SVERIGES LANTBRUKSUNIVERSITET SLU

Institutionen för skogsekonomi

General Equilibrium Effects of Increasing Carbon Taxes in Sweden

by

Glenn W. Harrison and Bengt Kriström

Arbetsrapport 235, 1997

We regret that some of the pages in this report may not be up to the proper legibility standards, even though the best possible copy was used for scanning

NEI-SE--296

General Equilibrium Effects of Increasing Carbon Taxes in Sweden

by

Glenn W. Harrison and Bengt Kriström†

February 10, 1997

MASTER

† Harrison is Dewey H. Johnson Professor of Economics, Department of Economics, College of Business Administration, University of South Carolina (Columbia, USA). Kriström is Professor of Resource Economics, Department of Forest Economics, Swedish University of Agricultural Sciences (Umeå, Sweden). We are grateful to Åke Nordlander and Maude Svensson of the Swedish Ministry of Finance for discussions on these issues, to Runar Brannlund and Tom Rutherford for helpful suggestions, and to the Swedish Treasury Department for financial support. Address all correspondence to Glenn W. Harrison, Department of Economics, College of Business Administration, University of South Carolina, Columbia, SC 29208, U.S.A. (E-mail: HARRISON@DARLA.BADM.SC.EDU; Phone: (803) 732-7589; Fax: (803) 749-8924).

RB

CONTENTS

1. The Carbon Tax Debate in Sweden .... - 1 -
 1.1 Climate Policy in Sweden .... - 1 -
 1.2 The Remit of the "Green Tax" Commission .... - 2 -
 1.3 The General Structure of Swedish Energy Taxes .... - 3 -
  A. Industry Exemptions .... - 4 -
  B. The Carbon Dioxide Tax .... - 5 -
 1.4 The European Union .... - 5 -

2. A General Equilibrium Model .... - 6 -
 2.1 Basic Features .... - 6 -
 2.2 The Swedish Model .... - 8 -

3. Effects of Carbon Tax Policies .... - 14 -
 3.1 Baseline Policies and Simulation Scenarios .... - 14 -
 3.2 Effects of Expanding the Carbon Tax .... - 15 -
  A. Welfare Impacts .... - 15 -
  B. Emissions Impacts .... - 19 -
  C. Price and Production Impacts .... - 22 -
  D. Tax Replacement Schemes .... - 24 -
 3.3 Effects of Constraints on Nuclear Power .... - 26 -
 3.4 A Cost-Benefit Comparison .... - 28 -

4. Conclusions .... - 30 -

References .... - 33 -

LIST OF TABLES

Table 1: Sectors in the Swedish Model .... - 37 -
Table 2: Households in the Swedish Model .... - 38 -
Table 3: Benchmark Carbon Taxes (percent) .... - 39 -
Table 4: Benchmark Energy and Sulphur Taxes (percent) .... - 40 -
Table 5: Simulation Scenarios .... - 41 -
Table 6: Labor Types in the Swedish Model (percent employment in sector) .... - 42 -
Table 7: Carbon Emissions in the Swedish Model .... - 43 -
Table 8: Welfare Impact of Doubling the Carbon Tax (Scenario C100) .... - 44 -
Table 9: Sectoral Impact of Doubling the Carbon Tax (Scenario C100) .... - 45 -
Table 10: Impacts on Welfare and Aggregate Carbon Emissions of All Scenarios .... - 46 -
Table 11: Detailed Carbon Tax Revenue Effects of Doubling the Carbon Tax (Scenario C100) .... - 47 -
Table 12: Sectoral Impact of Doubling the Carbon Tax with a Nuclear Shutdown (Scenario N75) .... - 48 -
Table 13: Costs and Benefits to Swedes in SEK of Doubling the Carbon Tax (Scenario C100) .... - 49 -

LIST OF FIGURES

Figure 1: Revenues from Energy Taxes in 1994 (millions of SEK) .... - 36 -

Sweden was one of the first countries to introduce carbon taxes. Along with many other countries that are concerned with the risk of global warming, it is currently evaluating further carbon taxes. We were asked to advise a government Commission charged with undertaking the official Swedish evaluation. We did so by constructing and simulating a computable general equilibrium (CGE) model of Sweden.

We review the carbon tax debate in Sweden in section 1. The model is described in section 2, and the main results presented in section 3.

1. The Carbon Tax Debate in Sweden

1.1 Climate Policy in Sweden

Sweden has signed the Rio Declaration, which means that the current goal is to stabilize CO_2 emissions at the 1990 level. Indeed, the 1991 carbon tax was introduced with this target in mind: to reduce Swedish emissions by the year 2000. Given that 1990 was a particularly "mild" year for Sweden in terms of economic activity and carbon emissions, this goal is likely to be relatively difficult for Sweden to attain.

The most important issue in future energy policy in Sweden is the fate of nuclear power. The current interpretation of the 1980 referendum is that nuclear power should be abolished by 2010, a goal that may conflict with unilateral climate policy goals. The future of nuclear power in Sweden is therefore unclear. A Commission on Future Energy Policy has been reviewing the matter and reported in 1995. In essence it recommended *against* a complete shutdown in 2010, generating considerable debate in policy circles. Uncertainty about future energy policy may have induced the government to change its climate policy from an active unilateral policy to the vague, internationally cooperative, framework that currently dominates the political discussion in Sweden.

An important analysis of the costs of closing nuclear power within a binding CO_2 constraint was carried out by Bergman [1991]. His calculations, based on a small CGE model, suggested significant costs of closing nuclear power while stabilizing (or reducing) CO_2 emissions. Assuming freely mobile capital internationally, this model suggests a significant leakage of Swedish firms to lower-cost countries. This leakage argument has also influenced the debate and may have been important in redirecting earlier CO_2 goals.

In summary, Sweden's climate policy is mainly affected by three issues. The first is the concern for the international competitiveness of energy-intensive industry. We discuss below how this concern has been mapped into various exemptions and deductions. The second is the awareness of the link between nuclear power and CO_2 emissions, which we also evaluate later. The third is the new emphasis on international cooperation, the entrance into the EU being the most dramatic example.

