Carbon Emissions and the Economic Costs of Transport Policy in Sweden

by

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In recent years the Swedish transport system has become a target for intensive political discussion. One can single out “the environment” and “infrastructure” as the typical buzzwords of this debate. Sweden has invested a significant amount of its prestige in showing that it can stick to agreements made in conjunction with the Rio Summit in 1992. The growing transport sector is a key challenge, and perhaps it is here that Sweden will face the most substantial difficulties in meeting the obligations. Nevertheless, the notion that it is possible to create an environmentally “friendly” transport sector has become a theme of many recent proposals on the future of Swedish transport policy. We evaluate several of these proposals by constructing and simulating a computable general equilibrium (CGE) model of Sweden.

We review the salient features of the transport policy debate in Sweden in section 1. The model is described in section 2, and the main results presented in section 3.

1. The Transport Policy Debate in Sweden

1.1 Current Issues

Sweden's transport policy is based on five objectives, as indicated in the 1988 Transport Policy Resolution: availability, efficiency, safety, environmental quality and regional balance. A substantial number of reports have assessed the success of the policy during the past few years. According to a recent assessment, SOU [1996:26; p. 30-31], a number of improvements have been secured. For example, safety has improved; the target set previously of a maximum of 600 fatalities per year has been met (ibid., p.32). Deregulation of air traffic and the introduction of new high-speed trains have contributed to the efficiency of the transport system, although a complete evaluation of the airline deregulation remains to be undertaken. Emissions of certain pollutants have diminished considerably. On the downside, carbon dioxide (CO_2) emissions from the transport sector have increased. This has led to a number of different proposals to mitigate those emissions, mainly from various recent government Commissions and quasi-government Committees. We return to these proposals and the evolving debate around them below.

The 1988 Transport Policy Resolution suggested a number of guiding principles for costing the transport system. An important principle is that charges are to be set in proportion to social costs. Indeed, Sweden has since 1988 introduced environmental taxes on sulphur, nitrogen dioxide and carbon dioxide emissions. Whether or not the levels of those taxes have been set according to the marginal cost of damage from the relevant externality is impossible for us to say. Still, a general contention is that these taxes have led to reductions in emissions, *ceteris paribus.* A detailed assessment is on the way by the so-called Green Tax Commission, due to be published in 1997 (see Harrison and Kriström [1997]).

One of the key ingredients in the 1988 and 1991 Environmental Policy Resolutions is the principle of "sector responsibility". Thus, rather than having general environmental goals for the whole economy, they should be broken down on the sector level. Since then, a number of goals have been suggested for the transport sector, sometimes detailing particular types of traffic. For example, The Air Aviation Board has announced a target to stabilize the 2010 emissions of carbon dioxide from air traffic to the 1990 level. This is different from the national goal of stabilizing to 1990 levels by the year 2000.

Recent proposals to reduce the emissions of greenhouse gases have originated from individual political parties, from Non-governmental organizations and from various official investigations. We discuss two of those here.

The main task of the Traffic and Climate Committee (SOU [1995:64]) was to propose measures for reducing emissions of carbon dioxide and other greenhouse gases from the transport sector. Because Sweden is prevented by international agreements from taxing fuels for air traffic and shipping in the same way as for road transport, the proposals focused on measures to reduce road traffic emissions. The committee concluded that carbon dioxide emissions from the transport sector should not increase up until the year 2005. Again, this is different from the overall environmental goal for Sweden, but need not be inconsistent with it. The price of petrol should be raised by SEK 0.40 per liter with effect from January 1, 1997 and for four years subsequently. The tax increase should hit all fossil fuels and be uniform across all sectors. In mid-1996 the price of petrol in Sweden was about 8 SEK per liter, or roughly 1.23 USD per liter. Because the carbon tax today is 0.37 SEK per liter, the proposal effectively means a *doubling of the* CO_2 *tax on petrol* over four years.

The committee pointed out that the carbon dioxide target was not independent of the development of Sweden's energy policy. A key issue here is the destiny of nuclear power, currently planned to be decommissioned by 2010. The Commission argued that the carbon dioxide target should be reassessed in conjunction with the development of future energy policy and the development of international agreements on greenhouse gases.

The so-called “KomKom” Commission (“Commission on Communications”) (SOU [1996:26]) proposed that the carbon dioxide tax be increased such that the real price of gasoline increases by 0.10 SEK per year between 1998 and 2020. The same increase is proposed for diesel. In this way, the gasoline price would be increased to SEK 2.30 per liter by 2020. The tax revenues should be returned to the transport sector in the form of government support of environmental measures. The Commission argued that this proposal would have substantial, indeed “unacceptable,” distributional effects in certain regions of the country and suggested some “regional policy measures” to lessen the regressive impacts of the proposals.

1.2 The General Structure of Swedish Energy Taxes

Sweden has used taxes on energy since 1929, when a tax on gasoline was introduced. Electricity has been taxed since 1951, followed by a broadening of the energy taxes in 1957. The motivation underlying these taxes was purely financial. In the 1970s, propelled by the global energy crisis, energy taxes were increasingly motivated by a desire to discourage consumption of fossil fuels. Thus, increased taxes on oil products were coupled by a significant expansion of electricity supply in order to promote a different profile of energy consumption.

Environmental concerns entered the discussion in the 1980s, manifested by the introduction of a tax differentiation of leaded gasoline in 1986. This was followed by the Environmental Tax Commission that recommended a rich array of environmental taxes in their final proposal (see SOU 1990:59). This investigation led the government to propose taxes on emissions of CO_2 and sulphur, *inter alia*, in 1991. While this was not the first official body in Sweden to discuss environmental taxes, this mission was unique in that it was coupled with a major overhaul of the Swedish tax system in the beginning of the 1990s. The general tax reform included a reduction of income taxes, to be financed partially by an increased use of energy and environmental taxes (including the introduction of VAT on energy consumption).[1]

For the purpose of harmonizing Swedish energy taxes with those prevalent within the

[1] Of the total change in tax revenues, estimated at about 90 billion SEK, energy and environmental taxes were estimated to generate 3 billion SEK in the absence of changes in the VAT treatment of energy. The addition of VAT on energy added another estimated 14 billion SEK in revenue (Åke Nordlander, personal communication).

most important competing countries, another reform of energy taxation passed on January 1, 1993. This reform was closely tied with the international competitiveness concerns that have been a recurring issue in the design of Swedish energy policy. It meant that manufacturing industry no longer paid energy tax on the use of fuels and electricity in their processes. In addition, there was a reduction in the CO_2 tax for the manufacturing industry, as detailed below.

A. Industry Exemptions

In an international context Swedish energy taxes are high. Because export-oriented industries are competing on markets with significant price elasticities, it is not surprising that several tax exemptions are being used. Beginning in 1974, through the law on (partial) exemptions of the general energy tax, energy-intensive manufacturing industries and the horticulture industry have escaped some part of energy taxes. This, of course, is not unique in Europe. Similar exemptions have also been used in Denmark and Norway for manufacturing.

These exemptions for manufacturing are a key feature of the tax system we evaluate. In the tax system prior to 1993 approximately 100 energy-intensive firms were granted reduced tax rates on fuels and electricity. In 1992 the reduction for energy-intensive industry was worth 1.3 billion SEK. The new energy and carbon tax system introduced in 1993 resulted in significantly reduced tax rates for industry. The total amount of energy and carbon tax collections dropped from 3.8 billion SEK in 1992 to just 0.5 billion SEK in 1994. We approximate these exemptions as applying to manufacturing industries *in toto*, so that manufacturing industry and horticulture are assumed to pay 25% of the general carbon tax rate.

Before the 1993 change of the energy tax system, tax exemptions were essentially granted on a case-by-case basis. Thus energy-intensive industries could apply for a reduction of the energy tax on electricity and fuels. With a zero energy tax on electricity and fossil fuels, such applications are now redundant. There are still possibilities for deductions for fuel use, some of them of considerable importance for individual firms (see SOU [1994:85; p. 106]). These deductions are only possible for firms producing cement, lignite and glass. They only apply to the carbon tax on coal and natural gas, and not on the use of oil products. In 1995 less than 10 energy-intensive firms could benefit from this rule, and the value of the reduced tax was less than 50 million SEK.

B. The Carbon Dioxide Tax

By far the most important of the environmental taxes introduced as the result of the Environmental Tax Commission is the carbon dioxide tax. Introduced in January 1991, the tax of 0.25 SEK per kilogram of emitted CO_2 was followed by intense controversy. Eventually, a reform of energy taxes in 1993 led to significant reductions for manufacturing industries, as explained above. The government argued that it was important to reduce Swedish energy taxes to European levels for internationally competitive industries, lest firms move abroad or remain at a significant cost disadvantage. Carbon taxes in Sweden in 1995, the base year of the model's representation of the tax system, are generally about 0.34 SEK per kilogram of emitted CO_2 for non-exempted sectors and 0.083 SEK per kilogram for manufacturing sectors.

1.4 The European Union

An advisory referendum held in Sweden in November 1994 resulted in a 52% to 47% win for the proponents of entering the EU. As a result Sweden has been a member of the EU since January 1995. It is not currently clear what kinds of restrictions there will be on the possibilities of pursuing an independent environmental policy. On the one hand, current EU policy is based on minimum requirements, which means that a member country has an option to use a stricter policy. On the other hand, it is difficult to block imports of goods that have been approved in another country. Membership in the EU does not prevent country-specific environmental policies *de jure*, but it may make a deviation from EU policy impossible *de facto*.

When Sweden entered the EU a new energy tax law (SOU 1994:1776) replaced the old one. It replaced laws on general energy taxes, CO_2 taxes, sulphur taxes, gasoline taxes and diesel taxes. The new law substantially harmonizes Swedish rules with those in the EU. Generally, the above taxes are due on fuels used for heating purposes, or as propellants for engines. Biofuels are exempted from energy taxes, following a long tradition in Swedish energy policy to encourage substitution towards these fuels. Fossil fuels and electricity used in manufacturing are treated favorably, the motivation again being the concern with international competitiveness.

Current Swedish energy taxes generated about 40 billion SEK in 1994. The structure of these revenues, in terms of the CO_2 tax and other energy taxes, are shown in Figure 1. The total revenues from energy and environmental taxes in 1994, including sales taxes on motor vehicles and annual road taxes, were roughly 47 Billion SEK (Treasury of Sweden [1995; p. 60]). This corresponds to about 6% of total tax revenues (Treasury of Sweden [1995; fig 13.1, p. 61]) or about 3% of GDP.

2. A General Equilibrium Model

2.1 Basic Features

Our Small Open Economy (SOE) model is designed for tax policy analysis with a large number of sectors. The model is a "generic" general equilibrium model of a single economy along the lines of Melo and Tarr [1992], Harrison, Rutherford and Tarr [1993] and Rutherford, Rutström and Tarr [1994]. We describe here the general features of the base model, adding details about the 1992 version for Sweden later. Further details on the database construction are provided in Harrison and Kriström [1997; Appendix A]. The complete database and model is available in machine-readable form from web page http://theweb.badm.sc.edu/glenn/sweden.htm.

