production function (equ.2) comprising capital *(K_i)* and labour *(L_i)*. $\alpha_{ir}^{\frac{1}{\sigma^{IG}}}$ and $(1-\alpha_{ir}^{\frac{1}{\sigma^{IG}}})$ indicate the expenditure shares, σ^F the elasticity of substitution.

$$(2) \qquad F_i = [\alpha_i^{\frac{1}{\sigma^F}} L_i^{\frac{\sigma^F-1}{\sigma^F}} + (1-\alpha_i^{\frac{1}{\sigma^F}}) K_i^{\frac{\sigma^F-1}{\sigma^F}}]^{\frac{\sigma^F}{\sigma^F-1}} \qquad \sigma^F = 0 \text{ and } \forall i = 1,...,37$$

Referring to Bergmann (1991), the elasticity of substitution between capital and labour can range from 0 to 1.2. For the present study, an elasticity of 0 is assumed in order to show the largest economic effects resulting from the introduction of a nationwide kilometre-based toll for lorries.

2.2 Foreign trade

Based on the usual approach with regard to foreign trade relations of small open economies, the Armington assumption is used (Armington, 1969). I.e. imported goods are assumed different from domestically produced goods and constitute imperfect substitutes in consumption. Additionally, a differentiation between exports and domestic commodities is made in the model. As a result, five output aggregates are distinguished for each sector. (Figure 2)

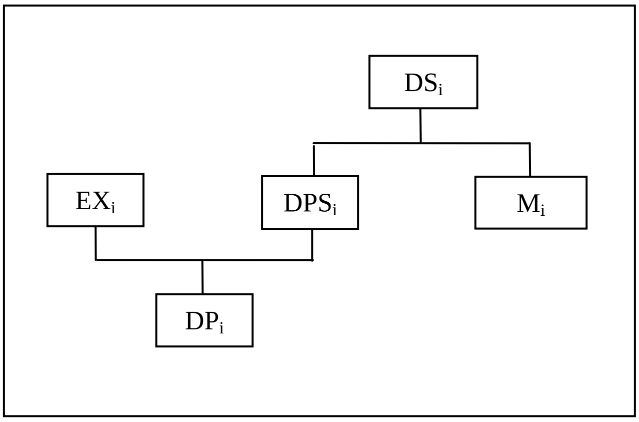

Figure 2. Armington trade structure

Domestic production *DP_i* can be delivered either to the domestic market or to the export market. A CET-function (constant elasticity of transformation) is used to specify – for any amount of goods produced for both, the domestic (*DPS_i*) and the export market (*EX_i*) – the overall domestic production (*DP_i*) (equ3).

$$(3) \qquad DP_i = [\alpha_i^{\frac{1}{\sigma^{DP}}} DPS_i^{\frac{\sigma^{DP}-1}{\sigma^{DP}}} + (1-\alpha_i^{\frac{1}{\sigma^{DP}}}) EX_i^{\frac{\sigma^{DP}-1}{\sigma^{DP}}}]^{\frac{\sigma^{DP}}{\sigma^{DP}-1}} \qquad \sigma^{DP} \geq 0 \text{ and } \forall i = 1,...,37$$

where $\alpha_i^{\frac{1}{\sigma^{DP}}}$ and $(1-\alpha_i^{\frac{1}{\sigma^{DP}}})$ denote the expenditure shares and σ^{DP} the elasticity of transformation. The latter differs across sectors and is based on foreign trade elasticities derived from Reinert and Roland-Holst (1992).

The overall domestic supply (*DS_i*) consists of goods produced for the domestic market (*DPS_i*) and imported goods (*M_i*), which are assumed to be used for final consumption only. A CES-function describes this relationship (equ.4).