1.2 The Remit of the "Green Tax" Commission

In March 1995 the Swedish government launched a Commission to provide an analysis of a tax system intended to have a stronger environmental profile. The Commission was asked to evaluate prevailing environmental taxes, and to scrutinize the potential for a "double dividend" from new carbon taxes. The terms of reference include scrutiny of impacts on labor markets, the budget effects, "competitiveness," dynamic impacts, distributional impacts, environmental aspects, as well as an analysis of the administrative properties of any proposal the Commission might want to put forward.

In the economics literature the "double dividend" argument has come to circle around revenue-neutral substitution between labor and environmental taxes.[1] While there certainly exists other sets of taxes with the appropriate mix of distortionary impacts, the discussion within the Commission and in the academic literature focuses mainly on energy-labor tax substitutions.

Because Sweden is a small open economy, it is also important look at the impact of a tax-swap on international "competitiveness". The Commission should also describe the effects of its proposals on the environment and detail the distributional impacts of the reform. Finally, the Commission should also map out the potential environmental gains of the eventual reform.

---

[1] See Goulder [1995a] for a review.

1.3 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).[2]

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

[2] 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).

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 [1996; 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 goods from different sectors compete subject to the budget constraint of the consumer, and all income elasticities are unity. In the second 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. Public consumption is balanced with revenue.

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 balances the value of exports and imports taking into account exogenously-fixed capital inflows. Our model allows for changes in these fixed world prices.

2.2 The Swedish Model

Based on 1992 input-output data for Sweden, the model identifies 87 sectors.[3] These are listed in Table 1, along with their pseudo-Swedish acronym. This is the level of disaggregation available through the input-output statistics, and provides excellent detail for our purposes. It is possible to aggregate to a smaller number of sectors, such as has been popular in previous CGE models of Sweden, but there seems little advantage in doing so and potential for misleading analysis in the present context.[4] Moreover, it is always possible to assess the information loss of employing specific aggregations if the model is fully disaggregated, while the reverse is obviously not true.

The household disaggregation is based on the 1992 Household Expenditure Survey conducted by the "Statistiska Centralbyrån" (SCB). It provides detailed information on expenditure patterns of 30 households. These households are differentiated by family status and income, and are listed along with their acronyms in Table 2. One difficulty is that the expenditures of each household are defined over consumer goods, and no ready mapping exists from our industrial products to those goods. We resolve this problem by using our intuition, and using the data from the household expenditure survey to allow different households to have different expenditure patterns for different industrial goods.

We also assume that each household receives it's income from slightly different

---

[3] The input-output database formally identifies 88 sectors, but one of these is effectively a "dummy" sub-industry which contains no transactions and is therefore deleted. We therefore refer to the model as having 87 sectors.

[4] The primary argument for aggregation, given the ready availability of powerful software and hardware for these models, has to do with the "reliability" of data and priors at the proposed level of aggregation. Several of 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 [1996;Appendix A] documents our data collation efforts, and the instances where we needed to map one aggregate sector into 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 basis for individual sectors at the latter level of disaggregation. With respect to the use of *a priori* judgements, our belief is that it is much easier to apply serious priors to detailed sectors than it is to synthetic aggregates. In any event, if the priors in question are essentially held in a diffuse manner over a range of sectors, then nothing is lost if one so applies them in our disaggregated model. Providing the reader knows when such uniform assumptions are being applied, and is not dazzled by the fake detail of the analysis, it is foolish to "hardwire" in the level of application of priors by aggregation. Formal decision-theoretic methods of aggregation of input-output sectors are explored by Harrison and Manning [1976] and provide statistically informative alternatives to naïve aggregation as practiced by many early-generation CGE modelers. However, sophisticated or naïve aggregation is simply misplaced in the present setting.

sources. In other words, each household has a slightly different *share* of each primary factors in it's 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.[5]

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.[6] 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 factors, the

---

[5] 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.

[6] 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.

corresponding supply curve for that industry becomes more inelastic. The intuition is clear: as the relative demand for output for that industry falls, *ceteris paribus* all input prices, the factor that is specific to this industry cannot escape to other sectors. It must therefore experience a larger drop in real return than 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 supply price in that industry than when the factor is assumed mobile. The converse argument applies to increases in demand in the industry, of course. Thus we can arbitrarily constrain the supply response of resource-based industries by specification of this parameter.[7] Given that the primary policy focus of these simulations is on the use of fossil fuels, such assumptions may be important.

Each sector produces output using intermediate inputs and a value added composite of the primary factors. Although the natural assumption might be to model the substitutability of the intermediate inputs by assuming a Leontief technology[8], 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 typically impact in Sweden. The value added composite is produced using a CES production 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.

Trade is modeled as occurring at fixed world prices. However, Swedish importers may 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 a constant elasticity of transformation between (a) sales to domestic markets and a composite foreign market, and (b) sales of the composite export to any of several foreign trading partners. The key feature of our model in these regards is that Swedish

---

[7] 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].

[8] 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 nested-CES functions, although they can be used to represent globally regular functional forms in a locally flexible manner (see Perroni and Rutherford [1995a][1995b]).

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 [1996; Appendix A]. The rates assumed for the value added taxes and factor taxes reflect statutory rates

---

[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.

applicable in 1995, and the other rates reflect actual collections as documented in the Input-Output table for 1992. Although these pre-existing distortions are all incorporated at a detailed sectoral level, in 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-best" effects from the carbon tax scenarios considered later.

Estimates of elasticities of substitution must be assumed for primary factor substitution, value added and intermediate input substitution, import demand, detailed import components, 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 into detailed export components, and the allocation of exports to destination. Despite our literature search, there are many elasticities about which there is considerable uncertainty. Our solution for that problem is to undertake a systematic sensitivity analysis in Harrison and Kriström [1996] with respect to key elasticities. Harrison and Vinod [1992], 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 plausible ranges of uncertainty about key elasticities.

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 production, as untaxed foreign production is substituted for taxed domestic production. We 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 relation to elasticity estimates used in some modeling exercises (e.g., Harrison, Rutherford and Tarr [1995][1996]), 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.[10]

---

[10] The popular reason for using higher trade elasticities is that one can thereby avoid these effects, which are deemed unlikely *a priori* for a country as small in international trade terms as Sweden. Although the 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 [1996]), these are not debates which are relevant here.