Goods are produced using primary factors and intermediate inputs. Primary factors include capital and six types of labor. Production exhibits constant returns to scale and individual firms behave competitively, selecting output levels such that marginal cost at those output levels equals the given market price. Output is differentiated between goods destined for the domestic and export markets. Exports are further distinguished according to whether they are destined for specific foreign markets. This relationship is characterized by a two-level constant elasticity of transformation frontier. Composite output is an aggregate of domestic output and composite exports; composite exports are aggregates of exports for distinct foreign markets.

Final demand by private households arises from nested constant elasticity of substitution (CES) utility functions. This allows consumer decision-making to occur in the form of multi-stage budgeting. At the top level the consumer trades off a composite bundle of consumer goods with leisure (the own-consumption of the consumer's labor endowment). At the second level goods from different sectors compete subject to the budget constraint of the consumer, and all income elasticities are unity. In the third stage the consumer decides how much to spend on domestic or imported goods in each sector, subject to income allocated to spending in that sector in the first stage. Finally, having decided how much to spend on imports as a whole, the consumer allocates this expenditure on imports from specific countries. Each allocation decision is modeled as a CES function.

The model allows tariff rates to differ depending on whether the imports are from specific trading partners. Exports can be sold at different prices depending on whether they are destined for distinct foreign markets. The same is possible on the import side.

Government expenditures and investment demand are exogenous. Funding of government expenditures is provided by tax revenues and tariff revenues. In addition to tariffs, the government also derives income from indirect taxes (net of subsidies). These are modeled as Value Added Taxes (VAT). Unless otherwise specified the government recovers any lost revenues by increasing taxes on labor collected at the enterprise level; similarly, it reduces those taxes for any increase in revenue due to a counter-factual scenario.

Since private consumption equals the income from primary factors plus net transfers to the consumer by the government (from domestic and foreign trade taxes), Walras law is satisfied. Changes in public consumption are balanced with changes in revenue, so that the public deficit in the base year is effectively exogenous.

World market import and export prices are fixed, so there are no endogenous changes in the terms of trade. In other words, import supplies and export demands are infinitely elastic at given world prices. The current account imbalance in the base year is assumed to be matched by an exogenous capital inflow or outflow. These capital flows have no affect on the stock of domestic capital, nor on interest payments to foreigners. Domestic prices change to ensure that the *change* in the current account is zero. The fixed world prices that Sweden is assumed to face may be changed parametrically.

2.2 The Swedish Model

These

are listed in Table 1, along with their pseudo-Swedish acronym. This is the level of

our purposes. It is possible to aggregate to a smaller number of sectors, such as has been

potential for misleading analysis in the present context.[3]

while the reverse is obviously not true.

conducted by the "Statistiska Centralbyrån" (SCB). It provides detailed information on

and income, and are listed along with their acronyms in Table 2. One difficulty is that the

from our industrial products to those goods. We resolve this problem by using our intuition,

different expenditure patterns for different industrial goods.

In other words, each household has a slightly different of each primary factors in it's

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[2]

industry which contains no transactions and is therefore deleted. We therefore refer to the model as having 87

[3] The primary argument for aggregation, given the ready availability of powerful software and hardware

the data items required for our analysis are only available at an aggregated level, although far fewer than one would think and still at a relatively disaggregated level of about 20 or 30 sectors. Harrison and Kriström [1997;Appendix

several of our disaggregated sectors. For example, basic data on factor payments were generally available only at the 3-digit SNR level, while our full model employs many 4-digit sectors. Hence we needed to use the former as the

a priori

belief is that it is much easier to apply serious priors to detailed sectors than it is to synthetic aggregates. In any

one so applies them in our disaggregated model. Providing the reader knows when such uniform assumptions are

application of priors by aggregation. Formal decision-theoretic methods of aggregation of input-output sectors are

practiced by many early-generation CGE modelers. However, sophisticated or naïve aggregation is simply misplaced endowment. In the absence of better data, we are not overly confident of this feature of the model, and prefer to view households as being primarily distinguished on the basis of their expenditure patterns. Hence we primarily capture variations in the cost of living for different households, and probably do not capture all of the variations in the value of endowment income for different households.

Primary factors are used in the production of value added in each sector. In general two types of factors are free to move across sectors to equate after-tax rates of return: labor and capital (K). Labor is differentiated by skill categories and occupational status into six groups: blue collar unskilled (L_BC_U), blue collar skilled (L_BC_S), white collar unskilled (L_WC_U), white collar semi-skilled (L_WC_SS), white collar skilled (L_WC_S) and self-employed (L_SE). The percent distribution of labor types in each sector is shown in Table 6. We allow the labor types to substitute with each other at a different rate than their composite does with K, although our formulation allows all primary factors to be equally substitutable as a special case.[4]

The model allows the specification of sector-specific capital types in any set of sectors. This possibility allows the identification of sectors that employ a significant amount of a primary factor that can be interpreted as specific to that sector. We could interpret this as referring to some "short run" in which capital is applied to sectors in a manner that does not permit it to be readily moved to other sectors.[5] Instead, we use it to capture the limited range of activities which resources can be applied to. As one increases parametrically the assumed share of benchmark payments to K that is attributable to such specific factors, and thereby decrease the share that is assumed to attributable to the mobile K, the corresponding supply curve for that industry becomes more inelastic. The intuition is clear: as the relative demand for output

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[4] This formulation employs a nested production function in which K and composite labor substitute at the "top level" to produce value added in a given sector. At the "bottom level" the labor types then substitute to produce the composite labor factor. Both levels are CES, hence setting the elasticities of substitution at each level to the same value results in the nests "collapsing" into one level in which the three substitute at that rate.

[5] It is common to assume in the "short run" that factors are likely to be sector-specific, and in the "long-run" that factors tend to be mobile across sectors. We would expect a short run model of his kind to generate smaller welfare gains from a "first-best" liberalization, since resources are constrained in their ability to reallocate to more productive uses. On the other hand, we would expect the short run model to exhibit less extreme changes in production structure since the sector-specificity of factors generates less elastic supply schedules. We also recognize that some factors are likely to be specific to one or other sectors even in the long run. An obvious example might be the natural resources used in mining.

ceteris paribus all input prices, the factor that is specific to this industry

when it is inter-sectorally mobile and facing the same drop in derived demand for it's value marginal product. This relatively sharp decline in factor input cost results in a larger drop in the

applies to increases in demand in the industry, of course.

Thus we can arbitrarily constrain the supply response of resource-based industries by

[6] Given that the primary policy focus of these simulations is on

observed payments to K that are payments to K that is specific to that sector is 0.2 for sectors STEN, PETR and SMOR, and 1 for sectors JORD, SKOG and FSKE.

the primary factors. Although the natural assumption might be to model the substitutability of the intermediate inputs by assuming a Leontief technology , we use instead a CES function with a low elasticity of substitution (0.25) across all sectors. This specification allows for later evaluation of the effects of varying degrees of substitutability at the point at which energy taxes

function and consists of two inputs: a labor composite and a capital composite. Each of these composites, in turn, is produced in a lower CES nest.

substitute between alternative import sources, and indeed between domestic production and an import composite. Similar assumptions apply on the export side, where Swedish producers have

foreign market, and (b) sales of the composite export to any of several foreign trading partners.

Although we do not offer a detailed model of the rigidities in the oil and extraction sectors, this feature of our model is similar in effect to the model used in Bovenberg and Goulder [1995; fn.15].

[7]

Since the matter continues to be confused by commentators that should know better (e.g., Jorgenson and Wilcoxen [1995; p.176]), we stress that the assumption of a Leontief technology is not mandated by our use of the calibration approach to estimation, nor by computational constraints. In general we do restrict ourselves to

manner (see Perroni and Rutherford [1995a][1995b]).

The key feature of our model in these regards is that Swedish producers have no market power in world markets.

In the present version we identify trade with Finland, Norway, Denmark, the Rest of the EU, Japan, the United States, and a residual Rest of World (ROW). Hence there are 7 trading partners in the model. No data is available to identify different tariff rates or NTB policies for any trading partner, so we assume that the trade distortions applying in aggregate (estimated from the input-output data) apply in a non-discriminatory fashion to all importers. We could extend this to allow for the discriminatory rates applying to EU member countries following Sweden's recent accession to the EU.

The specification of energy and carbon taxes are central to the model. To capture their structure, particularly with respect to the use of sectoral exemptions, we model them as falling on trade in intermediate inputs. This allows us considerable flexibility to calibrate the model precisely to capture the distortionary effects of existing taxes at the correct margin in terms of our model. Table 3 lists the estimates we have generated of the carbon taxes applicable in Sweden in 1995, and Table 4 lists the estimates for energy and sulphur taxes. These rates are displayed as follows: each column shows the good whose use as an *input* in the production of the row good generates the percentage tax liability indicated.[9] Thus, for example, production in sector JORD uses intermediate inputs from sector PETR and effectively incurs an *ad valorem* carbon tax of 64% on those inputs. Similarly, sector JORD uses inputs from sector GASV and pays instead an effective carbon tax of 61%. These estimates take into account the partial exemptions for Manufacturing sectors applicable for carbon taxes in 1995. The energy and sulphur taxes should be read the same way.

Information on value added taxes, social security taxes on labor, capital taxes, import tariffs, production taxes (other than energy or pollution taxes), and production subsidies are assembled from various sources described in Harrison and Kriström [1997; Appendix A]. The

[9] The rates are defined legally as falling on the use of one of several primary energy types. We estimate the physical usage of each energy type in each sector, then estimate the value of the usage of each energy type in each sector by applying average 1995 prices for each type, and then infer value of carbon (sulphur) taxes paid by each sector on it's use of each energy type. We then aggregate these inferred tax payments, aggregate the payments for the use of energy by that sector, and calculate an *ad valorem* carbon tax on a net basis. These calculations allow us to generate carbon tax estimates for each sector that properly reflect the primary energy usage of each sector.

rates assumed for the value added taxes and factor taxes reflect statutory rates applicable in 1995, and the other rates reflect actual collections as documented in the Input-Output table for

many cases the sectoral variations are small. This feature of the model could be improved with additional work on the background data, and would likely result in more substantial "second-

Estimates of elasticities of substitution must be assumed for primary factor substitution,

import source, and domestic demand; elasticities of transformation must also be assumed for the allocation of domestic supply into domestic and exported markets, the allocation of exports

literature search, there are many elasticities about which there is considerable uncertainty. Our solution for that problem is to undertake a systematic sensitivity analysis as described in

Harrison, Jones, Kimbell and Wigle [1993] and Harrison, Rutherford, and Tarr [1993] demonstrate the role of systematic sensitivity analysis of models such as these with respect to

The trade elasticities assumed in the model are particularly important. Higher trade elasticities tend to result in greater substitution away from energy-intensive sectors in Swedish

therefore use trade elasticities that reflect the best econometric estimates currently available (Reinert and Roland-Holst [1992] and Reinert and Shiells [1991]). Although they are low in

Tarr [1995][1997]), it is important to stress that they are (a) based on explicit econometric estimates, and (b) used in a model that rules out any "terms of trade effects" by assumption.