(4) $DS_i = [\alpha_i^{\frac{1}{\sigma^{DS}}} DPS_i^{\frac{\sigma^{DS}-1}{\sigma^{DS}}} + (1-\alpha_i^{\frac{1}{\sigma^{DS}}}) M_i^{\frac{\sigma^{DS}-1}{\sigma^{DS}}}]^{\frac{\sigma^{DS}}{\sigma^{DS}-1}}$ $\sigma^{DS} \geq 0$ and $\forall i = 1,...,37$

Similar to equation (1), the expenditure shares are given by $\alpha_i^{\frac{1}{\sigma^{DS}}}$ and $(1-\alpha_i^{\frac{1}{\sigma^{DS}}})$; the elasticity of substitution between imported and domestic goods is defined by σ^{DS}. Again, foreign trade elasticities based on Reinert and Roland-Holst (1992) are used.

The annual quantity of imported goods (M_i) depends on the relative price-ratio between prices of imports (P_i^w) and prices of domestic goods (P_i) (equ.5). Similarly, the amount of exports (EX_i) is determined by the prices, which can be realised at the export market (P_i^w) relative to the equilibrium prices at the domestic market (P_i) (equ.6). M_i^0 and EX_i^0 represent the amount of imports and exports in the base year, respectively.

(5) $M_i = M_i^0 (\frac{P_i}{P_i^w})^{\Sigma i}$ $\forall i = 1,...,37$

(6) $EX_i = EX_i^0 (\frac{P_i^w}{P_i})^{\Sigma i}$ $\forall i = 1,...,37$

2.3 Labour market

The market for labour is out of equilibrium. Unemployment is caused by a rigid minimum wage (classical unemployment). The nationwide introduction of the kilometre-based heavy vehicle toll as well as the required investments for the kilometre-based toll-system affect the domestic production directly (e.g. through additional demand for labour in the data-handling sector) and indirectly (e.g. through additional demand for labour for the production of data-handling devices). As a result, the demand function of labour changes. However, an increase (decrease) in demanded for labour does not immediately affect the prices of this production factor. Instead, an increase (decrease) in the amount of labour deployed is the first consequence. Thus, a reduction of unemployment leads to the usage of additional quantities of the production factor labour, which were previously unutilised. This, in turn, positively affects value added as well as domestic demand.

2.4 Final consumption

Market clearance must hold for all commodities, meaning all goods produced are consumed. Within the model, total demand includes intermediate demand, final demand and exports. Intermediate demand is covered in the discussion of production; exports in the discussion of foreign trade. Final demand comprises consumption of households and the public sector.

Household consumption – modelled by taking one representative consumer – is characterized by utility maximization. The demanded consumption bundle (CON) includes private consumption and investment (equ. 9). The expenditures required for consumption are financed by the aggregated household income (*HI*), which is made up of factor incomes of both labor (*wL*) and capital (*rK*), unemployment benefits (*UB*) as well as other social transfer payments of the public sector (*T*) (equ.8). Thus, the representative consumer maximizes his/her utility (equ.7) with respect to a budget constraint (equ. 9).

(7) $\max U = \prod_i DS_i^{\beta_i} \qquad \sum_i \beta_i = 1, \qquad \forall i = 1,...,37$

(8) $HI = wL + rK + UB + T$

(9) $CON = \sum_{i=1}^{n} P_i DS_i = HI \qquad \forall i = 1,...,37$

In order to determine the allocation of expenditures for each sector, a Cobb-Douglas utility function is chosen to constitute a linear expenditure system. I.e. relative price changes of consumed goods lead to proportional changes in the demanded amount of these commodities. This ensures that the household budget shares spent on each good remain constant.

The second consuming agent is the public sector. Public demand is framed in a linear expenditure framework, using a Cobb-Douglas utility function as well. The public sector income consists of factor income tax revenues (on capital and labour), indirect tax revenues (specified as ad-valorem tax per sector) as well as of further fees and taxes revenues (e.g. capital transfer tax, property tax, etc.). Public expenditures are used for public consumption and social transfers to households. Of these transfers, government expenses for unemployment benefits are separately modelled (as a fixed amount per person unemployed, thus reacting to the labour market situation); while the remaining transfer payments are determined as a fixed share of household income.