Estimates of carbon emissions in each sector were derived on the basis of information on 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. Although unimportant in terms of overall emissions, the TRAF (fibreboard) sector also has an extremely high emission relative to the value of it's output.

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 carbon taxes and sectoral emissions is that, of the two biggest aggregate emitters, only EL_O pays the big tax on inputs of coal (output from sector STEN). Thus one could imagine the incentive within that sector to move away from coal-fired generators as the result of scalar increases in carbon 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

---

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

in future work.

The SOE model is generated with the GAMS/MPSGE software developed by Brooke, 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 [1996; 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 Carbon Tax 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.

We study the effects of alternative revenue replacement tax instruments with simulations C100V and C100LS. The first uses the VAT, and the second uses lump-sum taxes as a replacement device. Lump-sum taxes are levied on each household in proportion to their benchmark income, but are otherwise lump-sum.

The effects of politically-imposed constraints on nuclear power plants are studied in the N100 and N75 simulations. In each case we assume the same basic scenario as the core simulation, C100, but impose a constraint that the physical output of the Electricity sector (EL_O) be maintained at no more than 100% or 75% of the benchmark level. Since nuclear-generated power represents roughly 50% of existing electricity in Sweden, these constraints are a plausible representation of the partial effects of maintaining the proposed ban on nuclear power. This constraint is complementary slack in the model to a tax on the electricity sector, such that if the constraint is violated then the sector is taxed until it reduces output and meets the constraint. It is expected that this constraint will significantly increase the welfare cost of the carbon tax increase, as consumers and industry face higher electricity prices. The model incorporates all of the general equilibrium effects of the tax on electricity required to meet the constraint.

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.[12] 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 the direct benefits to the household of the resulting reduction

---

[12] 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.

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.[13]

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.[14] 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-

[13] 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.

[14] By the first author.

efficient) urban transportation networks into suburban transportation networks.[15]

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.[16] 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.[17] 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

---

[15] 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.

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

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

willingness to pay for carbon reductions. On the 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.

The first of the three columns, marked CO2_D, shows the change due to changes in *domestic* production in that sector brought about by the C100 scenario. Thus we see that a reduction in domestic production of the STEN sector, indicated by a 6% reduction in the value of domestic value added in column VA%, led to a reduction in physical emissions from that sector of 5 Ktons.

The fact that some sectors expand when there is an increase in carbon taxes is exactly what one would expect from a general economic equilibrium. The doubling of the carbon tax changes *relative* prices against the *most* carbon-intensive activities. The cheapest way for some industries to contract their use of the (intermediate) inputs of these carbon-intensive sectors *may* be to substitute towards the use of the products of other sectors that, while less carbon 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-intensive? Simple: their existing technology may not call for them to be used at all. So, even if 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.

For example, the DRYC sector is a wonderful sector, justifiably patronized by many 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 for all modes of industrial transportation, sectors RALS, BILA and FLYG in our model, it cannot "turn to DRYC" despite the temptation. It must re-allocate amongst these three transportation sectors, and in fact such decisions tend to go against RALS and in favor of the other two. The common sense 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 JORD sector has virtually no (direct) inputs of DRYC in the benchmark year of our Input-Output table, but it has substantial inputs of all three of the transportation inputs. Hence, by Marshall's second law of derived demand[18] the elasticity of demand for the alternative 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.[19] 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 PETR and SMOR, and indeed in the physical quantity of imports. If we were to assume that foreign producers are

---

[18] Which is sometimes stated as "the importance of being unimportant," in the sense that the smaller (greater) the share of an input in cost the smaller (greater) will be the absolute value of the derived demand elasticity for the input. This law is valid in the present case, since the elasticity of product demand (around 1) 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).

[19] 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 deba.e in Sweden, not to posture by generating strategically creative environmental accounts for negotiators.

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 assumptions as to how much "dirtier" foreign production is[20] are not so important as the general logic that accounts for the foreign change in emissions. That logic is important since it is global emissions that matter for the final environmental good, reduced risk of ***global*** warming. Hence it is incumbent on Sweden to take into account the "leakage" effects of just reducing on-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 leakage issue, and there are obvious limitations to calculations of this kind. It is possible that 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 general equilibrium of foreign economies, we are not accounting for the full effects of changes 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 ***potentially*** offsetting effects of carbon tax reforms when international trade is taken into account. There are, of course, many sectors where the foreign effect works in the same direction as the domestic effect (e.g., STEN), so our incorporation of foreign effects should not be viewed as imparting a presumptive bias into the estimation of global emissions.

The final column in Table 9, CO2_W, shows the aggregate world change in emissions of carbon in each sector. The foreign effects ***tend*** to be dominated by the domestic change, since imports are generally a much smaller of domestic consumption in most sectors than domestic production.

---

[20] Specifically, we assume that Japan is just as efficient (due to nuclear power use), Norway is just as efficient (due to hydro power), the European Union countries are 50% less efficient, the United States is 100% less 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 estimates of foreign emissions in time.

C. Price and Production Impacts

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 policy. By examining them one gets an idea of what is happening to the Swedish economy as the result of the C100 policy. However, it may be useful to look more directly at the changes in 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.

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.[21] Three are those 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.[22]

---

[21] 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.

[22] 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.

D. Tax Replacement Schemes

The increase in carbon taxes in scenario C100 might be expected, *a priori*, to generate a net increase in government revenues in the absence of any other changes. Indeed this is in fact what happens in our model, at least before we allow relative prices to change to return the Swedish economy to a general equilibrium. When prices and behavior changes, we discover that the carbon tax increase generates a net *increase* in government revenue as expected. The net increase requires a 1.5% decrease in labor taxes to re-balance the government budget.