Estimates of carbon emissions in each sector were derived on the basis of information on

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The popular reason for using higher trade elasticities is that one can thereby avoid these effects, which are deemed unlikely *a priori*
specification of trade elasticities that mitigate these effects is more involved than just assuming "large" or "small" values (e.g., see Harrison, Rutherford and Tarr [1997]), these are not debates which are relevant here.

physical usage of primary energy inputs. These data can then be used to infer the amount of carbon dioxide generated by each sector, since emissions are a reliable multiple of the physical amount of primary energy used. These estimates are listed in Table 7 for each sector, and reveal a familiar structure of the "carbon economy". The biggest emissions in aggregate terms come from SAMF (transport), EL_O (electricity generation), and the iron and steel complex (sectors JRN_, FERR, JNGJ, META, METV, and I_JA). Between them these sectors account for 71% of total domestic emissions.

Another measure of the "dirtiness" of a sector can be obtained by the level of carbon emissions for each million SEK of output it produces. By this measure the iron and steel complex comes off much worse than the transport and electricity sectors, generally by an order of magnitude.

Comparing the estimates of carbon taxes and the estimates of carbon emissions, the absence of taxes on the iron and steel complex is immediate. The formal reason for this is that these sectors are exempt. The stated rationale underlying this exemption is that they are particularly vulnerable to foreign competition and would be unable to "pass on" any taxes on one of their inputs unless their competitors also bore comparable taxes.

Another feature of this comparison of sectoral taxes and sectoral emissions is that, of the two biggest aggregate emitters (SAMF and EL_O), only EL_O pays any tax on inputs of coal (output from sector STEN). Moreover, this tax is levied as an energy tax, and not as a carbon tax. Thus one could imagine the incentive within that sector to move away from coal-fired generators as the result of scalar increases in *energy* taxes. This margin of choice is incorporated in the model, to the extent that sector EL_O can substitute away from intermediate inputs of STEN and towards PETR (or, to a lesser extent, GASV and SMOR).[11] The current version of the model adopts a CES production technology with respect to intermediate inputs, and assumes an elasticity of substitution of 0.25. It would obviously be useful to consider richer specifications of the energy technology in sector EL_O in future work.

The SOE model is generated with the GAMS/MPSGE software developed by Brooke,

[11] It should be noted that the STEN sector also has some oil importing activity, all of which is sold to the PETR sector.

Kendrick and Meeraus [1992] and Rutherford [1992][1995]. It is then solved using the MILES algorithm developed by Rutherford [1993] or the PATH algorithm developed by Dirkse and Ferris [1995]. Harrison and Kriström [1997; Appendix B] documents the computer software in some detail. Each scenario typically solves in less than a minute on a Pentium-based personal computer running at 90mhz with at least 16mb RAM.

3. Effects of Policies

3.1 Baseline Policies and Simulation Scenarios

Table 5 lists the simulations we report here. The core simulation, which we then interpret with the other simulations, is called C100 and involves a 100% increase in existing carbon taxes in Sweden. As a default we lower labor taxes so as to ensure equal government revenue after the carbon tax policy. Thus C100 incorporates the existing structure of carbon taxes, in particular the current exemptions.

In order to describe the DIESel and PETROL scenarios in some detail, it is useful to review the current energy taxes on these fuels. Assuming a net price of 1468 SEK per m^3 for diesel and a net price of 2175 SEK per m^3 for petrol, the energy tax imposes a percentage increase of 109% and 148% on diesel and fuel. By contrast the carbon tax imposes a percentage increase of only 67% and 36%, respectively.[12]

The primary purpose of the energy tax is to raise revenue. The carbon tax, on the other hand, reflects an underlying tax of 0.34 SEK/kg CO_2 and is designed to meet an explicit environmental goal. Because diesel and petrol are roughly comparable in terms of kWh per m^3, it is apparent that diesel has a much lower energy tax. When converted to SEK per /kWh we obtain an energy tax of 0.17 on diesel and 0.4 on petrol. The corresponding carbon tax in these terms if 0.11 and 0.1, which is much more uniform.[13]

The purpose of the DIESel scenario is to study the impact of raising the energy tax for diesel such that diesel and petrol has the same energy tax (in terms of kWh). This means that the tax of diesel changes from 109% to 248% in the simulations. This represent the intuitively

[12] These calculations use 1995 data.

[13] The energy tax varies across different types of diesel and petrol. These numbers represented un-weighted averages across different classes of diesel and petrol. Source: Treasury of Sweden [1996].

appealing idea of making the tax system more symmetric.

The PETROL scenario simply involves doubling the price of petrol. This policy is consistent with one of the key proposals to be floated in Sweden by the Traffic and Climate Committee (SOU [1995:64]), as discussed earlier.

3.2 Effects of Expanding the Carbon Tax

A. Welfare Impacts

The detailed welfare impacts of the C100 scenario are presented in Table 8. The first column lists the acronym of the household, defined in Table 2. The second and third columns report the percentage share of each household type in the total population of households or individuals.[14] We can use households or individuals as the bases of alternate social welfare function. Using individuals has the effect, relative to using households, of giving the “single person” household groups a lower weight in social welfare, and enhances the weight of those households with more children.

The fourth column reports the value of the utility index for each household, normalized without loss of generality to 100 in the benchmark. Thus a value of 99.7 in this column indicates that the household type has experienced a decrease in the utility index of 0.3%. A more meaningful evaluation is provided in the final two columns, which list the equivalent variation (EV) in income needed to make the individual or household as well off as they are in the new counter-factual equilibrium (evaluated at benchmark prices).

The EV is positive for welfare gains from the counter-factual policy scenario, and negative for losses. We report it in terms of SEK over a one-year period for *each individual in the household group* or for *each household in the household group*. Thus these values can be interpreted as the minimum amount of money that each individual or household in each household group would need to have received, if the policy or scenario had not occurred, for them to just as well off as if it had occurred. It is important to note that this welfare evaluation takes no account of

[14] We do not distinguish vertically-challenged individuals (children) from the rest. If one wants to do so, then the use of household shares as a proxy has the unfortunate implication of unduly penalizing multiple-individual households. It would be possible to make some plausible inferences about the number of children in each of our household groups, given the way that they are defined, but we see no logic in disenfranchising those that happen to be politically disenfranchised by current voting entitlements.

the direct benefits to the household of the resulting reduction in aggregate emissions of either pollutant. Thus we can view these estimates as indicators of the minimum benefits which each consumer would have to perceive from the reduction in pollution in order for that consumer to regard the policy as a good one from an individual perspective.

In the C100 scenario we can therefore see that all household groups *lose* from a doubling of the existing carbon tax. For the single-adult household the cost is relatively modest, and well below the cognitive threshold value of 500 SEK. The costs become more substantial for all other *households*, especially those with children. Married households with no children experience slightly higher costs than single households with no children. In general richer households within any group tend to bear higher costs, reflecting the greater carbon-intensity of their expenditure patterns and their higher initial incomes.[15]

There is an intriguing effect of having extra children on the costs of the carbon tax increase for households. Having one or two children tends to raise the cost to a married household. But having three or more children actually reduces the household cost. The puzzle is resolved by examining how expenditure patterns change with extra children, not to mention some introspection.[16] Having children implies that households must use consumption technologies that have a significant fixed cost component: the purchase of durables such as prams and toys. These tend to be more carbon-intensive than the variable cost component of having children (i.e., toys actually have more embodied carbon-content than diapers), and it is the variable cost component that plays more of a role for the second child since the fixed cost expenditures do not have to be as large. The effect from having more than one child appears to be due to an increase in the share of household expenditures being allocated to transport. Presumably this reflects the need to take more family holidays, or the effects of re-location decisions as households tend to move out of dense (and carbon-efficient) urban transportation

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[15] The welfare changes are measured in terms of income-equivalents expressed in SEK per year. These income values are derived by applying the percentage change in utility to the benchmark income level of the household. If the percentage changes in utility are the same across households then richer households will have a larger income change due solely to their larger base incomes in SEK.

[16] At the time of writing, by the first author.

networks into suburban transportation networks.[17]

The costs of the carbon tax increase is greatest for households that are married with two children, and for richer households. The "other households" group also tends to bear a relatively high burden; this group consists mainly of children above the age of 17 living at home with their parents.[18] These households experience losses that are generally greater than 1000 SEK per year, and in several cases are more than 2500 SEK per year.

To repeat an important point, the fact that all households experience a loss does *not* mean that they would not benefit overall from the carbon tax increase. The reason is that we have neglected the direct benefit they would reap from the reduction in aggregate carbon emissions that would (presumably) result from the policy. In fact our model estimates that there would be a reduction of carbon dioxide of 52 Ktons, as discussed later.[19] Although this is a modest reduction in percent terms, it is *possible* that household M_2C_4 would value it at more than the 3033 SEK per year that would be the cost to that household to bring about the reduction. In the absence of any formal attempt to estimate the direct benefits to Swedish households from carbon reductions of various magnitudes, such judgments will have to be made politically. We provide some guidance on this matter later, but do not pretend that we know what these gross benefits are.

It should also be added that different households might have very different perceptions of the direct benefits of carbon reductions. Hence it could be the case that household M_2C_4 does get a benefit that exceed the "price" it pays of 3033 SEK, but that household S_NC_2 does *not* get a benefit that exceeds the more modest "price" of 283 SEK which it must pay. The gross benefits of any given commodity, whether it be "stor stark öl" or "52 less Ktons of carbon on the planet," can vary from household to household and individual to individual. Indeed, it is plausible that having more children would make one more concerned about the quality of the environment in the future, and increase one's willingness to pay for carbon reductions. On the

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[17] These speculations are supported by inspection of the differences across household expenditure shares that are "driving" these results in our model, but is not modeled formally as a household technology with these scale effects.

[18] The other groups, "single" and "cohabiting" households, only include one or two adult persons, respectively.

[19] The term "Ktons" refers to one *thousand* tons.

other hand, having children may also increase your discount rate, such that the enhanced benefits of carbon reduction in the future are insufficient to offset the enhanced "price tag" to be paid now.

This is not to say that our estimates of welfare costs are worthless, but simply to identify the many factors which must be considered before they can be properly used to guide decision-making. Implicit or explicit estimates of discount rates and gross benefits from carbon reductions must be made before an overall assessment of the C100 policy is possible. We stress these considerations since we will generally proceed to ignore them when describing the results.

There are several ways to "aggregate" these detailed welfare impacts. The first is to just add up the EV values for all households, ignoring the distributional impact. In effect this represents the evaluation one gets from a simple utilitarian social welfare function (SWF). This type of SWF ignores who gains and loses, and only focuses on whether the aggregate pie has increased or not. In the present case it has clearly decreased, and the aggregate loss in income is 4 *billion* SEK per year. This aggregate is obtained by adding up the EV values in either of the last two columns of Table 8, multiplying each by the number of individuals or households in the household type as appropriate. It openly ignores the distributional burden of the welfare impacts.

Another way in which the overall impact of the C100 policy could be viewed is that it is the *aggregate* "price tag" for the Swedish economy of a reduction in emissions of 52 Ktons of CO_2. A social counterpart to the more complete cost-benefit calculus described above for each individual household could now be undertaken. Such a calculus would require an estimate of the aggregate social benefits to Sweden of this reduction in physical emissions, perhaps by some official body such as the Green Tax Commission. This calculation would again entail the implicit or explicit use of a discount rate, in this case the social discount rate.