2.5 Heavy Vehicle Duty

The modelled cost increases in intermediate input goods resulting from the introduction of the nationwide heavy vehicle duty differ across sectors, depending on the respective expenses incurred for their transportation. To quantify the cost changes per commodity used as input good, we build on the following data (as derived in the transport reaction model indicated in section 3 below): the driving performance (in veh-km), the transport performance (in tkm) and the corresponding costs (per km and tkm respectively) in the base scenario

Driving performance (per vehicle) and transport performance (per commodity transported and vehicle used) are adopted from simulation results of a transport model developed for a previous study. The average costs per km and type of vehicle are derived from various studies in the past[3], which are based on interviews with transport companies and are adjusted to the current situation. The average costs per tkm depend on the average kilometre costs of the truck used, the commodity transported as well as on the respective average load factors for each commodity group. The latter again is calculated based on results of the transport model.

In the counterfactuals, the introduction of the nationwide kilometre-based heavy vehicle duty leads to a cost increase per vehicle-kilometre driven. The new transport expenses are calculated for each commodity group, based on the driving performance and transport performance in the base scenario (see above). This cost increase leads – in a next step – to a change in driving performance and transport performance patterns (e.g. higher loading factors, less ‘empty drives’), which finally

[3] E.g. Herry (2001) and Due Torri (2007)

constitute the final transport costs per ton-kilometre and commodity group. Knowing the demand for intermediate commodities for each production sector, it is now possible to calculate the percentage cost increase for intermediate commodities.

2.6 Implementation

The model presented in this section has been implemented within GAMS (Brooke et al., 1998) using the modeling framework MPS/GE (Rutherford, 1999) and the solution algorithm PATH (Dirkse and Ferris, 1995).

3. The transport reaction analysis

Let us define the following three rate scenarios:
(A) Expansion of the current heavy vehicle duty rate from the primary road network to the secondary road network (same rate)
(B) As (A), yet with a doubling of the rate in the whole network (primary and secondary)
(C) Expansion of the heavy vehicle duty rate to the secondary network at only half the rate that is charged (and continued to be charged) at the primary road network.

A detailed transport reaction analysis by freight good category (NSTR), including optimization of vehicle loading factors, route optimization, change of routes domestic and substitution by foreign transport routes has been carried out in a freight transport model for each rate scenario. The results on vehicle-kilometers and ton-kilometers are given for the nationwide aggregate in *Table 1*.

Table 1. Transport reaction to nationwide expansion of heavy vehicle duty tax

rate-scenario	vehicle-kilometers			ton-kilometers		
	total	primary road network	secondary road network	total	primary road network	secondary road network
			change in %			
A	-1.9	-1.0	-3.5	-1.0	-0.4	-2.6
B	-9.1	-9.2	-8.9	-6.5	-6.7	-6.0
C	-0.9	-0.5	-1.7	-0.5	-0.2	-1.3

4. Nationwide implications of a heavy vehicle duty tax

Employing the CGE model as presented in section 2 to analyse the introduction of a nationwide heavy vehicle duty tax, we find at the aggregate level an impact on value added and employment, which is crucially dependent on the rate scenario and revenue use option chosen. We therefore need to specify options to use the new tax revenues. In the main scenario of revenue use we deduct system costs and use half of the remaining for infrastructure maintenance of the secondary road network and the rest for a general reduction of the tax burden. We also test for the two other extremes, of using the revenues after system costs only for maintenance or only for general tax reduction. As *Figure 3* presents, the higher the share of revenues used for general tax reduction (which is implying also a labor tax reduction), the more positive are impacts on GDP and employment.

