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Environmental Tax Reforms in Switzerland

A Computable General Equilibrium Impact Analysis

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A Computable General Equilibrium Impact Analysis

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Abstract

The Swiss energy strategy until 2050 envisages ambitious CO_2 emission reduction targets along with substantial cutbacks in electricity consumption to establish a low-carbon economy without nuclear energy. Our computable general equilibrium analysis find that compliance with stringent CO_2 constraints requires high CO_2 taxes on economic activities which are not eligible for international emissions trading; likewise, electricity consumers are burdened with substantial electricity taxes. Environmental tax reforms are not likely to generate welfare gains without accounting for the benefits of improved environmental quality. However, economic adjustment costs to a low carbon economy without nuclear energy remain modest and can be markedly reduced through revenue-neutral cuts of initial distortionary taxes. On the other hand, alternative recycling strategies pose a trade-off between efficiency and distributional justice which has to be resolved on normative grounds.

JEL-Classification: H21, D58, Q48

Keywords: environmental tax reforms, computable general equilibrium

1. Introduction

Over the next decades Switzerland will be challenged with a massive restructuring of its energy system. The main driver is the objective to curb domestic CO_2 emissions in response to the threat of global warming. Switzerland aims at a reduction of its CO_2-per-capita emissions from 5.8 tons in 2012 to 1.5 tons in 2050. Transition to a low-carbon economy will be complicated by the waiver of a nuclear option. Following the devastating earthquake that struck Japan in March 2011 and the ensuing nuclear disaster at Fukushima, Switzerland decided to withdraw from the use of nuclear energy within the next decades on a step-by-step basis: The existing five nuclear power plants are to be decommissioned when they reach the end of their safe service life, and will not be replaced by new ones.

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In 2011 the Federal Council and Parliament endorsed a variety of policy measures to promote expansion of renewable energy production and energy efficiency improvements. These measures have been designed to fill the nuclear gap and at the same time achieve a reduction in per-capita CO_2 emissions to roughly 3.8 tons in 2050. However, the adopted measures – constituting meanwhile the business-as-usual (*BaU*) – will still not be sufficient to reach Switzerland's ambitious climate policy targets.

Against this background, the Swiss energy strategy until 2050 considers additional policy initiatives to further reduce electricity demand and CO_2 emissions. The proposal "Politische Massnahmen Bundesrat" (thereafter referred to as *POM*) envisages a reduction of CO_2 emissions by 26% and reduction of electricity demand by 12% vis-à-vis the *BaU* development. The proposal "Neue Energiepolitik" (thereafter referred to as *NEP*) which is in line with 1.5 tons of energy-related CO_2 emissions per capita is even more ambitious: The targeted cutback in CO_2 emissions amounts to 63% and the electricity demand reduction to 23% from *BaU* levels in 2050.

Central to the *POM* and *NEP* policy proposals is the idea that the initial subsidy system and command-and-control regulation will be replaced by market-based regulation where CO_2 emission pricing and electricity taxation should accommodate least-cost adjustment to the political targets. Contrary to command-and-control measures such as efficiency mandates emission and energy taxes furthermore raise public revenues which can be used to reduce existing tax distortions. Revenue recycling may provide prospects for a triple dividend from environmental tax reforms (PEARCE, 1991; REPETTO, 1992; GOULDER, 1995). The first dividend refers to an improvement in environmental quality. The second dividend might emerge from a reduction in the overall excess burden of the tax system by using additional tax revenues for a revenue-neutral cut of existing distortionary taxes; a second dividend reflects efficiency gains in resource allocation translating in an increase in real income. The third dividend relates to the possibility that environmental tax reforms could generate employment gains through cuts in labor costs. In practice, most governments that have introduced environmental taxes have reduced distortionary labor taxes, particularly employers' social security contributions (OECD, 2007). Revenue recycling also plays an important role in the alleviation of adverse distributional impacts triggered by policy reforms.