B. Emissions Impacts

How did we arrive at the estimate that a reduction of 52 Ktons of CO_2 would result from the C100 policy? The sectoral impact shown in Table 9 shows how these estimates were arrived at. Consider the last three columns, which show the aggregate change in physical emissions of CO_2 attributable to each sector.

domestic production in that sector brought about by the C100 scenario. Thus we see that a

of domestic value added in column VA%, led to a reduction in physical emissions from that sector of 4 Ktons.

what one would expect from a general economic equilibrium. The doubling of the carbon tax changes prices against the *most*
industries to contract their use of the (intermediate) inputs of these carbon-intensive sectors
may
intensive than the ones they displace, might still be more carbon intensive than average for the economy as a whole. Why don't they substitute towards the products that are least carbon-

they have the best relative price ratio because of the carbon tax hike, the value of their marginal product (as inputs) is still virtually zero.

Swedes. It also has a relatively low (direct) carbon intensity of only 3 Ktons of carbon per billion SEK of output. But when some sector such as JORD is contemplating increased prices

equipment in sectors RALS, BILA and FLYG in our model, it cannot "turn to DRYC" despite the temptation. It must re-allocate amongst these three transportation input sectors, and in fact

reason that DRYC does not get the nod is that it has nothing technologically to do with reality-based transportation. The formal counterpart of this sobering intuition in our model is that the

Output table, but it has substantial inputs of all three of the transportation inputs. Hence, by Marshall's second law of derived demand[20]

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[20] Which is sometimes stated as "the importance of being unimportant," in the sense that the smaller

elasticity for the input. This law is valid in the present case, since the elasticity of product demand (around 1) transport inputs will be relatively large and we can expect to see some net substitution effects there. Conversely, the elasticity of demand for DRYC will be relatively low, so we will not see any changes in the derived demand for it, despite it having a relatively favorable price ratio compared to transport inputs.

Turning now to the next to last column in Table 9, CO2_F, we see the effect of the Swedish policy on *foreign* emissions of CO_2.[21] Virtually any domestic policy is going to have some impact on the structure of Swedish imports, as changes in the relative prices of domestic goods cause Swedes to substitute in favor of or against foreign goods. In the present case there will be substitution away from those goods whose input price, shown in percentage change form in Table 9 in column IPRICE%, has increased. The clearest instances are as expected, PETR and GASV. In each case there is a large increase in domestic prices brought about by the doubling of the carbon tax: after all of the general equilibrium effects have worked themselves out, the final domestic price increase is about 18% or 16%. This results in a fall in domestic production, and a switch towards imports, shown in percentage change form in Table 9 in column IMP%. There is also a reduction in exports, shown in column EXP% in Table 9, for the same reason: Swedish exports in these carbon-intensive goods are simply unable to compete with foreign goods at (unchanged) world prices.

Hence we have an increase in the value of foreign imports of SMOR, and indeed in the physical quantity of imports. If we were to assume that foreign producers are just as carbon-efficient as Swedish producers in the same industry, then there would be an increase in carbon emissions overseas due to the increased foreign production needed to meet Sweden's increased import demand. In fact we assume that foreigners are *not* as carbon-efficient as Sweden, which is generally a plausible assumption apart from extremely nuclear-intensive countries. The exact

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clearly exceeds the elasticity of input substitution (we are referring to intermediate inputs which have an assumed elasticity of substitution of 0.25 in our model).

[21] There is some controversy in international negotiation circles as to whether or not foreign-induced emissions should be "counted" towards a country's contributions to changes in global carbon emissions. Apart from the obvious point of avoiding double-counting, this is a non-debate: of course they should. It is another matter to debate legal liability for policing foreign economic activity induced by (internationally legal and acceptable) domestic policies (e.g., see Harrison [1994]). Our concern here is to inform the policy debate in Sweden, not to posture by generating strategically creative environmental accounts for negotiators.

assumptions as to how much "dirtier" foreign production is[22]
general logic that accounts for the foreign change in emissions. That logic is important since it
global warming.

shore carbon-intensive activities and substituting off-shore production of those products.

We acknowledge that we do not undertake a full multi-regional evaluation of this

changes in Sweden's exports will change production patterns overseas in ways that could increase or decrease carbon emissions globally. More generally, since we do not model the

in Sweden's net trade pattern. Given these qualifications, which are inherent to the use of a single economy model, we believe it important to acknowledge the offsetting effects of carbon tax reforms when international trade is taken into account. There are, of course,

STEN), so our incorporation of foreign effects should not be viewed as imparting a presumptive bias into the estimation of global emissions.

carbon in each sector. The foreign effects *tend*
imports are generally a much smaller of domestic consumption in most sectors than domestic production.

The evaluation of welfare impacts and emissions impacts are, in an important sense, the "bottom line" of our policy simulations since they provide the ultimate basis for evaluating the

the result of the C100 policy. However, it may be useful to look more directly at the changes in

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[22] Specifically, we assume that Japan is just as efficient (due to nuclear power use), Norway is just as

efficient, and the Rest of World is 200% less efficient. These aggregate efficiency measures are used to scale up the sectoral emissions for Sweden, depending on the endogenous source of imports. It should be possible to refine these prices, production and trade to see the underlying causes of these effects.

From the IPRICE% column in Table 9 we see that the PETR and GASV sectors face a large price increase. Given the structure of carbon taxes, as shown in Table 3, these “first order” impacts are not surprising.

Why do prices for PETR and GASV, however, only rise by about 17% when the *ad valorem* rates of carbon taxes listed in Table 3 look to be anywhere from 15% up to 90%? The answer is to recall that the higher rates do not apply to all sectors that use PETR and GASV, particularly energy-intensive manufacturing sectors. Thus if we average out the carbon tax rate on PETR and GASV over all sectors, including those that are exempt from it and are not listed in Table 3, the average rate would be closer to the observed price changes. In addition, the final price changes shown in Table 9 will reflect additional “second-order” impacts due to resource re-allocations by consumers, producers and foreigners. Nonetheless, we would expect the first-order effects on prices to dominate for a scenario like this one.

Why is there such a small impact on the price of electricity, sector EL_O? Indeed, there is a slight increase in the price of sector EL_O, but it does not round up to 1% and hence is shown as a “blank” in our reports. Nonetheless, why is there not a larger increase, since EL_O *has* to be carbon-intensive? The immediate response is that Swedish electricity generation is dominated by nuclear and hydro, which are *not* carbon-intensive; that sector EL_O includes “district heating,” which is not carbon-intensive; and that sector EL_O is exempt from carbon taxes on the use of coal.

Essentially the same answer to this question comes from considering in detail the usage of intermediate inputs that are hit with the carbon tax, and then seeing what happens to their prices. Since we know that PETR and GASV have substantial price increases, the implication of a small price increase for EL_O is that it must not use very much of these as intermediate inputs. It is instructive in the economics of our model to work this issue through further.

Sector EL_O has five sources of primary energy inputs in our model.[23] Three are those

[23] There is a sixth source: wood. There were substantial intermediate sales from the SKOG sector to the EL_O sector in 1992, comparable in value to sales from the GASV sector. These inputs represent the use of wood scraps to generate supplementary electricity in some specialized pulp factories. Since it is not liable for carbon taxes, we ignore it in our discussion.

listed in the columns of Table 3 as bearing carbon taxes: STEN, PETR and GASV. The fourth is SMOR, which does not bear any carbon taxes. The fifth is EL_O itself, which is where all of the nuclear-generated primary energy comes from in the Input-Output database. Of *these five* intermediate inputs, the cost shares in 1992 were: STEN 39%, PETR 26%, SMOR 0%, GASV 15% and EL_O 20%. However, it would still seem that the taxes on STEN, PETR and GASV should impact EL_O prices. However, these percentages are misleading as to the complete cost structure of the EL_O sector. For example, the EL_O sector spent about as much on "consulting and lobbying services" (Uppdragsverksamhet, or UPPD) in 1992 as it did on PETR, and while consultants and lobbyists obviously generate a lot of negative externalities they are not (yet) subject to any pollution tax!

As a share of *total* intermediate inputs, then, the cost shares in 1992 were much smaller: STEN 11%, PETR 8% and GASV 5%. A simple piece of arithmetic suggests that the weighted carbon tax on EL_O from these three inputs is only 7.13% = (0% × 0.11) + (87% × 0.08) + (61% × 0.05). However, even this calculation overstates the effective tax in our model and the economy, since there are some possibilities for EL_O to substitute away from the more heavily taxed input PETR, and indeed away from all of the taxed inputs, since there are other inputs used in the benchmark technology to product it's output.[24]

3.3 Effects of The Petrol Tax and Diesel Tax Proposals

The tax revenues are used to reduce labor taxes, as described earlier, such that there is no net revenue effect on government. There is, nevertheless, a welfare loss of 0.4 to 3 billion SEK, which is equivalent to about 100 SEK and 750 SEK per household respectively. Using an exchange rate of USD1 ≈ SEK 6.50, the equivalent variations are roughly 15 USD and 115 USD per household. The second column presents the aggregate welfare loss in percentage

[24] The current specification of technology in our model does not differentiate energy inputs from non-energy inputs. Hence the derived elasticity of demand for UPPD would be about the same as for PETR in the model, given that the intermediate input cost shares are about the same for EL_O. An extension of the model could add this differentiation, allowing an extremely low elasticity of substitution between energy and non-energy inputs as composites, but some substitution between the items within each composite. In such a version it would be harder for EL_O to substitute away from taxed inputs. The only way it could do so would be to substitute towards the EL_O energy input, which we interpret as nuclear-generation. If we further added constraints on that avenue of "escaping taxes by substitution," such as specified in the N100 scenario, the EL_O sector would be hit *much* harder by the carbon tax increase.

terms, where the DIESel scenario is associated with very small percentage losses (less that 0.1%).

The higher diesel tax primarily hits the transportation sector. It is important to note the possibility of “tax-leakages” in this context, given the fact that about 9% of the total distance driven by trucks (above 3.5 ton) in Sweden are foreign (see SCB [1990]). Because the diesel price is generally higher in Sweden compared to neighboring countries (Norway is an exception), it is likely that the tax-leakage effect is small. Foreign vehicles are most likely not using Swedish diesel, although we have no data to confirm this intuition.

The differences between diesel-prices between neighboring countries suggest increased incentives for border-trade. In order to grasp the amount of tax-leakage through this channel, it is useful to note that Swedish trucks tend to drive short distances. According to Akeriforbundet [1994] only 6% of all transports cover distances exceeding 300km. Consequently, the price hike is going to hit mainly Swedish trucks and while there is some possibility for border-trade (mainly the Swedish-Finnish border in the north), the tax leakage is likely to be quite small.

The environmental impacts are small according to the model. Neither scenario involves drastic reductions of the CO_2 emissions. The higher diesel tax leads to a minute increase of foreign emissions through increased imports. These effects are so small to be negligible. It is important to realize that CO_2 emissions might increase in some sectors, because CO_2 emissions are modeled via fixed-coefficients on sectoral output, and expansion of some sectors implies an increase of their emissions. In other words, we do not allow in the present version of the model for the possibility that pollution mitigation expenditures might be employed to reduce the rate at which carbon is emitted in relation to output. This mitigates some of the decreases one expects from sectors that are heavy users of diesel, such as the transportation sectors.