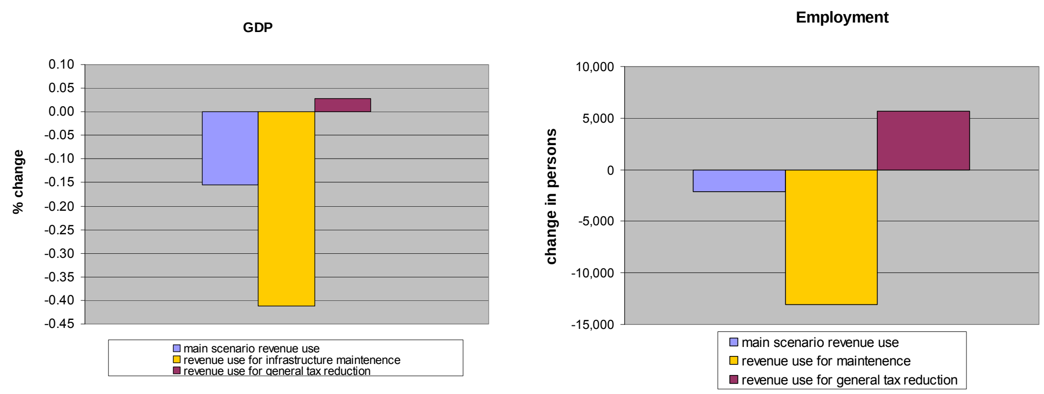

Figure 3. Macroeconomic impacts of heavy vehicle duty tax scenario A under different revenue use options

Impacts do differ substantially across economic sectors. Strongest hit in terms of reduced production level and increased production cost is the sector "Stone and Glass Products, Mining" (see Figure 4).

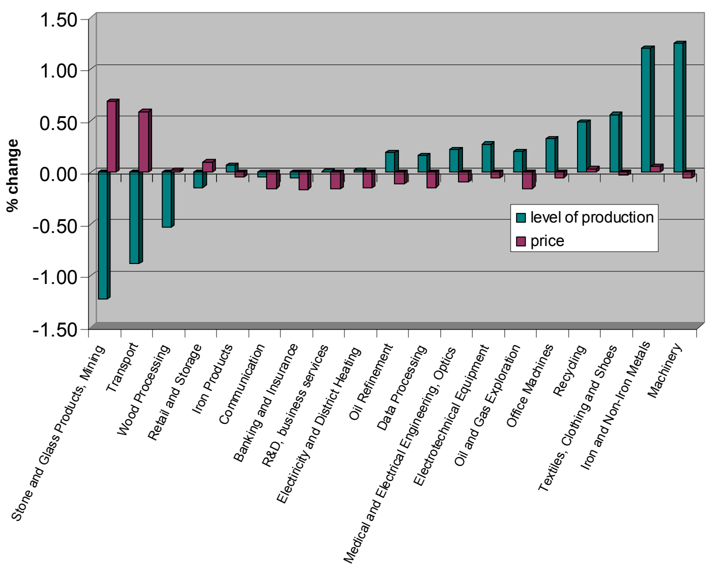

Figure 4. Output and price changes by sector, rate scenario A, selection of sectors with strongest impact

5. Comparison of results with an input-output analysis

In the CGE analysis we have already accounted for counterbalancing impacts, such as wage reductions due to employment reductions compensating for part of the transport cost increases in the overall production cost impact. For the short term, not all of these counterbalancing effects may be generated, or at least may not be fully generated. Therefore, to get an upper bound on consumer price impacts for the short run, we employ a straight input-output analysis for price changes. We use absolute additional freight transport expenses for intermediate inputs, as derived from the sectorally differentiated results from section 3. Assuming that all production cost increases can be passed on to consumers we get price changes by sector as denoted in Figure 5.