We use a computable general equilibrium (CGE) model calibrated to empirical data for Switzerland to quantify the economic impacts of the *POM* and *NEP* policy proposals for alternative revenue recycling strategies which beyond lump-sum transfers include cutbacks in value-added taxes, corporate profit taxes, payroll taxes (social insurance contributions), and federal income taxes. The key findings from our numerical simulations can be summarized as follows: Compliance with the CO_2 reduction targets requires high CO_2 taxes on economic activities that are not eligible for international emissions trading. To meet additional cutback targets for electricity demand, electricity consumers must face substantial electricity taxes. The more ambitious the reduction targets for CO_2 emissions and electricity demand, the higher are the CO_2 and electricity taxes. The choice of the revenue-recycling strategy has important implications for the aggregate efficiency impacts, the employment effects and the distributional consequences of *POM* and *NEP*. When tax revenues are recycled lump-sum, the aggregate efficiency impacts are clearly negative ranging from a loss of real income between 0.2% for the case of *POM* to 1% for the case of *NEP* (relative to the *BaU* aggregate income level). However, overall adjustment costs can be markedly reduced when environmental taxes are swapped for existing distortionary taxes. With the more moderate targets under *POM* and revenue-neutral reductions in the federal income tax there is even scope for a small second dividend: The excess burden of the CO_2 and electricity taxes are smaller than that of the decreased federal income tax – financing of public good provision becomes more efficient which yields welfare gains. However, there is a trade-off between aggregate efficiency gains from tax recycling and distributional impacts across heterogeneous households. While lump-sum transfers are not desirable under aggregate efficiency considerations, they constitute the single recycling variant with a progressive effect where poorer households suffer less in relative terms than richer households. Regarding aggregate employment, recycling via reductions of payroll or federal income taxes has positive employment effects whereas cuts in value-added or profit taxes are neutral – lump-sum recycling ranks last with negative employment effects. It should be noted that *POM* and *NEP* by definition fix the first dividend in terms of an exogenously imposed CO_2 emission reduction. If one includes external cost reductions in the economic welfare calculations then environmental tax reforms under *POM* always yield aggregate welfare gains whereas the more ambitious *NEP* proposal is still associated with welfare losses except for the case when tax revenues are recycled via the reduction of federal income taxes.

The remainder of this paper is organized as follows. Section 2 provides a short non-technical summary of the model and the data underlying the analysis. Section 3 presents details of the policy scenarios and discusses simulation results. Section 4 concludes.

2. Method of Assessment: Computable General Equilibrium Analysis

For the economic impact assessment of the *POM* and *NEP* proposals we use SWISSGEM-E, a computable general equilibrium (CGE) model for Switzerland destined to analyze energy and climate policy measures (ECOPLAN, 2012a). CGE models have become a wide-spread numerical framework for quantifying the economy-wide impacts of policy reforms. CGE models build upon general equilibrium theory that combines assumptions regarding the optimizing behavior of economic agents with the analysis of equilibrium conditions: producers combine primary factors and intermediate inputs at least cost subject to technological constraints; given preferences consumers maximize their well-being subject to budget constraints. CGE analysis provides counterfactual ex-ante comparisons, assessing the outcomes of a policy reform against a business-as-usual development without reform. The main virtue of the CGE approach is its comprehensive representation of price-dependent market interactions based on rigorous microeconomic theory. The simultaneous explanation of the origin and spending of the agents' incomes makes it possible to address both economy-wide efficiency as well as distributional impacts of policy interventions. CGE models thus do not only deliver positive information on policy-induced changes in key economic indicators at the macroeconomic level (e.g. GDP, investment, consumption, tax revenues), at the sector level (e.g. production, export, import) and at the household level (e.g. income and expenditure) but also allow for normative rankings of alternative policy reforms compared to the status quo.