Similarly, there is no detailed modeling of the possible substitution between diesel and petrol. We do allow firms to substitute intermediate inputs whose prices might vary due to changes in the relative price of diesel and petrol, to the extent that this inputs are used in benchmark data, but these possibilities are limited. We also allow consumers to substitute away from final gods that experience a relative price increase due to the relative intensity of diesel and petrol in their production, so some indirect substitution between diesel and petrol can occur at this level. Again, these possibilities are relatively limited. What would be needed is a detailed model of how each industry chooses which of fuel to use (and how it then chooses the vintage composition of it's capital stick to accommodate those fuel choices).

Taken together these features of the model suggest that the actual reductions of CO_2 might be larger than suggested by our simulations.

3.4 A Cost-Benefit Comparison

Our model is constructed to generate estimates for each household of the "price tag" or cost of increases in taxes directed at reducing CO_2 emissions. Is it possible to relate these, even roughly, to estimates of gross benefits from carbon tax reductions? Although proper gross benefit estimates do not exist for Sweden, or indeed for any country, there have been some estimates floated in international circles that can be usefully related to our cost estimates.

The source for these gross benefit estimates is the Inter-Governmental Panel on Climate Change (IPCC), specifically Working Group 3.[25] Based on some loose "avoided cost" calculations, they tentatively offer USD 125 per *ton of carbon* as an upper bound on gross benefits. We carefully translate that into *kTons of* CO_2 for comparison with our model, and then into SEK from USD.

The IPCC report does not indicate if they intend this number to refer to individuals or households, so we apply it to both. The IPCC report also does not say if this estimate is an *aggregate* over individuals or households, or is meant to be interpreted *per* individual or *per* household. Since the underlying avoided cost calculations are aggregative in nature, we assume that this estimate applies as an aggregate. To be conservative, we further assume that it applies to the aggregate population (of individuals or households) in *Sweden*, and not the *planet*. We then apportion the benefits proportionally across households, according to that household's share of the aggregate number of individuals or households. This assumption is appropriate given that we have no priors or data to suggest that one household group would value carbon reductions any greater than another.

We further assume that this gross benefit estimate is linear in the Kton reduction in CO

[25] The source for these estimates is their summary report, available on web site http://www.unep.ch/ipcc/sumwg3.html. The estimates appear near the end of §7 of that report.

$_2$ that our model generates for any particular scenario. In the case of C100, for example, we estimate a 52.2 kTon reduction, so we are in effect assuming that each household receives the same gross benefit from the first kTon reduction as from the last. Although we might justify such an assumption based on the small scale of this carbon reduction, and hence the approximate linearity of the unknown marginal benefit schedule, our primary concern is to keep the arithmetic simple and transparent. It should *not* be assumed that marginal benefit would decline, due to diminishing marginal utility arguments, since households may correctly perceive the importance of threshold effects in carbon reductions. In other words, I might be willing to pay nothing for small decreases in carbon emissions, but substantially more if I perceive that the aggregate emission reduction might make a difference to the risk of global warming.

Our cost estimates do, however, take into account the non-linearity of the underlying preferences and technologies for larger and larger reductions in emissions.

The resulting estimates for each household in scenario C100 are presented in Table 12. Comparable estimates for the PETROL scenario are shown in Table 13. In each case the last row shows the average benefit and cost over all households, and each row shows the arithmetic for each household. We use an estimate of the gross benefit which is actually double the upper bound of the IPCC estimate, so as to avoid any risk of understating those benefits.

The conclusion is clear. The benefits[26] of doubling the carbon tax or the petrol tax in Sweden are a tiny fraction of the "price tag" which Swedes must pay in the form of higher prices and reduced incomes. The results for the DIESel simulation are comparable, with average estimates of the cost to individuals of 53 SEK (115 SEK), and benefits that do not amount to 0.5 of *one* SEK. Although we do not put much credence in any of these gross benefit numbers, they do serve to highlight the basis of our conclusion that carbon, diesel or petrol tax increases are not currently justifiable in Sweden. They also serve to focus the debate on the net

[26] We are considering here only the gross benefits from the reduction in carbon emissions that would flow from the proposed policies, since those were the ones that were claimed for them in the policy debate. Since there are other externalities associated with the use of transportation, our analysis should not be viewed as a complete cost-benefit calculation. The most significant such externalities are emissions of other pollutants, congestion and the lost time spent in transit, and the risk of accident. Small and Gómez-Ibáñez [1996] provide a good review of the literature on externalities from transportation. It is not obvious that all of these externalities are positive or negative for all households, however.

benefits of further carbon, diesel or petrol taxes onto the question of estimating gross benefits for Swedes. *If these numbers are correct*, then advocates of these tax increases are telling the average Swede that he or she must pay a lot more for some environmental good than that Swede appears to derive as a benefit. This might be because the *advocate* derives significant enough benefits and would be willing to pay the price tag, but that does not justify foisting the price on others.

4. Conclusions

Our most important conclusion is that unilateral increases in carbon taxes, diesel taxes and petrol taxes do not appear to generate emissions reductions that are sufficient to justify the cost they impose on Swedes. While our model might under-estimate the reductions in emissions, it is well-known that the relevant price elasticities are small. In particular, the short-run price elasticity of gasoline is small. In addition, the average cost share of fossil fuels is small, which intuitively suggests that the demand reductions will be insignificant in production sectors. Coupling these facts with the result that carbon emissions can actually increase in some sectors due to general equilibrium repercussions, we find support for the model's prediction that the environmental benefits are unlikely to be significant since the emissions reductions are tiny.

We openly admit that we must rely on some heroic assumptions to undertake such a complete cost-benefit calculation, particularly with regards to the gross benefits of emission reductions. However, advocates of these tax increases must also be implicitly making comparably heroic calculations. Our role as modelers is to bring these unstated assumptions into the open, so that they can be rationally debated and evaluated.

These results may not be what everyone likes to hear. Since we are not naïve to the political pressures surrounding this issue in Sweden, nor so cynical as to dismiss them as being unworthy of debate, it is incumbent on us to attempt to direct debate on our model and it's results into productive areas.

The model is incomplete in terms of a number of important *parameters*. Specifically, we need to (1) add better data on the differences in factor endowments of households, to better consumption in the benchmark, as well as labor supply elasticities for different household types; and (3) employ data-based estimates of differences in carbon emissions in foreign

be introduced directly into the existing model instantly.

The model may also be incomplete in terms of it's treatment of the of some sectors. Specifically, we could (1) provide a richer specification of the production

combines with other intermediates in a Leontief manner, but which incorporates some degree of substitutability between energy types; and the use of non-separable production functions);

electricity which may be constrained by resource availability and/or network logistics; (3) model the way in which labor taxes impact households in a way that captures differences

effects of labor unemployment, including implications for unemployment benefits and the government budget; and (5) model the use of nuclear and non-nuclear technologies more

are conceptually straightforward, and use relatively familiar modeling tools, but are beyond the scope of the current project. We believe that each could be significant for current policy

The model could also be evaluated in terms of more *radical changes in structure* Specifically, we could consider (1) incorporating measures of environmental benefits explicitly

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[27] Some analysts have proposed using the estimated cost of the carbon tax structure as a crude

politely. At *best*
median voter, and then only if one were to make heroic assumptions about that political process representing the outcome "as if" a series of dichotomous-choice referenda had been undertaken at alternative tax-prices. Although a

uses a hypothetical survey to mimic the results of real referenda of this type (see Cummings, Elliot, Harrison and Murphy [1996]). Even assuming away these problems, knowing the marginal value that the voter places on some public good tells us nothing whatsoever about the distribution of benefits, at least in the absence of super-
Fantomen blush. Without information on that distribution one cannot

simplifying utilitarian assumptions. There is simply no acceptable substitute for estimating those benefits directly, into the household utility function, to allow a complete cost-benefit analysis to be undertaken; (2) explicit dynamics, with attention given to the rate at which households and firms discount future environmental benefits relative to current costs; (3) lobbying activities surrounding green tax reforms, and endogenous political activity over the selection of reforms; and (4) endogenous technical change induced by carbon taxes. Each of these entail exciting methodological extensions.

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and accounting fully for the potential biases in hypothetical survey elicitation procedures (e.g., see Blackburn, Harrison and Rutström [1994]).

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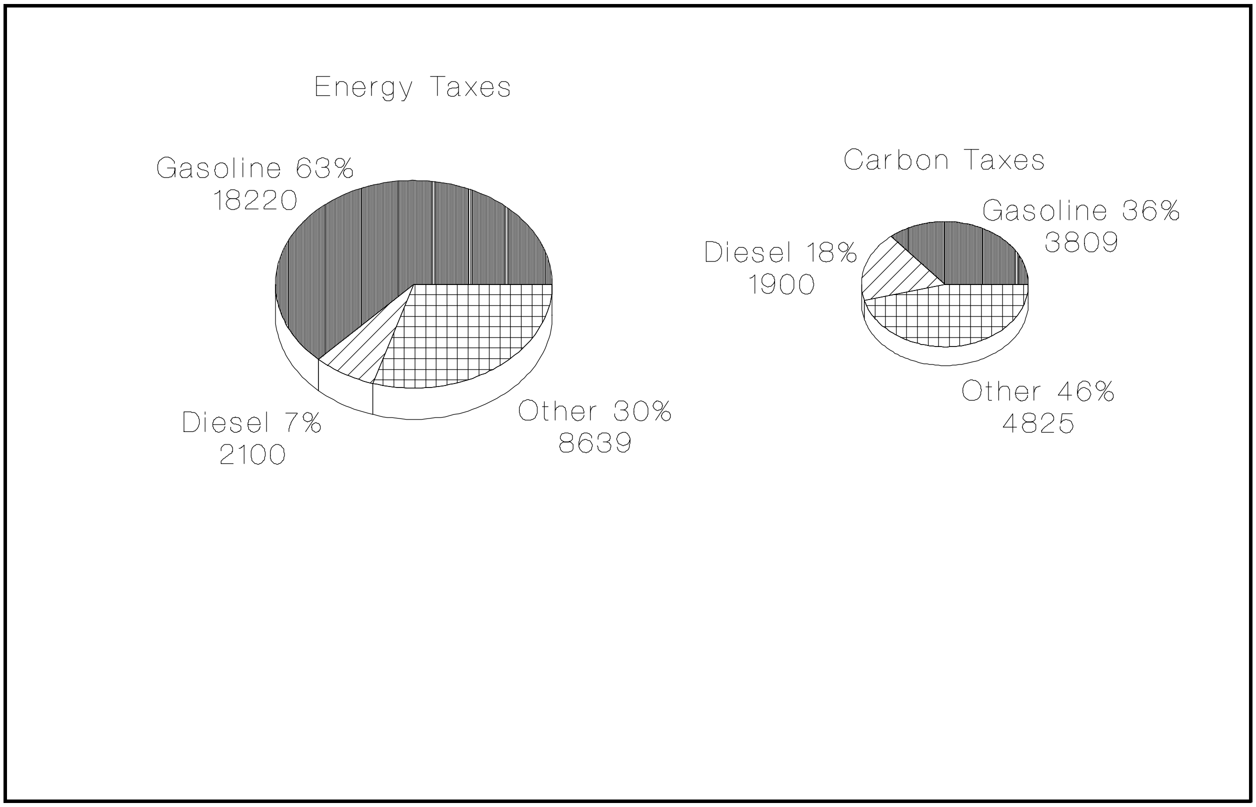