However, although net revenues increase due to the carbon tax increase, gross revenues from the *energy* tax actually decrease. How can such a "perverse" effect on government revenues come about? In principle there is no surprise here, since it is possible that consumption and production may move away from products that already have a large tax. In practice, this is what happens. The large increase in revenues collected by the carbon tax is offset in part by a decrease in revenues collected under the energy tax. There are also decreases in taxes collected under the factor taxes and the VAT, but these are of "second order" in comparison to the offset from the energy tax.[23]

Intuitively it is also easy to explain what is generating the qualitative result that the revenue effect from energy taxes offsets the revenue effect from carbon tax increases. The energy tax hits all manufacturing sectors without major exemptions, unlike the carbon tax. If the doubling of the carbon tax causes a decreased demand for products from those sectors, since they are now relatively less attractive than before due to the increase in their input costs brought about by the carbon tax, then there will be less demand for the products of sectors that bear the energy tax. Hence there may be some gains of revenue from the energy tax in those sectors which bear both the energy and carbon tax, but there will be offsetting losses in revenue from the energy tax in those sectors which bear only the energy tax.

---

[23] In a formal sense it is easy to see what assumptions in the model generate this result. The first possibility is that there is a great deal of direct substitutability in terms of intermediate inputs *away* from the use of products that are "hit" by the energy tax. This could occur because of the elasticity of substitution of 0.25 assumed between intermediate inputs. The second possibility is that there is an effect coming from the substitutability of *final* goods that use carbon and energy intensively.

Depending on the elasticity of demand for those products, it is perfectly plausible that the net change in revenues from the energy tax will be negative: higher demand elasticities resulting in more revenue losses from the energy tax. Since the derived demand elasticity for energy-intensive intermediate inputs depends on both the direct elasticity of substitution between intermediates *and* the elasticity for the final products produced by sectors using energy relatively intensively, the formal simulations results discussed above are perfectly intuitive.

The "bottom line" of these substitution effects on carbon tax revenues is easy to see in Table 11. The first series of columns show the tax revenues in billions of SEK from the carbon taxes in the benchmark, and the second series of columns show the change in tax revenues in scenario C100. For ease of interpretation and comparison we evaluate these changes in revenues using benchmark prices. Just as with the interpretation of the tax *rates* listed in Table 3, the payments are from each row sector for their usage of the column input. The vast bulk of carbon tax revenues comes from inputs of PETR, and the lion's share of revenues in the PETR column of panels (a) and (b) comes from just a handful of sectors: SAMF, BYGG, VARU and EL_O.

Now consider the effect of using the VAT or lump-sum transfers to keep government expenditures constant after a 100% increase in carbon taxes. The results are very similar to those found with the C100 scenario and labor tax replacement.

One implication of these small differences in the alternate use of labor taxes, the VAT and lump-sum taxes is that there seems to be relatively little distortionary impact from these replacement tax instruments. This may be an artifact of several model assumptions which could be examine further, such as the use of constant labor taxes for each household type, and for each household income level. A distinction between marginal and average labor tax rates would likely add significant distortions from the use of the labor tax.

On the other hand, the more important part of this "tax replacement story" is not the size of the marginal excess burden (MEB) of the taxes but the fact that welfare *decreases* with the increase in carbon taxes irrespective of the tax replacement instrument. This outcome vitiates the "double dividend" argument, which presumes that increases in carbon taxes will generate increased revenue that allow a reduction in highly distortionary taxes elsewhere in the economy. Even with the expected net increase in government revenues, we do not find a net welfare gain from any of the replacement schemes. Hence ***the double dividend story does not hold here***, at least in the strong form that hypothesizes a possible net welfare gain.

On the other hand, there are some benefits from using the VAT or a lump-sum tax to replace revenues, relative to using labor taxes. The welfare cost of an average Kton of CO_2 reduced using the C100 scenario is 74 million SEK (= 3.9 b.SEK ÷ 52.2 Ktons of CO_2). But the welfare cost drops to an average of only 43 m.SEK im scenario C100V and 39 m.SEK in scenario C100LS. Since the lump-sum tax replacement option is not realistic in the sense of having a policy counterpart, we therefore tentatively recommend that the VAT be used as the tax replacement instrument instead of labor taxes. Again, this finding is conditional on our rudimentary treatment of income taxes in the model. Alternative specifications, discussed earlier, would increase the MEB of labor taxes to the point where they would be preferred to the VAT as a replacement instrument. Further work should be undertaken on this feature of the model before we would have more confidence in this particular finding.

3.3 Effects of Constraints on Nuclear Power

Although the model does not distinguish "nuclear" components of the electricity generation industry EL_O, it is possible to examine the effects of carbon tax changes with a rudimentary representation of the political constraint on nuclear power in Sweden. We do so by recognizing that nuclear power is roughly 50% of the current domestic power supplied in Sweden, and that it has a very low carbon-intensity under normal operating circumstances. Constraints on the production of EL_O can be imposed on our model, providing some economic instrument is also added to ensure that the constraint is met. The most natural is simply a tax on domestic value added in the EL_O sector, set such that the industry does not find it "economical" to produce at any higher level.

We impose constraints in this fashion that correspond to the EL_O industry not being allowed to expand relative to the benchmark (N100), and to it having to contract to

75% of the benchmark. This 75% contraction may be viewed as half-way towards the goal of complete elimination of nuclear. In each case we also impose the scenario C100, so these constraints should be evaluated relative to the impacts for C100 discussed earlier.

The nature of these constraints on EL_O also suggest that we should carefully interpret the carbon emissions estimates. If we were just allowing EL_O to change, without regard to whether it is the "cleanest of the clean" electricity plant or the "dirtiest of the dirty," then we would just apply the industry-wide carbon emissions coefficient for that sector. This is exactly what we do in all other simulations, since our model is otherwise silent on the composition of the EL_O activity.[24] But here we are explicitly trying to capture the effects of nuclear reductions, so it is appropriate for us to modify our carbon emissions for sector EL_O accordingly. We therefore set all carbon emissions for this sector equal to their benchmark level, implicitly assuming that nuclear-generated electricity generates no carbon emissions at all. As a first approximation to the dirtier alternatives, this is acceptable.