SWISSGEM-E emphasizes specific features that are central to the policy debate on environmental tax reforms in Switzerland. The model includes a detailed representation of the Swiss tax system to capture initial tax distortions and thereby the scope for a second dividend from revenue recycling of additional environmental tax income. Technological options for generating electricity which determine the adjustment costs to CO_2 emission constraints are represented in a detailed bottom-up fashion based on discrete activity analysis. To assess the incidence of tax reforms, the representative household sector is decomposed into heterogeneous types based on socio-economic criteria such as standard of living, work situation, and family status.

2.1 Model Structure

We restrict the model description to a non-technical summary of the main characteristics (for a more detailed representation of the model structure see ECOPLAN, 2012a).

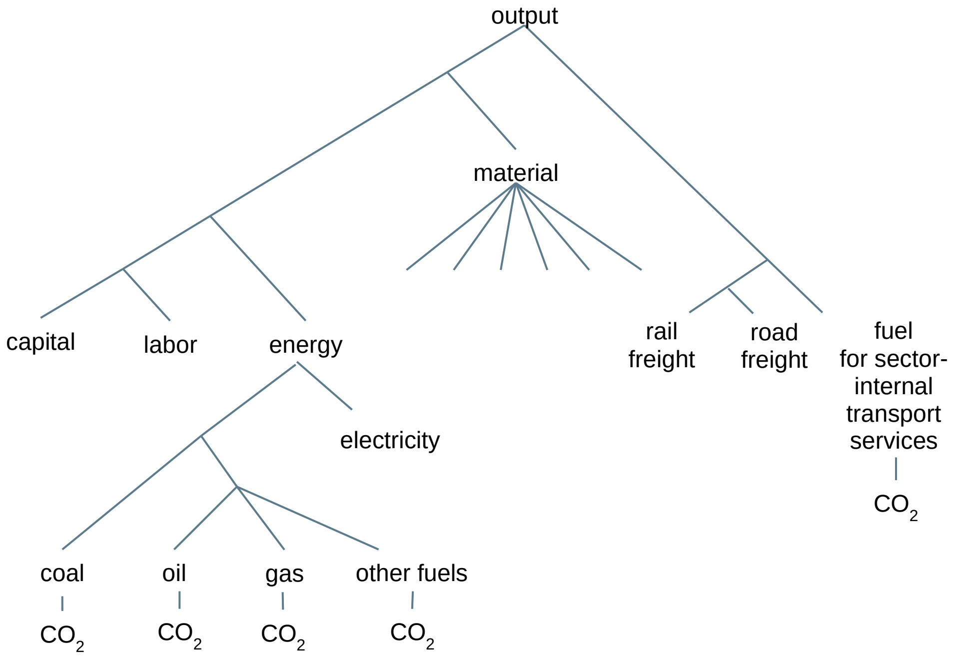
Factors

Primary factors of production are labor and capital. Labor supply is elastic. Capital and labor are inter-sectorally mobile in the home country, but only capital can move across domestic borders. The rates of return on mobile capital are determined by the international interest rate. We assume perfectly competitive factor markets in which factor prices adjust so that supply equals demand.

Production

Production of commodities is captured by nested constant-elasticity-of-substitution (CES) cost functions that describe the price-dependent use of capital, labor, energy and material in production. At the top level, a composite transport good trades off with an KLEM aggregate of capital (K), labor (L), energy (E) and material (M). The composite transport good is a CES aggregate of freight transportation (which in turn is a CES composite for rail and road freight) and fuel demand for sector-internal transport services. The KLEM aggregate is composed of a CES composite in capital, labor and energy and a CES composite in materials where both composites trade off with each other at a constant elasticity of substitution. At the next level, a CES function describes the substitution possibilities between the energy aggregate and the value-added composite of capital and labor. Capital and labor substitution possibilities within the value-added composite are captured by a CES function. Electricity and a CES aggregate of non-electric energy carriers enter the energy composite subject to a constant elasticity of substitution. Finally, the CES composite of non-electric energy carriers consists of coal and a CES aggregate of liquid fuels and gas. Figure 1 sketches the nesting structure in production.