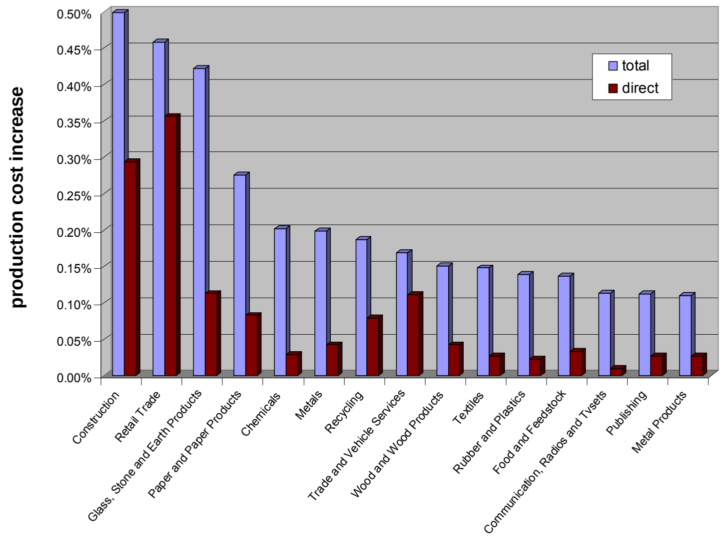

Figure 5: Production cost increase by sector, direct and indirect effects, heavy vehicle duty tax scenario A, selected sectors

Combining these results with the respective shares of products in the standard consumption basket we get the impact on the consumer price index, in the short term and as upper bound. In this way we can restrict the consumer price rise to below 0.15% for rate scenario A (and 0.50% and 0.08% for rate scenarios B and C, respectively).

6. Regional differentiation in impacts

Peripheral regions are characterized by a stronger dependence on the secondary road network. We may therefore expect that these regions could be stronger hit by an expansion of the heavy vehicle duty tax to the secondary road network. Selecting one exemplifying peripheral region, we looked at whether – as a consequence of nationwide expansion of the heavy vehicle duty tax – production costs increase more than in the nationwide average, and whether the sectors hit hardest are of particular importance in these regions. Overall we found both affirmative. Still, for most peripheral regions it is not the sectors most dominant that are the ones hit strongest by this instrument. But the sectors hit strongest are more relevant in peripheral regions than in central regions.

Due to data restrictions no fully fledged regional input-output tables can be constructed, and thus no regional CGE model. Yet, we use the average nationwide sectoral intermediate input structure with the regional specific share of primary and secondary road transport and respective regional specific distances for intermediate freight transport. This shows that production cost impacts are up to 1% point higher in peripheral regions (e.g. for the sector “Stones and Earth” production costs rise by 3% in the peripheral region rather than 2% in the nationwide average). Figure 6 presents the sectoral results.

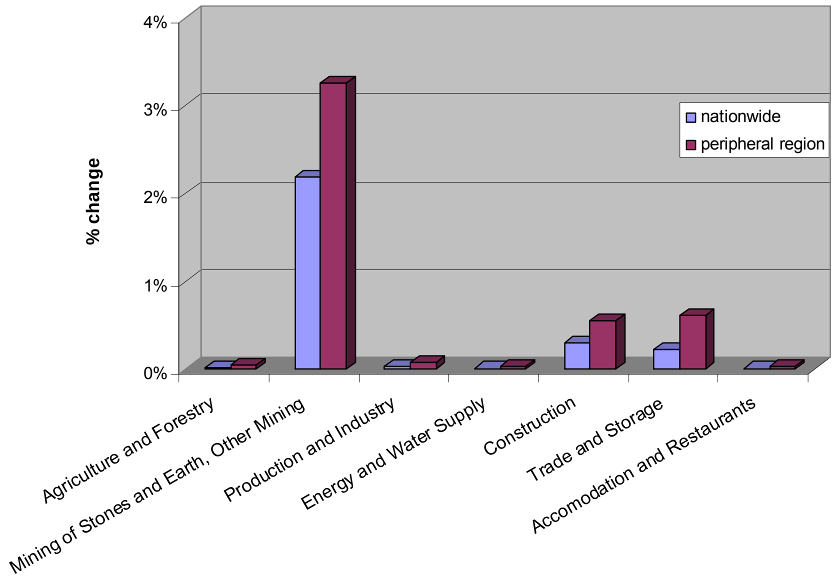

Figure 6. Direct production cost impact of heavy vehicle duty tax by sector, rate scenario A, peripheral region relative to nationwide

Second we find that sectors such as "Stones and Earth", which carry the strongest production cost increase, are over-proportionally relevant in peripheral regions (see Figure 7) . Most important for the generation of value added in peripheral regions are other sectors, however, not strongly hit by the expansion of the heavy vehicle duty tax to the secondary road network. Therefore we conclude that peripheral regions are harder hit than the nationwide average, yet still at – under tariff scenario A – rather small overall significance.