Figura 1: Revenues from Energy Taxes in 1994 (millions of SEK)

Tabella 1: Sectors in the Swedish Model

JORD	JORDBRUK	Agriculture and Hunting
SKOG	SKOGSBRUK	Forestry and Logging
FSKE	FISKE	Fishing
JARN	JARNGRUVOR	Iron Ore Mining
A_ME	A MET.GRUVOR	Other Metal Mining
STEN	STENBROTT A.GR.	Stone Quarrying & Other Non-Metallic Mining
SLAK	SLAKTERIER	Meat Slaughtering
MEJE	MEJERIER	Dairy Products
FRUK	FRUKTKONSERVER	Canning of Fruits & Vegetables
FISK	FISKKONSERVER	Canning of Fish
FETT	FETT OLJOR	Oils and Fats
KVAR	KVARNPRODUKTER	Grain Mill Production
BAGE	BAGERIPROD.	Bakery Products
SOCK	SOCKER	Sugar
CHOK	CHOKLAD KONF.	Confectionary
DIVX	DIV.LIVSMEDEL	Other Food
FODE	FODERMEDEL	Prepared Animal Feeds
DRYC	DRYCKER	Beverages
TOBA	TOBAK	Tobacco
GARN	GARN VAVNAD	Spinning and Weaving
TEXT	TEXTILSOMN.	Textiles Other than Clothing
TRIK	TRIK2VAROR	Hosiery and Knitted Goods
OVRT	OVR TEXTIL	Other Textiles
BEKL	BEKLADNAD	Clothing
LADE	LADER SKOR	Leather and Shoes
S2GV	S2GVERK	Wood Preparations
TRAH	TRAHUS SNICK.	Wooden Building Materials
A_TR	A TRAMATERIAL	Other Wooden Materials
OVR_	OVR TRAVAROR	Other Wood Products
TRAM	TRAMOBLER	Wooden Furniture
PAPP	PAPPERSMASSA	Paper Pulp
PPPP	PAPPER PAPP	Paper and Board Manufacturing
TRAF	TRAFIBERPL.	Fibreboard
PFRP	PAPPFORP.	Paper Packaging Products
OVRX	OVR. PAPPER	Other Paper Products
GRAF	GRAFISK IND	Printing and Publishing
KEMI	KEMIKALIER	General Chemicals
GODS	GODSELMEDEL	Fertilizers and Pesticides
BASP	BASPLAST	Plastics and Synthetic Fibres
PLAS	PLAST HALVF.	Semi-finished Plastic Products
FARG	FARG	Paints
LAKE	LAKEMEDEL	Drugs and Medicines
TVAT	TVATTMEDEL	Soaps and Detergents
OVRK	OVR KEMIK.	Other Chemical Products
PETR	PETROL.RAFF	Petroleum Refining
SMOR	SMORJMEDEL	Lubricating Oils & Greases
GUMM	GUMMIVAROR	Rubber Products
PLSV	PLASTVAROR	Plastic Products
PORS	PORSLIN	Pottery
GLAS	GLAS	Glass and Glass Products
TEGE	TEGEL	Structural Clay Products
CEME	CEMENT	Cement and Plaster
OVRM	OVR MINERAL	Other Non-Metallic Mineral Products
JRN_	JRN O ST2L	Iron and Steel
FERR	FERROLEGERING	Ferro-Alloys Manufacturing
JNGJ	JNGJUTERIER	Iron and Steel Casting
META	METALLVERK	Metal Fabrication
METV	METALLVALSV.	Metal Rolling Mills
I_JA	I JARNGJUTERI	Iron and Steel Casting
METR	METALLVAROR	Other Metal Casting
MSKN	MASKINER	Industrial Machinery
ELMO	ELMOTORER	Electrical Machinery
TELE	TELEPRODUKTER	Electronics and Telecommunications
HUSH	HUSH2LLSMASK.	Domestic Eletrical Appliances
OVRE	OVR.ELPROD.	Other Electrical Goods
VARV	VARV B2TAR	Ship Building and Repair
RALS	RALSFORDON	Railroad Building and Repair
BILA	BILAR	Motor Vehicles and Parts
CYKL	CYKLAR	Bicycles and Motorcycles
FLYG	FLYGPLAN	Aircraft Manufacture and Repair
OVRR	OVR TRANSP.M.	Other Transport Equipment
INST	INSTRUMENT	Scientific Instruments
A_TI	A TILLVERKN.	Other Manufacturing
EL_O	EL O VARMEVERK	Electricity and Steam
GASV	GASVERK	Gas
VATT	VATTENVERK	Water
BYGG	BYGGNAD	Construction
VARU	VARUHANDEL	Trade
HOTE	HOTELL REST.	Hotels and Restaurants
SAMF	SAMFARDSEL	Transport and Storage
POST	POST TELE	Communication
BANK	BANK FORSAKR.	Banks and Insurance
EGNA	EGNAHEM FRITID	Housing
FAST	FASTIGHETSFORVALTN	Other Real Estate
UPPD	UPPDRAGSV.	Business Services
REPA	REPARATIONER	Repair Services
OVRP	OVR. PR. TJ	Personal Services

Tabella 2: Households in the Swedish Model

S_NC_1	Single adults with no children - first quartile
S_NC_2	Single adults with no children - second quartile
S_NC_3	Single adults with no children - third quartile
S_NC_4	Single adults with no children - fourth quartile
S_C_1	Single adults with children - bottom half
S_C_2	Single adults with children - top half
M_NC_1	Multiple adults with no children - first quartile
M_NC_2	Multiple adults with no children - second quartile
M_NC_3	Multiple adults with no children - third quartile
M_NC_4	Multiple adults with no children - fourth quartile
M_1C_1	Multiple adults with 1 child - first quartile
M_1C_2	Multiple adults with 1 child - second quartile
M_1C_3	Multiple adults with 1 child - third quartile
M_1C_4	Multiple adults with 1 child - fourth quartile
M_2C_1	Multiple adults with 2 children - first quartile
M_2C_2	Multiple adults with 2 children - second quartile
M_2C_3	Multiple adults with 2 children - third quartile
M_2C_4	Multiple adults with 2 children - fourth quartile
M_3C_1	Multiple adults with 3 or more children - first quartile
M_3C_2	Multiple adults with 3 or more children - second quartile
M_3C_3	Multiple adults with 3 or more children - third quartile
M_3C_4	Multiple adults with 3 or more children - fourth quartile
O_NC_1	Others with no children - first quartile
O_NC_2	Others with no children - second quartile
O_NC_3	Others with no children - third quartile
O_NC_4	Others with no children - fourth quartile
O_C_1	Others with children - first quartile
O_C_2	Others with children - second quartile
O_C_3	Others with children - third quartile
O_C_4	Others with children - fourth quartile

Tabella 3: Benchmark Carbon Taxes (percent)

Purchasing Sector	Input: STEN	Input: PETR	Input: GASV
JORD	268	64	61
SKOG		59	61
FSKE		66	61
JARN	268	84	61
A_ME	268	90	61
STEN		67	61
SLAK	67	19	15
MEJE	67	20	15
FRUK	67	21	15
FISK	67	19	15
FETT	67	20	15
KVAR	67	18	15
BAGE	67	18	15
SOCK	67	24	15
CHOK	67	22	15
DIVX	67	20	15
FODE	67	21	15
DRYC	67	20	15
TOBA	67	20	15
GARN		22	15
TEXT		17	15
TRIK		18	15
OVRT		19	15
BEKL		15	15
LADE		15	15
S2GV	67	18	15
TRAH	67	18	15
A_TR	67	23	15
OVR_	67	16	15
TRAM	67	17	15
PAPP	67	24	15
PPPP		24	15
TRAF	67	25	15
PFRP	67	21	15
OVRX	67	19	15
GRAF	67	13	15
KEMI	67	20	15
GODS	67	19	15
BASP	67	23	15
PLAS	67	21	15
FARG	67	15	15
LAKE	67	22	15
TVAT	67	15	15
OVRK	67	20	15
PETR		25	15
SMOR	67	21	15
GUMM	67	18	15
PLSV	67	17	15
PORS		18	15
GLAS		20	15
TEGE		19	15
CEME		20	15
OVRM		19	15
JRN_	67	20	15
FERR	67	20	15
JNGJ	67	21	15
META	67	20	15
METV	67	20	15
I_JA	67	20	15
METR	67	17	15
MSKN	67	16	15
ELMO	67	14	15
TELE	67	17	15
HUSH	67	17	15
OVRE	67	16	15
VARV	67	18	15
RALS	67	18	15
BILA	67	16	15
CYKL	67	18	15
FLYG	67	14	15
OVRR	67	18	15
INST	67	12	15
A_TI		16	15
EL_O		87	61
GASV	268	87	61
VATT			61
BYGG		58	61
VARU		55	61
HOTE		55	61
SAMF		66	61
POST		55	61
BANK		55	61
EGNA		76	61
FAST		76	61
UPPD		55	61
REPA		55	61
OVRP	268	55	61

Tabella 4: Benchmark Energy and Sulphur Taxes (percent)

(a) Energy Taxes

Purchasing Sector	Input		
	STEN	PETR	GASV
JORD	77	108	16
SKOG		117	16
FSKE		111	16
JARN	77		16
A_ME	77		16
STEN	77		16
EL_O	77	68	16
GASV	77	68	16
VATT			16
BYGG		112	16
VARU		110	16
HOTE		110	16
SAMF		109	16
POST		110	16
BANK		110	16
EGNA		70	16
FAST		70	16
UPPD		110	16
REPA		110	16
OVRP	77	110	16

(b) Sulphur Taxes

Purchasing Sector	Input	
	STEN	PETR
JORD	56	0.5
SKOG		0.2
JARN	56	5
A_ME	56	7
STEN	56	0.3
EL_O		7
GASV	56	7
BYGG		0.1
SAMF		3
EGNA		2
FAST		2
OVRP	56	

Tabella 5: Simulation Scenarios

BENCH	Maintain all policies at their initial level and replicate the benchmark economy.
C100	Increase the existing structure of carbon taxes in Sweden by 100% above their benchmark rates, maintaining the existing exemptions from carbon taxes. Reduce labor taxes to maintain constant government revenue.
DIES	Increase the diesel tax so as to match the petrol tax in terms of carbon emissions. Reduce labor taxes to maintain constant government revenue.
PETROL	Double the petrol tax. Reduce labor taxes to maintain constant government revenue.