Figure 1: Production structure

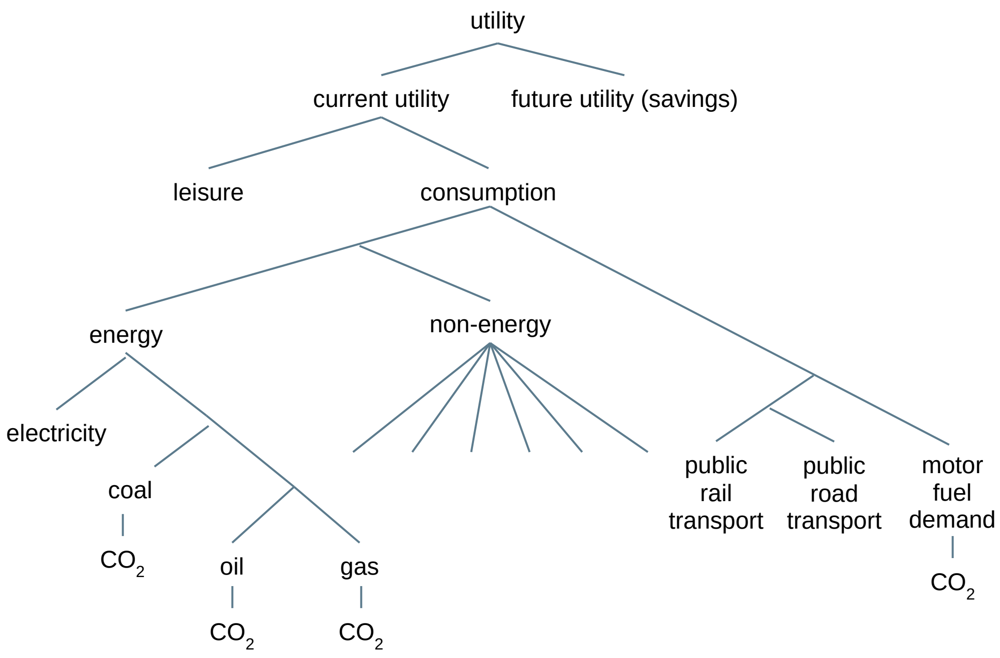


Given the paramount importance of the electricity sector with respect to CO_2 emission abatement the standard top-down representation of power production by means of continuous CES production function is replaced by a bottom-up activity analysis where several discrete generation technologies compete to supply electricity (BÖHRINGER, 1998; BÖHRINGER and RUTHERFORD, 2008). Technologies include hydro power (pumped storage, run-of-the-river), gas power (combined cycle, cogeneration), biomass, wind, photovoltaic and geothermal power plants. For each technology a specific factor reflecting capacity restrictions (such as the limited availability of hydro power sites) trades off with a Leontief composite of all other inputs at a constant elasticity of substitution. The CES elasticities are calibrated to reflect technology-specific supply responses to changes in electricity prices (RUTHERFORD, 2002). In addition, lower and upper bounds on production capacities can prescribe explicit limits to the decline and the expansions of technologies. The technologies' output is treated as a perfect substitute such that there is a single electricity price. The price of electricity then is determined by the production costs of the marginal supplier.

Household Behavior

Demands for final consumption, leisure and savings (i.e. investment) are determined by households who maximize welfare subject to a budget constraint. Total income of each household consists of net factor income and transfers. The consumption structure of the households is reflected in the nesting of multi-level utility functions. At the top level, households allocate income between current consumption and savings subject to a unitary elasticity of substitution (reflecting a constant marginal propensity to save). Current consumption is then composed of leisure and commodity consumption. Commodity consumption in turn is a CES aggregate of transport services and a CES composite of energy and non-energy goods. The transport services consists of public transports (a CES composite of rail and road) and fuel demands for private transports that trade off at a constant elasticity of substitution. Substitution possibilities within the non-energy consumption bundle are given by CES preferences. Within composite energy demand, electricity trades off at a constant elasticity of substitution with fossil fuels. The fossil fuel aggregate consists of coal and a CES composite of liquid fuels (gas and oil). Figure 2 sketches the generic nesting structure of the households' utility functions.