The detailed sectoral results for scenario N75 are shown in Table 12, and the aggregate impacts of the scenarios with nuclear constraints are reported in Table 10. In welfare terms there is a substantial increase in the "price tag" of the carbon tax increase (from 3.9 bSEK to 7.8 bSEK) as we move from scenario N100 to N75, and a jump in the aggregate reduction in domestic carbon emissions (from 47 Ktons to 229 Ktons). There are modest changes in foreign emissions, such that the global reduction in emissions is driven again by the change in domestic emissions.[25] The main reason for the increase in carbon emission reductions is the generally depressing effect of the nuclear power constraint on domestic production. Despite the larger welfare cost of reducing carbon emission with the nuclear constraint the reduction in carbon emission is even larger, such that the price tag of carbon reductions is lower with this constraint in place. Specifically, the welfare cost of an

---

[24] Actually, since the model solves for the intermediate inputs used by EL_O, and one might be able to identify those as being associated with "dirty" or "clean" technologies, it would be possible to allow carbon emissions to capture these effects. We prefer to model such detail when we have more information on the technology of each activity used in the EL_O industry.

[25] The largest increase in emissions, not surprisingly, is for imports of sector EL_O. It is an open issue if these would indeed be carbon-intensive. If generated from Norwegian hydro-electric sources they probably would not, but if generated by German coal they may be. Our model is currently silent on these possibilities, although it should be possible to refine the estimate of foreign carbon emissions to capture these differential effects.

average Kton of CO_2 reduced in scenario N100 is only 34 million SEK (= 7.8 b.SEK + 229 Ktons), compared to 74 m.SEK in scenario C100 and 43 m.SEK in scenario C100V.

Despite the possibility that they could interact, it appears that the carbon tax reductions and the nuclear constraint are roughly "additive" in effects. Scenario NU75 imposes a 75% constraint on sector EL_O, but without the doubling of the carbon tax. It therefore looks at the "pure" effect of the nuclear constraint. The aggregate results, also shown in Table 10, are virtually the same as the simple difference between the results for C100 and N75.

These aggregate results do mask a substantial restructuring of Swedish industry, however, as seen in Table 12. With a 25% reduction in domestic value added, and a substantial tax on value added, electricity prices rise by 55% and generate large changes in relative prices in most other sectors. The biggest losers in terms of domestic production are those that are relatively intensive users of electricity, of course: JARN, A_ME, PAPP, PPPP, CEME, JRN_, FERR, META and GASV. In many of these industries domestic production is partially replaced by imports, but in most cases these is a substantial reduction in demand for the product (whether produced by domestic or foreign producers). With such widespread devastation of some major Swedish industries, it is no surprise that one sector to *expand* is our old friend, the "consulting and lobbying" sector (UPPD)! Indeed, there are many sectors that expand slightly as the result of the nuclear shutdown: LAKE, GUMM, machinery industries (e.g., MSKN, ELMO and INST), transportation (e.g., BILA and FLYG), and some service sectors (e.g., EGNA and OVRP).

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 carbon taxes. 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.[26] 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_2 that our model generates for any particular scenario. In the case of C100, 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

---

[26] 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.

preferences and technologies for larger and larger reductions in emissions.

The resulting estimates for each household are presented in Table 13. 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 of increasing the carbon tax in Sweden are a tiny fraction of the "price tag" which Swedes must pay in the form of higher prices and reduced incomes. Although we do not put much credence in these gross benefit numbers, they do serve to highlight the basis of our conclusion that carbon tax increases are not currently justifiable in Sweden. They also serve to focus the debate on the net benefits of further carbon taxes onto the question of estimating gross benefits for Swedes. *If these numbers are correct*, then advocates of carbon 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 the effects of the existing carbon tax in Sweden are surprisingly counter-intuitive. The *a priori* beliefs which we started with reflected that intuition and the prevailing "conventional wisdom": that the exemptions for manufacturing would probably diminish the impact on carbon emissions, but that otherwise the tax was well targeted at the externality in question and ought to have a dramatic effect. If combined with a reduction in taxes on some highly distortionary tax, such as the labor tax, it could provide an attractive means of meeting the environmental goal at least cost. Maybe a double dividend was too much to hope for, but some benefit from the tax replacement could be expected.

The results presented here, if correct, undermine this conclusion in several respects.

First, increases in the carbon tax itself has relatively "modest" impact on aggregate carbon emissions. The reason is that there are many avenues of substitution open in terms of production and consumption choices, such that attempts to tax certain externalities in some sectors generate an incentive to expand other sectors. The only interesting question is whether the net impact on carbon emissions will be positive: there should be no sensible debate on the fact that some sectors will emit more carbon when the carbon tax is increased while some reduce carbon emissions.

Second, increasing carbon taxes results in a net increase in government tax revenues, just as a partial equilibrium analysis would predict. However, it induces offsetting increases and decreases from different tax bases, such that it is conceivable that there could be a net decrease under certain circumstances (e.g., extremely high trade elasticities). The reason is that the carbon tax induces significant substitution in inputs and between products, resulting in a reduction in the use of inputs or products that would otherwise be paying substantial energy taxes. Normally these effects would be of "second order," such that an increase in one tax would be expected to increase revenue. However, the close overlap of the energy and carbon taxes in terms of legal incidence, combined with the greater magnitude of the energy taxes in the base year in *ad valorem* and revenue terms for some sectors, means that these second order effects cannot be completely neglected in this case. Nonetheless, the net revenue effects on carbon tax revenues is much larger than the net revenue effects on energy tax revenues.

Third, imposed constraints on the nuclear generation of electricity would significantly enhance the reductions in carbon emissions flowing from carbon tax increases. This effect comes from a general decline in energy-intensive production in Sweden, due to energy price increases. Despite an increase in the *aggregate* welfare cost, nuclear constraints lower the *average* welfare cost of carbon reductions.

Finally, our "bottom line" is that simple *expansions* in the existing carbon tax carry too high a price tag for most Swedish households to be justifiable. This overall cost-benefit assessment rests on some admittedly fragile estimates of the gross benefit that Swedes will get from carbon reductions. Our job was only to generate the gross costs of those policies, and for that side of the "cost-benefit equation" our model is relatively well suited. However, if the gross benefit estimates currently in use in international carbon tax debates are to be believed, Sweden cannot justify further *unilateral* increases in carbon taxes.

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 reflect differences in their income sources; (2) incorporate data-based estimates of leisure 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 countries relative to Sweden. As revised estimates for these parameters are generated they can be introduced directly into the existing model instantly.