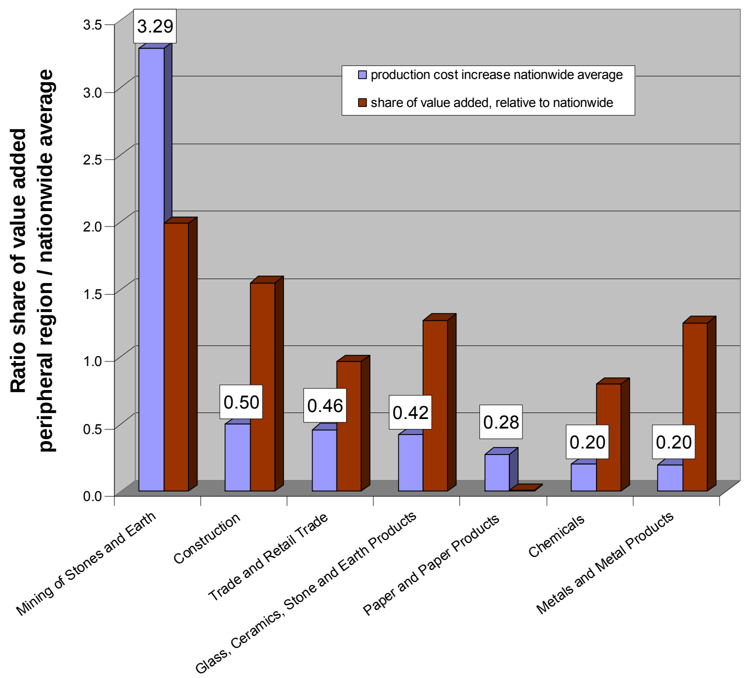

Figure 7. Relative relevance of vehicle duty hit sectors in peripheral region

7. Conclusions

We develop a methodological framework in this paper to analyse economic impacts of an expansion of the heavy vehicle duty tax system to also cover the secondary road network. The core steps in our analysis are the following: We define three scenarios for the kilometre based rate in the secondary (and primary) road network. A sectorally detailed transport reaction analysis supplies the thus triggered changes in vehicle- and ton-kilmetres, taking account of loading factor adjustments, rout optimization both domestically and internationally, and route changes. Further reaction options have been found to be of marginal relevance only.

A nationwide CGE model with a special focus on freight transport as intermediate input by economic sector is employed to quantify medium to long term sectoral and overall macroeconomic impacts. We couple the transport reaction model with the CGE model by means of implicit freight transport taxes by sector raising the costs of intermediate inputs and triggering direct and indirect (feedback) effects. The model also acknowledges the long-term change in the investment structure due to the set up and maintenance of the heavy vehicle duty charging system.

To derive maximum price implications of such a policy for consumers also in the short run, we further employ an input-output analysis to cover direct and indirect effects.

For the analysis of the impacts of such an instrument in a peripheral region we face lack of region specific economic interdependence data. We therefore combine information on the region specific economic output structure (value added by sector) and region specific dependence on the secondary road network for transporting intermediate inputs by sector to derive direct production cost impacts. We can compare these with the direct production cost impacts on the nationwide level. Finally we report the relative relevance of sectors highly dependent on secondary road freight transport in peripheral regions.

The core quantitative results are as follows. For three scenarios of expanding the heavy vehicle duty to the secondary road network the CGE analysis quantifies sectoral shifts in production (with -3,5% strongest in the sector “Stones and Earth”) and prices (strongest with +2% in the very same sector), as well as overall economic impacts, particularly on GDP and employment. These macroeconomic impacts depend crucially on the choice of revenue use. The larger the share that is used for a general tax relief, the better are macroeconomic implications. When all revenues beyond system costs are spent on tax reductions, and the duty rate is high enough, we get net positive employment and GDP effects.

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