Figure 2: Consumption structure



Government

The government collects taxes to finance transfers and the provision of a public good. The public good is produced with commodities purchased at market prices. Besides value-add taxes, income taxes, corporate profit taxes and social security contributions the model features industry-specific output taxes and subsidies as well as import and export levies. The economic impact assessment of policy interference involves revenue-neutral tax reforms in order to provide a meaningful welfare comparison without the need to trade off private consumption and government (public) consumption. This is done by keeping the amount of the public good provision fixed and balancing the public budget by means of an equal-yield tax instrument. By default, lump-sum transfers between the government and households proportional to *BaU* income levels are chosen as the equal-yield instrument.

International Trade

Switzerland is treated as small relative to the world market. That is, we assume that changes in Swiss import and export volumes have no effect on its terms of trade: Export and import prices in foreign currency are considered as exogenous. Domestically produced goods are converted through a constant-elasticity-of-transformation function into goods destined for the domestic market and the export market, respectively. Analogously to the export side, we adopt the Armington assumption of product heterogeneity for imports (ARMINGTON, 1969). A CES function characterizes the trade-off between imported and domestically produced varieties of the same goods. The Armington goods enter intermediate and final demand. Foreign closure of the model is warranted through a balance-of-payment (BOP) constraint which demands that the total value of exports equals the total value of imports accounting for an initial BOP deficit or surplus given by the base year statistics. The BOP constraint thereby determines the real exchange rate which indicates the endogenous value of the domestic currency vis-à-vis the foreign currency (the latter being exogenous in a small-open-economy setting).

CO_2 *Emissions*

CO_2 emissions in production and consumption are linked in fixed proportions to the use of fossil fuels with CO_2 coefficients differentiated by the specific carbon content of fuels. CO_2 emission abatement can take place via fuel switching (inter-fuel substitution) or energy savings (either by fuel-non-fuel substitution or a scale reduction of production and final demand activities). CO_2 abatement requirements are introduced by means of an additional constraint that holds CO_2 emissions to a specified limit. Scarcity rents on CO_2 emission constraints emerging as revenues from emission taxes or auctioned emission allowances accrue to the government.

2.2 Parameterization

Base-year Calibration

As is customary in applied general equilibrium analysis, the numerical model is based on economic transactions in a benchmark year. The benchmark quantities, prices, and elasticities fully determine the free parameters of CES functions that are used to characterize technologies and preferences: Substitution elasticities determine the curvature of isoquants and indifference surfaces, while their position is given by the benchmark quantities and prices (MANSUR and WHALLEY, 1984). As a consistency check the calibrated model must reproduce the initial benchmark equilibrium of the economy.

Forward Projection

CGE analysis quantifies the impact of policy regulation with respect to a reference situation where this regulation is not in place — the so-called business-as-usual. If policy targets and measures refer to the future there is the need to project a hypothetical business-as-usual capturing the evolution of the economy in the absence of these additional targets and measures. The *POM* and *NEP* proposals in the Swiss energy strategy prescribe CO_2 emission and electricity reduction targets for 2050 relative to a business-as-usual development which emerges from policies in place or disseminated by now. To provide a consistent point of reference for impact assessment in the future the calibrated model must be forward projected to an exogenous business-as-usual development. We adopt an iterative baseline projection procedure as laid out in BÖHRINGER et al. (2009) where production and utility functions are successively recalibrated to match emission projections associated with exogenous assumptions on GDP growth rates, fossil fuel prices, and energy demands by sectors.