The model may also be incomplete in terms of it's treatment of the *economic structure* of some sectors. Specifically, we could (1) provide a richer specification of the production technology of sectors with respect to energy inputs (e.g., allowing energy to be an input that 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); (2) incorporate some supply restrictions on imports in key sectors, particularly those such as 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 between marginal and average rates, as well as differences across households; (4) model the 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 explicitly, perhaps with a formal sub-model of the electricity sector. Each of these extensions 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 purposes.

The model could also be evaluated in terms of more *radical changes in structure*.

Specifically, we could consider (1) incorporating measures of environmental benefits[27] explicitly 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.

References

Anderson, Krister, and Norrman, Erik, "Capital Taxation and Neutrality. A Study of Tax Wedges with Special Reference to Sweden," *Lund Economic Studies Number 41*, Department of Economics, University of Lund, 1987.

Bergman, Lars, "Tillväxt och miljö," *Bilaga 21 till LU-90*, Finansdepartmentet, Stockholm. (In Swedish; "Growth and the Environment," Supplement 21 to the Swedish Medium-Term Economic Survey, Treasury of Sweden, 1991).

Blackburn, McKinley; Harrison, Glenn W., and Rutström, E. Elisabet, "Statistical Bias Functions and Informative Hypothetical Surveys," *American Journal of Agricultural Economics*, 76(5), December 1994, 1084-1088.

Bovenberg, A. Lans, and Goulder, Lawrence H., "Costs of Environmentally Motivated Taxes in the Presence of Other Taxes: General Equilibrium Analyses," *Working Paper No. 5117*, National Bureau of Economic Research, Inc., May 1995a.

Bovenberg, A. Lans, and Goulder, Lawrence H., "Optimal Environmental Taxation in the Presence of Other Taxes: General Equilibrium Analyses," *Unpublished Manuscript*, Department of Economics, Stanford University, May 1995b.

Brooke, Anthony; Kendrick, David, and Meeraus, Alexander, *GAMS: A User's Guide, Release 2.25* (Danvers, MA.: Boyd & Fraser, 1992).

---

[27] Some analysts have proposed using the estimated cost of the *existing* carbon tax structure as a crude measure of the environmental benefits from reduced emissions. We regard this inference as problematic, to put it politely. At *best* it could be inferred that the murky political process leading to the existing tax level represents the 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 matter of some controversy (e.g., see Harrison and Kriström [1995]), such inferences cannot even be made if one 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 *median* voter places on some public good tells us nothing whatsoever about the distribution of benefits, at least in the absence of super-heroic assumptions that would make even *Fantomen* blush. Without information on that distribution one cannot say anything about the net impact on welfare of individual households, or even about the aggregate impact under simplifying utilitarian assumptions. There is simply no acceptable substitute for estimating those benefits directly, and accounting fully for the potential biases in hypothetical survey elicitation procedures (e.g., see Blackburn, Harrison and Rutström [1994]).

Cummings, Ronald G.; Elliott, Steven; Harrison, Glenn W., and Murphy, James, "Are Hypothetical Referenda Incentive Compatible?" *Journal of Political Economy*, 105, 1996 forthcoming.

Cummings, Ronald G.; Harrison, Glenn W., and Rutström, E. Elisabet, "Homegrown Values and Hypothetical Surveys: Is the Dichotomous Choice Approach Incentive Compatible?," *American Economic Review*, 85(1), March 1995, 260-266.

Dirkse, Steven P., and Ferris, Michael C., "The PATH Solver: A Non-Monotone Stabilization Scheme for Mixed Complementarity Problems,"*Optimization Methods and Software*, 5, 1995, 123-156.

Goulder, Lawrence H., "Environmental Taxation and the Double Dividend: A Reader's Guide," *International Tax and Public Finance*, 2, 1995a, 157-183.

Goulder, Lawrence H., "Effects of Carbon Taxes in an Economy with Prior Tax Distortions: An Intertemporal General Equilibrium Analysis," *Journal of Environmental Economics and Management*, 29(3), November 1995b, 271-297.

Harrison, Glenn W., "Environmentally Sensitive Industries and an Emerging Mexico," *North American Journal of Economics and Finance*, 4(1), 1994, 109-126.

Harrison, Glenn W.; Jones, Richard; Kimbell, Larry J., and Wigle, Randall, "How Robust Is Applied General Equilibrium Analysis?" *Journal of Policy Modeling*, 15(1), 1993, 99-115.

Harrison, Glenn W., and Kriström, Bengt., "On the interpretation of responses in contingent valuation surveys," in P-O Johansson, B. Kriström and K-G Mäler (eds.), *Current Issues in Environmental Economics* (New York: Manchester University Press, 1995).

Harrison, Glenn W., and Kriström, Bengt., "Carbon Taxes in Sweden," *Final Report* to the Skatteväxlingskommittén, Stockholm, 1996 forthcoming.

Harrison, Glenn W., and Manning, Richard, "Best Approximate Aggregation of Input-Output Systems," *Journal of the American Statistical Association*, 83, December 1987, 1027-1031.

Harrison, Glenn W.; Rutherford, Thomas F., and Tarr, David, "Piecemeal Trade Reform in the Partially Liberalized Economy of Turkey," *World Bank Economic Review*, 7, May 1993, 191-217.

Harrison, Glenn W.; Rutherford, Thomas F., and Tarr, David G., "Product Standards, Imperfect Competition, and the Completion of the Market in the European Community," *Policy Research Working Paper 1293*, International Economics Department, International Trade Division, The World Bank, April 1994; forthcoming, *Journal of Economic Integration*.

Harrison, Glenn W.; Rutherford, Thomas F., and Tarr, David G., "Quantifying the Outcome of the Uruguay Round," *Finance & Development*, 32(4), December 1995, 32(4), 38-41.

Harrison, Glenn W.; Rutherford, Thomas F., and Tarr, David G., "Quantifying the Uruguay Round," in W. Martin and L.A. Winters (eds.), *The Uruguay Round and the Developing Countries* (New York: Cambridge University Press, 1996).

Harrison, Glenn W., and Vinod, H.D., "The Sensitivity Analysis of Applied General Equilibrium Models: Completely Randomized Factorial Sampling Designs," *The Review of Economics and Statistics*, 74, May 1992, 357-362.