Tabella 6: Labor Types in the Swedish Model (percent employment in sector)

	Blue Collar			White Collar					
Sector	L_BC_U	L_BC_S	L_BC	L_WC_U	L_WC_SS	L_WC_S	L_WC	L_EMP	L_SE
JORD	18	11	29	6	4	6	16	46	54
SKOG	40	15	55	10	12	11	33	89	11
FSKE	25	3	28	4	5	56	65	92	8
JARN	35	30	65	6	17	8	31	97	3
A_ME	35	34	69	7	13	7	27	96	4
STEN	26	15	40	16	18	19	52	93	7
SLAK	41	25	66	11	8	9	28	94	6
MEJE	47	7	54	18	12	12	41	95	5
FRUK	41	7	48	17	13	17	47	95	5
FISK	56	4	60	11	8	13	33	93	7
FETT	32	13	45	13	18	19	50	95	5
KVAR	31	15	46	12	13	22	47	93	7
BAGE	40	23	63	14	6	10	30	93	7
SOCK	32	25	57	9	14	13	37	94	6
CHOK	48	8	56	15	11	13	39	94	6
DIVX	39	8	47	18	12	16	47	94	6
FODE	38	11	50	20	9	16	45	95	5
DRYC	43	8	52	15	13	14	41	93	7
TOBA	45	14	59	8	13	15	37	96	4
GARN	55	7	63	12	10	10	32	95	5
TEXT	55	8	64	12	6	12	31	94	6
TRIK	61	7	67	11	8	9	29	96	4
OVRT	42	10	51	11	12	20	43	95	5
BEKL	57	10	67	10	7	11	27	94	6
LADE	58	8	66	9	5	14	28	95	5
S2GV	60	13	73	8	6	8	22	96	4
TRAH	30	34	64	10	11	11	32	96	4
A_TR	56	16	72	8	9	8	24	96	4
OVR_	57	11	68	8	9	9	26	94	6
TRAM	42	27	69	8	8	11	26	95	5
PAPP	34	31	65	10	15	8	32	97	3
PPPP	40	21	62	11	14	10	35	97	3
TRAF	45	22	67	9	11	10	29	96	4
PFRP	37	17	55	13	14	14	41	96	4
OVRX	38	20	58	13	10	16	38	96	4
GRAF	14	29	43	17	22	12	50	93	7
KEMI	18	20	38	13	23	21	57	95	5
GODS	26	27	53	9	15	17	41	95	5
BASP	24	25	49	13	21	13	47	96	4
PLAS	43	13	56	11	12	16	40	95	5
FARG	31	6	37	19	19	20	58	94	6
LAKE	15	6	20	13	27	35	75	96	4
TVAT	33	4	37	25	13	20	57	94	6
OVRK	35	14	49	13	17	17	47	96	4
PETR	13	23	35	10	35	14	60	95	5
SMOR	31	10	40	17	20	18	54	94	6
GUMM	54	6	61	9	12	12	34	95	5
PLSV	49	12	61	10	11	12	33	94	6
PORS	48	13	61	10	12	13	35	96	4
GLAS	51	17	68	8	10	10	28	96	4
TEGE	42	14	56	15	12	13	40	96	4
CEME	32	22	54	12	14	16	42	96	4
OVRM	44	15	59	11	14	11	36	96	4
JRN_	40	23	63	9	15	10	34	97	3
FERR	43	24	67	10	9	9	28	95	5
JNGJ	45	24	68	7	11	8	26	94	6
META	42	24	67	9	12	8	29	96	4
METV	43	17	60	11	14	11	36	96	4
I_JA	47	23	70	6	11	8	25	95	5
METR	31	31	62	8	12	12	32	95	5
MSKN	16	31	48	10	21	17	48	95	5
ELMO	17	27	44	9	25	18	52	95	5
TELE	15	16	31	10	31	23	63	95	5
HUSH	33	28	60	9	14	11	34	94	6
OVRE	27	23	49	10	21	15	46	95	5
VARV	15	41	56	7	17	14	38	94	6
RALS	17	48	65	6	16	9	31	96	4
BILA	34	22	57	6	20	12	38	95	5
CYKL	44	13	57	13	12	14	39	96	4
FLYG	12	28	39	8	31	18	57	97	3
OVRR	41	20	61	10	11	15	35	96	4
INST	12	21	33	11	26	24	62	95	5
A_TI	33	23	56	13	9	16	38	94	6
EL_O	7	28	35	11	36	14	61	97	3
GASV	4	15	19	11	28	35	74	93	7
VATT	6	46	53	9	27	8	44	97	3
BYGG	19	11	30	10	29	21	60	90	10
VARU	26	8	35	26	11	21	59	94	6
HOTE	25	27	52	12	13	10	35	88	12
SAMF	40	9	49	17	11	15	44	93	7
POST	54	2	56	17	13	10	40	96	4
BANK	2	1	2	27	37	30	93	95	5
EGNA	26	15	41	19	19	15	53	94	6
FAST	5	3	8	19	26	38	83	91	9
UPPD	6	46	53	13	7	21	41	94	6
REPA	23	20	43	15	5	30	49	93	7
OVRP	26	15	40	16	18	19	52	93	7
TOTAL	26	15	41	16	18	19	54	95	8

Tabella 7: Carbon Emissions in the Swedish Model

Sectors	Aggregate Emissions (1000 tons)	Percent of Domestic Emissions	Rank of Percent of Emissions	Cumulative Percent	Emissions per bill. SEK output	Rank of Per Unit Emissions
JORD	1388	3	10	77	29	21
SKOG	424	1	21	88	16	25
FSKE	192		34	95	96	11
JARN	266	1	27	92	73	13
A_ME	214		29	93	70	14
STEN	70		47	97	3	62
SLAK	113		38	96	3	64
MEJE	118		36	95	5	48
FRUK	57		52	98	5	47
FISK	39		61	99	5	44
FETT	38		62	99	6	40
KVAR	35		65	99	7	35
BAGE	98		41	96	6	42
SOCK	116		37	96	48	17
CHOK	57		53	98	6	39
DIVX	60		48	98	6	41
FODE	47		56	98	7	36
DRYC	98		42	97	3	59
TOBA	33		67	99	2	69
GARN	59		51	98	8	32
TEXT	17		80	100	3	66
TRIK	18		78	100	1	81
OVRT	19		77	100	3	65
BEKL	7		84	100		86
LADE	3		86	100		85
S2GV	98		40	96	4	51
TRAH	45		58	99	5	49
A_TR	27		70	100	6	38
OVR_	6		85	100	2	77
TRAM	28		69	99	1	79
PAPP	434	1	20	87	32	20
PPPP	398	1	22	89	9	30
TRAF	368	1	23	90	646	4
PFRP	95		43	97	15	26
OVRX	79		45	97	6	43
GRAF	105		39	96	2	70
KEMI	74		46	97	3	55
GODS	16		81	100	5	46
BASP	39		60	99	3	63
PLAS	53		54	98	5	45
FARG	21		73	100	3	57
LAKE	60		49	98	3	58
TVAT	17		79	100	2	71
OVRK	48		55	98	3	56
PETR	81		44	97	1	80
SMOR	59		50	98	16	24
GUMM	23		72	100	2	72
PLSV	46		57	99	3	61
PORS	179		35	95	65	15
GLAS	326	1	24	90	41	19
TEGE	213		30	93	147	8
CEME	225		28	92	166	7
OVRM	326	1	25	91	24	22
JRN_	2404	5	3	49	64	16
FERR	2404	5	3	49	1565	1
JNGJ	2348	5	5	58	1220	3
META	2170	4	6	63	264	5
METV	2160	4	7	67	217	6
I_JA	2155	4	8	71	1289	2
METR	208		33	94	3	68
MSKN	211		31	94	2	76
ELMO	20		74	100	2	75
TELE	33		68	99	1	83
HUSH	12		82	100	2	73
OVRE	37		63	99	1	78
VARV	37		64	99	5	50
RALS	33		66	99	8	31
BILA	209		32	94	2	74
CYKL	19		76	100	7	34
FLYG	44		59	99	3	67
OVRR	20		75	100	22	23
INST	24		71	100	1	82
A_TI	8		83	100	1	84
EL_O	9622	19	2	44	136	9
GASV	266	1	26	91	134	10
VATT			87	100		87
BYGG	1474	3	9	74	8	33
VARU	538	1	12	79	47	18
HOTE	538	1	12	79	12	28
SAMF	12352	25	1	25	80	12
POST	538	1	12	79	12	29
BANK	538	1	12	79	7	37
EGNA	459	1	18	85	4	54
FAST	459	1	18	85	4	52
UPPD	538	1	12	79	3	60
REPA	538	1	12	79	14	27
OVRP	538	1	11	78	4	53
TOTAL	50029	100				

Tabella 8: Welfare Impact of Doubling the Carbon Tax (Scenario C100)

Household	Percent Share of... Households	Percent Share of... Individuals	Utility Index	EV in SEK per... Individual	EV in SEK per... Household
S_NC_1	9.2	4.2	99.7	-415.0	-415.0
S_NC_2	9.1	4.2	99.8	-283.0	-283.0
S_NC_3	9.1	4.2	99.8	-409.0	-409.0
S_NC_4	9.2	4.2	99.9	-345.0	-345.0
S_C_1	1.8	1.9	99.8	-226.0	-521.0
S_C_2	1.8	2.2	99.7	-431.0	-1164.0
M_NC_1	7.3	6.7	99.5	-617.0	-1234.0
M_NC_2	7.4	6.8	99.7	-464.0	-928.0
M_NC_3	7.3	6.7	99.6	-653.0	-1307.0
M_NC_4	7.3	6.7	99.7	-693.0	-1387.0
M_1C_1	1.9	2.6	99.6	-386.0	-1157.0
M_1C_2	1.9	2.5	99.6	-448.0	-1343.0
M_1C_3	1.9	2.6	99.6	-537.0	-1611.0
M_1C_4	1.9	2.6	99.6	-762.0	-2287.0
M_2C_1	2.4	4.4	99.5	-416.0	-1666.0
M_2C_2	2.4	4.4	99.5	-481.0	-1924.0
M_2C_3	2.4	4.4	99.4	-602.0	-2407.0
M_2C_4	2.4	4.4	99.4	-758.0	-3033.0
M_3C_1	1.1	2.5	99.6	-299.0	-1557.0
M_3C_2	1.1	2.5	99.6	-363.0	-1887.0
M_3C_3	1.1	2.5	99.5	-461.0	-2397.0
M_3C_4	1.1	2.6	99.5	-537.0	-2900.0
O_NC_1	1.4	1.4	99.7	-436.0	-959.0
O_NC_2	1.4	1.7	99.7	-418.0	-1128.0
O_NC_3	1.4	1.8	99.7	-542.0	-1571.0
O_NC_4	1.4	2.1	99.7	-562.0	-1911.0
O_C_1	0.9	1.6	99.7	-348.0	-1323.0
O_C_2	0.9	1.8	99.7	-320.0	-1375.0
O_C_3	0.9	1.8	99.7	-456.0	-1963.0
O_C_4	0.9	1.9	99.6	-569.0	-2562.0

Tabella 9: Sectoral Impact of Doubling the Carbon Tax (Scenario C100)