Data

The core economic data characterizing the benchmark equilibrium in our model stems from the Swiss national input-output table for 2008 (NATHANI, SCHMID, and VAN NIEUWKOOP, 2011). Data on tax payments and transfers are taken from Switzerland's financial statistics for 2010 (FFA, 2010) and on the Swiss social insurance statistics (FSIO, 2011). The disaggregation of the electricity sector is based on information by PROGNOS (2012). The household sector is disaggregated using household budget surveys 2007 to 2009 by the Swiss Federal Statistical Office (FSO, 2011). Substitution elasticities in production are based on recent econometric estimates by MOHLER and MÜLLER (2012). Armington elasticites in trade based on DIMARANAN and MCDOUGALL (2002), SAITO (2004) and WELSCH (2008). Labor supply elasticies for different household categories are rooted in GERFIN (1993) and EVERS et al. (2008). Data on the business-as-usual development against which the economic impacts of future policy initiatives such as *POM* and *NEP* are measured is provided by PROGNOS (2012).

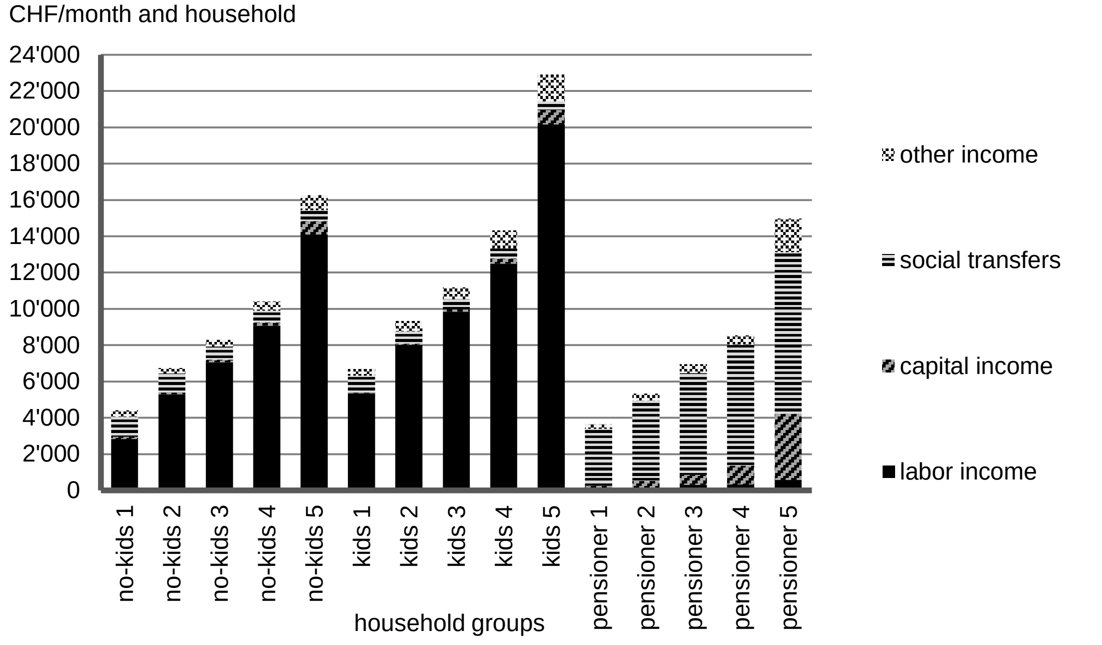
SWISSGEM-E does not explicitly incorporate external effects. However, it is possible to use exogenous estimates on the external costs of energy consumption and production for an ex-post monetarization of changes in external effects triggered by policy interference. In the economic impact assessment of the *POM* and *NEP* proposals the first dividend is quantified using external cost data for energy consumption and production based on ECOPLAN (2012a) – note that our ex-post external cost accounting does not include climate externalities and nuclear risks.