Jorgenson, Dale W., and Wilcoxen, Peter J., "Intertemporal Equilibrium Modeling of Energy and Environmental Policies," in P-O Johansson, B. Kriström and K-G Mäler (eds.), *Current Issues in Environmental Economics* (New York: Manchester University Press, 1995).

Melo, Jaime de, and Tarr, David, *General Equilibrium Analysis of U.S. Foreign Trade Policy* (Cambridge, MA: MIT Press, 1992).

Nordhaus, William D., "The Swedish Dilemma: Nuclear Energy *v.* The Environment," *Report* to Studieförbundet Näringsliv och Samhälle, Stcokholm, November 29, 1995.

Perroni, Carlo, and Rutherford, Thomas F., "Regular flexibility of nested CES functions," *European Economic Review*, 39, 1995a, 335-343.

Perroni, Carlo, and Rutherford, Thomas F., "A Comparison of the Performance of Flexible Functional Forms For Use in Applied General Equilibrium Analysis," *Discussion Paper 95-6*, Department of Economics, University of Colorado at Boulder, July 1995b.

Reinert, K.A. and D.W. Roland-Holst, "Armington Elasticities for the Manufacturing Sectors of the United States," *Journal of Policy Modeling*, 14(5), 1992, 631-639.

Reinert, K.A. and C.R. Shiells, "Trade Substitution Elasticities for Analysis of a North American Free Trade Area," *Unpublished Manuscript*, Office of Economics, U.S. International Trade Commission, January 1991.

Rutherford, Thomas F., "Applied General Equilibrium Modeling With MPSGE as a GAMS Subsystem," *Economics Working Paper 92-15*, Department of Economics, University of Colorado at Boulder, 1992.

Rutherford, Thomas F., "MILES: a Mixed Inequality and nonLinear Equation Solver," *Economics Working Paper*, Department of Economics, University of Colorado at Boulder, August 1993.

Rutherford, Thomas F., "Extensions of GAMS For Complementarity and Variational Problems Arising in Applied Economics," *Journal of Economic Dynamics and Control*, 19(8), November 1995, 1299-1324.

Rutherford, Thomas F., Rutström, E. Elisabet, and Tarr, David G., "L'Accord de Libre Echange entre le Maroc et la CEE: Une Evaluation Quantitative," *Revue d'Economie du Developpement*, 2, 1994, 97-133.

Statens Offentliga Utvedningar (SOU), *Sätt Värde på Miljön: Miljöavgifter och andra Ekonomiska Styrmedel* (In Swedish. Final Report from the Commission on Environmental Charges) Norstedts, Stockholm, 1990.

Statens Offentliga Utvedningar (SOU), *Ny Lag om Skatt på Energi: En Teknisk Översyn och EG-anpassning* (In Swedish. Report from the Committe on Energy Taxation, Part 1). Norstedt, Stockholm, 1994.

Treasury of Sweden, "Energi och Miljörelaterade Skatter I Sverige och I OCED-länderna" (In Swedish: "Energy and Environmentally Related Taxes in Sweden and the OECD Countries"), *Unpublished Manuscript*, Treasury of Sweden, August 6 1995, Stockholm.

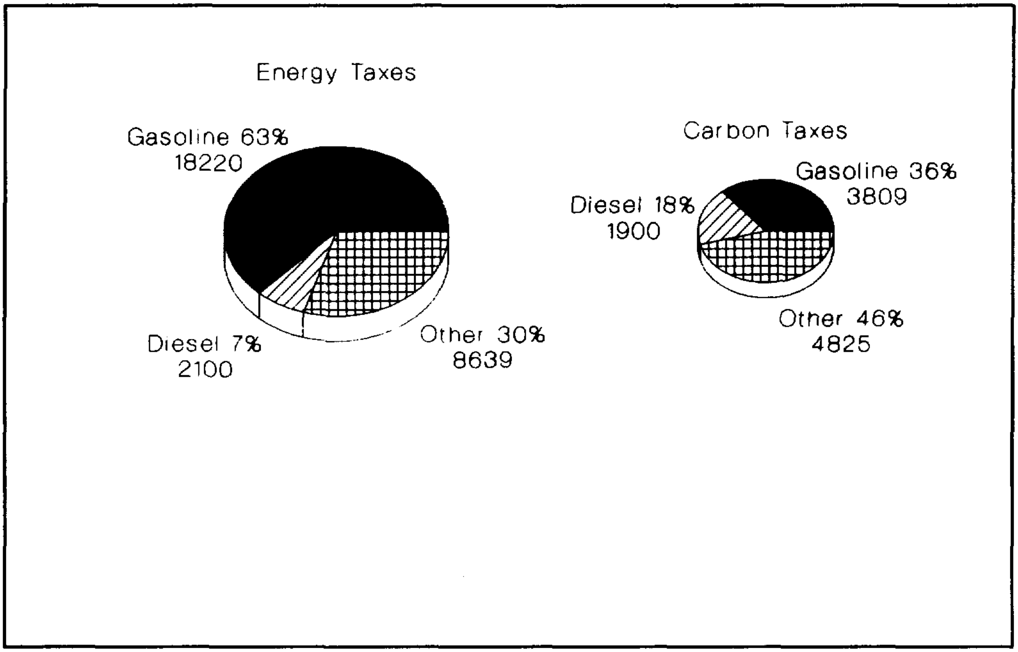

Figure 1: Revenues from Energy Taxes in 1994 (millions of SEK)

Table 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

Table 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

Table 3: Benchmark Carbon Taxes (percent)

Purchasing Sector	Input		
	STEN	PETR	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

Table 4: Benchmark Energy and Sulphur Taxes (percent)

(a) Energy Taxes

Purchasing Sector	Input STEN	Input PETR	Input 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	Input 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	

Table 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.

Table 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

Table 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				

Table 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

Table 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

Table 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

Table 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

Table 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

Table 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

Förteckning över Rapporter och Uppsatser	List of Research Notes

The Series was initiated in 1981. For a complete list of Research Papers, please contact the Institution.