Sector	IPRICE%	VA%	IMP%	EXP%	CO2_D	CO2_F	CO2_W
JORD				-1	-1	1	
SKOG	-1		-1				-1
FSKE				-1	-1		-1
JARN		-1		-2	-4		-4
A_ME				-1			
STEN		-6	-7	-7	-5	-8	-13
SLAK	-1						
MEJE				-1			
FRUK	-1						
FISK	-1						
FETT	-1						
KVAR	-1						
BAGE	-1						
SOCK	1			-1			
CHOK	-1						
DIVX	-1						
DRYC	-1						
TOBA	-1	1					
GARN	-1						
TEXT	-1	1	-1				
TRIK	-1	1		1			
OVRT	-1	1					
BEKL	-1	1					
LADE	-1	1					
S2GV	-1		-1				
TRAH				-1			
A_TR	-1						
OVR_	-1						
TRAM	-1						
PAPP			-1	-1	-2		-2
PPPP				-1	-2		-1
TRAF	-1				1		1
OVRX	-1	1					
GRAF	-1						
KEMI				-2			
GODS				-1			
BASP	-1						
PLAS	-1	1					
LAKE	-1	1		1	1		1
TVAT	-1						
OVRK	-1		-1				
PETR	18	-9	-2	-23	-11		-11
SMOR			-1	-1			
GUMM	-1						
PLSV	-1	1					
PORS	-1				1		1
GLAS							1
TEGE				-1	-1		
CEME			-1	-1	-1		-1
OVRM				-1			
JRN_				-1	-6	1	-4
FERR	-1				3	-1	2
JNGJ	-1	1			11	2	13
META					4	2	6
METV	-1				7	4	11
I_JA	-1	1			11	2	13
METR	-1						1
MSKN	-1	1			1		1
ELMO	-1	1					
TELE	-1	1		1			
HUSH	-1	1		1			
OVRE	-1	1					
VARV	-1						
RALS	-1		-1				
BILA	-1	1		1	2		2
CYKL	-1	1		1			
FLYG	-1		-1				
OVRR	-1						
INST	-1	1					
A_TI	-1						
EL_O				-1	-5		-5
GASV	16	-1			-13		-13
BYGG	-1				1		1
VARU			-1	-1	-2		-2
HOTE	-1				1		1
SAMF				-1	-57		-57
POST	-1				1		1
EGNA	-1	1			3		3
FAST	-1				1		1
UPPD	-1				1		1
REPA	-1				2		2
OVRP	-1	1			2		3
TOTAL					-52	6	-47

Tabella 10: Impacts on Welfare and Aggregate Carbon Emissions of All Scenarios

	Aggregate Welfare Impact		Aggregate CO_2 Emissions		
Scenario	b.SEK	%	Domestic	Foreign	Global
BENCH			50029	11786	61815
C100	-3.9	-0.3	-52.2	5.6	-46.6
DIES	-0.4	≈ 0	-6	0.1	-5
PETROL	-3.0	-0.2	-42	-0.6	-42

Tabella 11: Detailed Carbon Tax Revenue Effects of Doubling the Carbon Tax (Scenario C100)

	Benchmark Revenues (b.SEK)				Change in Scenario C100 (b.SEK)			
Sector	STEN	PETR	GASV	TOTAL	STEN	PETR	GASV	TOTAL
JORD	0.496	0.704		1.200	0.495	0.646		1.141
SKOG		0.222		0.222		0.203		0.203
FSKE		0.095		0.095		0.086		0.086
JARN	0.105	0.061		0.165	0.101	0.054		0.155
A_ME	0.013	0.045		0.058	0.014	0.041		0.055
STEN		0.058		0.058		0.047		0.047
SLAK		0.020	0.003	0.022		0.018	0.002	0.020
MEJE		0.019	0.005	0.023		0.017	0.004	0.021
FRUK		0.007	0.009	0.017		0.007	0.009	0.016
FISK		0.002		0.002		0.002		0.002
FETT		0.007	0.003	0.010		0.007	0.002	0.009
KVAR		0.002		0.002		0.001		0.001
BAGE		0.016	0.003	0.020		0.015	0.003	0.019
SOCK	0.009	0.012	0.014	0.035	0.008	0.011	0.013	0.032
CHOK		0.005	0.001	0.005		0.004		0.004
DIVX		0.007	0.001	0.008		0.007		0.007
FODE		0.005	0.001	0.006		0.004	0.002	0.006
DRYC		0.013	0.006	0.019		0.013	0.005	0.018
TOBA				0.001		0.001	0.001	0.002
GARN		0.013	0.001	0.014		0.012	0.002	0.013
TEXT		0.001		0.001		0.001		0.001
TRIK		0.001		0.002		0.002		0.002
OVRT		0.004		0.004		0.003		0.004
BEKL		0.002		0.002		0.002	0.001	0.003
LADE		0.001		0.001		0.001		0.001
S2GV		0.022		0.022		0.021		0.021
TRAH		0.009		0.009		0.008		0.008
A_TR		0.006		0.006		0.006		0.006
OVR_		0.002		0.002		0.002		0.002
TRAM		0.007		0.007		0.006		0.006
PAPP	0.028	0.046		0.074	0.028	0.042		0.070
PPPP		0.107	0.010	0.116		0.097	0.008	0.105
TRAF		0.001		0.001				
PFRP		0.007	0.002	0.009		0.006	0.002	0.008
OVRX	0.001	0.004		0.005		0.004		0.005
GRAF		0.016		0.017		0.015		0.016
KEMI	0.204	0.249	0.001	0.454	0.201	0.226		0.428
GODS	0.045	0.008	0.001	0.054	0.045	0.007	0.001	0.053
BASP	0.003	0.010	0.002	0.016	0.004	0.010	0.002	0.015
PLAS	0.007	0.007	0.002	0.015	0.006	0.006	0.001	0.014
FARG	0.003	0.009	0.001	0.012	0.004	0.007		0.011
LAKE		0.009		0.009		0.008		0.008
TVAT		0.002		0.002		0.001		0.002
OVRK	0.021	0.009	0.003	0.033	0.022	0.008	0.003	0.033
PETR		0.188		0.188		0.123		0.123
SMOR	0.243	0.024	0.002	0.269	0.240	0.023	0.002	0.265
GUMM	0.002	0.004		0.006	0.002	0.004		0.006
PLSV		0.009		0.009		0.008		0.008
PORS		0.004		0.004		0.003		0.003
GLAS		0.024		0.024		0.021		0.021
TEGE		0.004	0.003	0.008		0.005	0.003	0.008
CEME		0.007		0.007		0.007		0.007
OVRM		0.043	0.002	0.045		0.039	0.002	0.041
JRN_	0.145	0.125	0.006	0.275	0.144	0.114	0.005	0.263
FERR	0.003			0.003	0.002	0.001		0.003
JNGJ	0.018	0.003		0.021	0.018	0.003		0.021
META	0.028	0.010	0.002	0.039	0.028	0.008	0.001	0.038
METV		0.007		0.007		0.007		0.007
I_JA	0.013	0.002		0.015	0.013	0.003		0.015
METR	0.002	0.053	0.002	0.057	0.002	0.048	0.002	0.053
MSKN	0.006	0.048	0.002	0.057	0.006	0.045	0.002	0.054
ELMO		0.003		0.003		0.002		0.002
TELE		0.005		0.005		0.006		0.006
HUSH		0.001		0.001		0.001		0.001
OVRE	0.017	0.008		0.024	0.017	0.007		0.023
VARV		0.005	0.001	0.006		0.004		0.005
RALS		0.004		0.004		0.003		0.003
BILA	0.016	0.049	0.007	0.072	0.016	0.045	0.007	0.069
CYKL				0.001		0.001		0.001
FLYG		0.003		0.003		0.003		0.003
OVRR						0.001		0.001
INST		0.004		0.004		0.003		0.003
A_TI		0.003		0.003		0.002		0.002
EL_O		1.156	0.473	1.630		1.060	0.438	1.498
GASV		0.618		0.618		0.517		0.517
BYGG		1.599		1.599		1.467		1.467
VARU		1.572	0.085	1.657		1.430	0.078	1.508
HOTE		0.227	0.022	0.249		0.209	0.020	0.230
SAMF		4.183		4.183		3.809		3.809
POST		0.101		0.101		0.092		0.092
BANK		0.169	0.004	0.174		0.156	0.004	0.160
FAST		0.746	0.037	0.783		0.687	0.034	0.720
UPPD		0.659	0.022	0.681		0.605	0.020	0.625
REPA		0.091		0.091		0.083		0.083
OVRP	0.142	0.481		0.623	0.143	0.445		0.588
TOTAL	1.568	14.096	0.740	16.405	1.559	12.787	0.686	15.032

Tabella 12: Costs and Benefits to Swedes in SEK of Doubling the Carbon Tax (Scenario C100)

	Average Individual			Average Household		
Household	Benefit	Cost	Percent	Benefit	Cost	Percent
S_NC_1	3	415	1	6	415	2
S_NC_2	3	283	1	6	283	2
S_NC_3	3	409	1	6	409	2
S_NC_4	3	345	1	6	345	2
S_C_1	3	226	1	6	521	1
S_C_2	3	431	1	6	1164	1
M_NC_1	3	617		6	1234	1
M_NC_2	3	464	1	6	928	1
M_NC_3	3	653		6	1307	
M_NC_4	3	693		6	1387	
M_1C_1	3	386	1	6	1157	1
M_1C_2	3	448	1	6	1343	
M_1C_3	3	537	1	6	1611	
M_1C_4	3	762		6	2287	
M_2C_1	3	416	1	6	1666	
M_2C_2	3	481	1	6	1924	
M_2C_3	3	602		6	2407	
M_2C_4	3	758		6	3033	
M_3C_1	3	299	1	6	1557	
M_3C_2	3	363	1	6	1887	
M_3C_3	3	461	1	6	2397	
M_3C_4	3	537	1	6	2900	
O_NC_1	3	436	1	6	959	1
O_NC_2	3	418	1	6	1128	1
O_NC_3	3	542	1	6	1571	
O_NC_4	3	562	1	6	1911	
O_C_1	3	348	1	6	1323	
O_C_2	3	320	1	6	1375	
O_C_3	3	456	1	6	1963	
O_C_4	3	569	1	6	2562	
AVE	3	500	1	6	1090	1

Tabella 13: Costs and Benefits to Swedes in SEK of Doubled Petrol Tax (Scenario PETROL)

	Average Individual			Average Household		
Household	Benefit	Cost	Percent	Benefit	Cost	Percent
S_NC_1	2	310	1	5	310	2
S_NC_2	2	233	1	5	233	2
S_NC_3	2	306	1	5	306	2
S_NC_4	2	278	1	5	278	2
S_C_1	2	172	1	5	395	1
S_C_2	2	303	1	5	817	1
M_NC_1	2	409	1	5	819	1
M_NC_2	2	324	1	5	648	1
M_NC_3	2	444	1	5	889	1
M_NC_4	2	471		5	943	1
M_1C_1	2	262	1	5	787	1
M_1C_2	2	296	1	5	888	1
M_1C_3	2	359	1	5	1078	
M_1C_4	2	482		5	1447	
M_2C_1	2	270	1	5	1079	
M_2C_2	2	311	1	5	1243	
M_2C_3	2	381	1	5	1522	
M_2C_4	2	469		5	1874	
M_3C_1	2	201	1	5	1048	
M_3C_2	2	237	1	5	1235	
M_3C_3	2	293	1	5	1524	
M_3C_4	2	337	1	5	1822	
O_NC_1	2	306	1	5	672	1
O_NC_2	2	300	1	5	809	1
O_NC_3	2	374	1	5	1084	
O_NC_4	2	391	1	5	1331	
O_C_1	2	247	1	5	938	1
O_C_2	2	231	1	5	993	1
O_C_3	2	312	1	5	1340	
O_C_4	2	381	1	5	1713	
AVE	2	340	1	5	741	1