Disaggregation

On the production side, it is important to incorporate sector-specific differences in factor intensities, degrees of factor substitutability and the price elasticities of output demand for tracking the structural change in production which is induced by policy shifts. The model contains a disaggregate representation of 62 industries, whereby the electricity sector is modeled in explicit technological detail. To capture differences in emission and energy intensities as well as inter-fuel substitution possibilities across energy goods, the model identifies 5 primary and secondary energy goods: coal, gas, oil, fuel, and electricity.

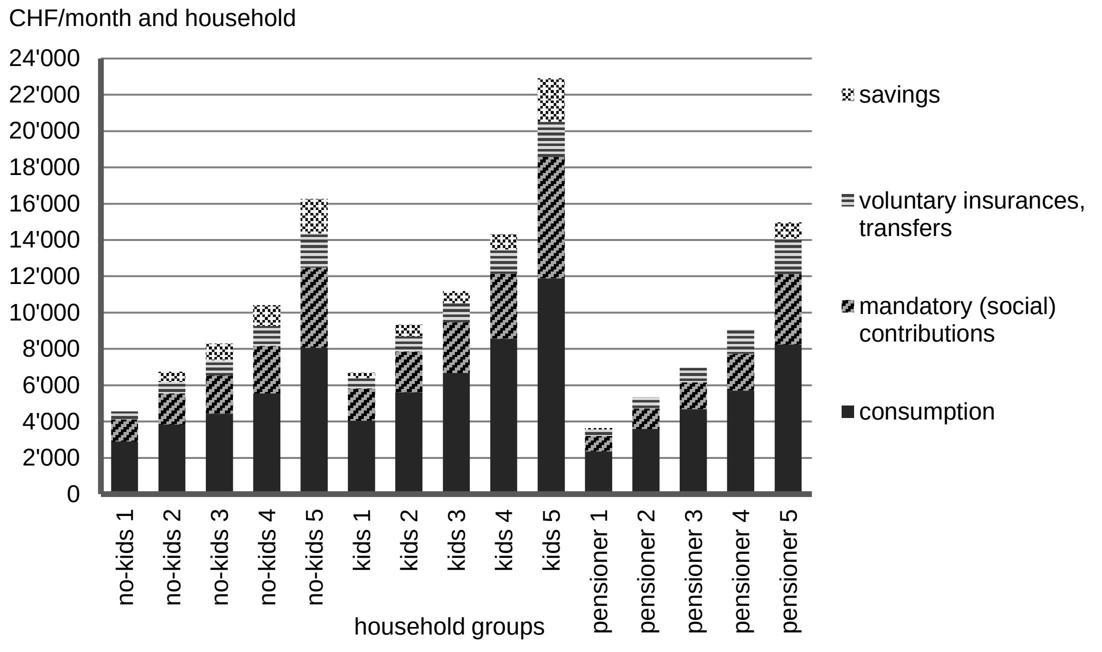
Depending on factor endowments (income sources) and consumption patterns (preferences) the imposition of new taxes as well as the recycling of tax revenues will cause differential impacts for household groups. To capture the incidence of policy regulation the model distinguishes 15 household groups which are classified according to standard of living (five income classes), family status (kids versus no-kids) and professional status (worker versus pensioner). Figures 3 and 4 characterize the household groups by income and expenditures.

Figure 3: Income structure of household groups



Source: ECOPLAN, 2012a.

Figure 4: Expenditure structure of household groups



Source: ECOPLAN, 2012a.

3. Policy Scenarios and Simulation Results

3.1 Policy Scenarios

We investigate two policy scenarios – *POM* ("Politische Massnahmen Bundesrat") and *NEP* ("Neue Energiepolitik") – which differ in their stringency of reduction targets for long-term CO_2 emissions and electricity demand. Table 1 summarizes these targets with respect to the business-as-usual (*BaU*) situation in 2050.

Table 1: Reduction targets for CO_2 emissions and electricity demand in 2050 (% from *BaU*)

Reduction targets with respect to the business-as-usual situation in 2050	scenario *POM*	scenario *NEP*
CO_2 emissions (excl. electricity production and district heating)	-26%	-63%
Electricity demand	-12%	-23%

Scenario *NEP* is markedly more ambitious than scenario *POM* both in terms of the mandated CO_2 emission reductions as well as targeted electricity demand cutbacks.