År	Nr	Titel	Författare
1994	180.	Privata skogsägares informationsbehov mot bakgrund av den nya skogspolitiken.	Per Westergren
	181.	Values of an endangered species - The case of the White-backed Woodpecker in Sweden.	Peter Fredman
	182.	Kostnader för naturvårdshänsyn inom privatskogsbruket - en empirisk analys.	Ola Carlén
	183.	Tillämpad Ekonomistyrning för skogliga problem.	Peter Lohmander
	184.	Nio PM. Skogspolitiska problem.	Jägmästarstudenter
	185.	A Note on an optimization method for identifying timber supply function coefficients.	Peichen Gong
	186.	How do adjustments in the forest landscape resulting from environmental demands affect the costs and revenues to forestry?	Per Holgen and Torgny Lind
	187.	Konkurrensen på virkesmarknaden och den nya konkurrenslagen.	Mats A. Bergman
	188.	Economic growth and the environment.	Sören Wibe
	189.	Adaptiva beslut vid etablering av granbestånd. Adaptive economic forest investment and management.	Sören Pettersson
	190a.	Uthållig skogsanvändning mot bakgrund av den nya skogspolitiken. Två uppsatser med olika infallsvinklar.	Leif Mattsson och Kjell Sjöberg
	190b.	Ett planeringssystem för ekonomiskt optimala timmertransporter på Södra.	Magnus Berg och Håkan Larsson
	191.	Long-run growth and taxation.	Sören Wibe
	192.	Att kvantifiera viltets jaktvärde.	Leif Mattsson

193.	Kalkylmodeller för naturvård. Ekonomisk analys av naturvårdsnivåer på Mellanskogs fastighet i Trönö.	Rickard Klingberg
194.	Vad kostar nyckelbiotoperna?	Peter Calderon
195.	Miljökonsekvensbeskrivningar. - Nuvarande och framtida tillämpning inom svenskt skogsbruk.	Henrik Forssblad
196.	Tillväxt och offentlig sektor i OECD-länderna.	Christer Löfgren
197.	Är tillväxten exponentiell?	Sören Wibe
198.	Wildlife valuation: Estimating the benefits of the Wolf in Sweden.	Mattias Boman and Göran Bostedt
199.	Non wood benefits in forestry - Survey of valuation studies.	Sören Wibe
200.	Some theoretical reflections on the economic valuation of single species or ecosystems.	Göran Bostedt
201.	A test of Nonresponse bias in a mail Contingent valuation survey.	Peter Fredman
202.	The existence of existence value.	Peter Fredman
203.	Biodiversitet och Monetära Miljöräkenskaper: Värderingsproblem, metoder och resultat.	Bengt Kriström
204.	Is the income elasticity of environmental Improvements less than one?	Bengt Kriström
205.	Endangered species and optimal environmental policy.	Peter Fredman and Mattias Boman
206.	Welfare measurement in single and multimarket models: Theory and application.	Runar Brännlund and Bengt Kriström
207.	Beräkning av skogskapitalets värdeförändring under räkenskapsåret - ett praktikfall på Stora Skog.	Anders Bogghed och Peter Jehander
208.	Tretton PM av jägmästarstudenter. Skogspolitiska problem.	
209.	Respondents and nonrespondents in contingent valuation surveys. Reducing uncertainty in value inference.	Göran Bostedt and Mattias Boman

1995	210.	Spike models in contingent valuation: Theory and Illustrations.	Bengt Kriström
	211.	Skogsskador i Sverige - en statistisk analys.	Ola Carlén, Per Holgén och Sören Wibe
	212.	Improving the management of nonindustrial Private forests: A conceptual analysis.	Peichen Gong
	213.	Ekonomiskt adaptiv styrning av transporter och lager i en skogsindustrikoncern.	David Eiderbrant
	214.	Technological progress and structural change in the Swedish Paper Industry 1972-1990.	Sören Wibe
	215.	Jakt på statligt och delvis statligt ägda marker i Sverige, Norge och British Columbia - en jämförelse med avseende på utdelning och prisnivåer.	Ulf Lindroth
	216.	Applied economic control - Part 1 - a graduate course with forest - and forest industry applications.	Peter Lohmander
	217.	Global warming and dynamic cost-benefit analysis under uncertainty: An economic analysis of forest carbon sequestration.	Kenneth Backlund, Bengt Kriström, Karl-Gustaf Löfgren and Eva Polbring
	218.	Forskarutbildning och handledning: - Angelägna överväganden.	Peter Lohmander
	219.	Regeneration Decision and Land Expectation Value: Numerical results of decision model evaluation and optimization.	Peichen Gong
	220.	Träd, bete, pengar och härlighetsvärden - en ekonomisk analys av olika driftsalternativ.	Susanne Johansson
1996	221.	Confrontation or compromise? Determining Appropriate Institutions for Environmental Conflict Resolution.	Göran Bostedt and Leif Mattsson
	222.	Flexibel styrprislista för högre lönsamhet och optimala lager.	Andreas Jonasson
	223.	Internredovisning för små nystartade företag Ett fall från verkligheten.	Erik Hernblom

	224.	Ersättningsform för fördelningsapterat timmer.	Christian Drott
	225.	Risk preference and efficient harvest policies with stochastic timber prices.	Peichen Gong
	226.	Skogsentrepenören ur ett småföretagarperspektiv Ekonomisk planering och kompetensutveckling.	Mats Warensjö
	227.	On the Incorporation of Non-market Outputs of forests into National Accounting Systems.	Bengt Kriström
	228.	The forest sector of Norh Carolina. Notes from a study tour.	Ed: Lars Lönnstedt
	229.	Redovisningsprinciper i Tyskland, Frankrike, Schweiz samt EU.	Linda Eriksson
	230.	Analyser av ekonomiskt optimala beslut på en skogsfastighet i Västerbottens kustland 1996.	Peter Lohmander
	231.	Evaluation of carbon fixation in the context of national accounts.	Peter Eliasson
	232.	Japan and its forest sector. Notes from a study tour June 1996.	Lars Lönnstedt
	233.	Contingent Valuation.	Bengt Kriström
1997	234.	Carbon Emissions and the Economic Costs of Transport Policy in Sweden.	Glenn W. Harrison and Bengt Kriström
	235.	General Equilibrium Effects of Increasing Carbon Taxes in Sweden.	Glenn W. Harrison and Bengt Kriström