To comply with the reduction targets for CO_2 and electricity demand we impose respective quotas where the equilibrium shadow prices indicate the level of CO_2 and electricity taxes consistent with the reduction targets. The revenues from CO_2 emission and electricity taxation enter the budget of the Swiss government which recycles "excess" income through revenue-neutral swaps with pre-existing taxes. The five prime candidates for revenue-recycling are (i) lump-sum per-capita transfers to households, (ii) proportional reductions of value-added taxes, (iii) proportional cuts of profit taxes (corporate income taxes), (iv) proportional reductions of payroll taxes (social insurance contributions), and (v) proportional reductions of marginal income tax rates that apply at the federal level.

The targets in *POM* and *NEP* do not only reflect diverging degrees of ambition for domestic environmental action but are also linked with different perspectives on how key trading partners deal with the challenge of global climate change. In scenario *POM* the assumption is that the international community will continue with fragmented and less stringent movements towards decarbonisation of the economy. In scenario *NEP* it is assumed that national energy policy initiatives will be coordinated at a more ambitious level to mitigate global warming. As a consequence of more rigorous constraints on fossil fuel use and tighter emission ceilings, the international fuel prices are expected to be lower in scenario *NEP* compared to scenario *POM* whereas international emission prices are higher in *NEP* compared to *POM*. While it is not possible to endogenise international policy developments within the single small-open economy framework of SWISSGEM-E, the assumptions on alternative evolutions of international fuel and emission prices can be exogenously imposed on scenarios *NEP* and *POM* (see Table 2).

Table 2: Assumption on international fuel prices and CO_2 emission prices

Assumptions on fuel prices (prices 2010)		**2008**	**2050** *BaU/POM*	**2050** *NEP*
World market price for crude oil	CHF/t	857	975	707
World market price for natural gas	CHF/t	640	846	672
CO_2 emission price in the EU ETS	CHF/t CO_2	22	42	103

Source: PROGNOS, 2012.

International emissions trading at the prevailing exogenous emission price plays an important role for Switzerland to achieve emission reduction targets in energy-intensive industries. These industries are supposed to form part of the EU emissions trading system (EU ETS) in the future. The EU ETS has been launched in 2005 as the central pillar of the EU climate policy to comply with the Kyoto Protocol. The EU ETS sets a cap on the total amount of CO_2 emissions that can be emitted by all participating installations. Emission allowances are then auctioned off or allocated for free, and can subsequently be traded. Installations covered by such a cap-and-trade system must monitor and report their emissions and are required to have sufficient allowances to cover their emissions. If an installation's emissions exceed its allowances, it must purchase the difference. In turn, if an installation's emissions are below its allowance, it can sell the excess rights. Market transactions then identify the cost-effective pattern of emission reductions within the cap-and-trade system. The EU ETS currently applies to the 28 EU Member States as well as the three members of the European Economic Area (Norway, Iceland, and Liechtenstein). The energy-intensive industries that are covered by the EU ETS include all primary and secondary energy sectors as well as air transportation, chemical products, iron and steel, non-ferrous metals, non-metallic mineral products, paper and pulp, and plastics. In the *POM* and *NEP* policy regulations these industries are exempted from paying the electricity duty reflecting concerns on their international competitiveness. On the other hand, such exemptions imply that the electricity tax on the remaining consumers must be higher in order to achieve a given economy-wide reduction target in electricity demand.

While energy-intensive industries in Switzerland can trade emission rights at an exogenous international emission price, the remaining part of the Swiss economy must cope with the emission reduction target domestically. This reflects the hybrid emission regulation currently in place for all EU countries where EU ETS sectors can trade emission rights across borders whereas each EU member state has to achieve domestic reduction targets for its non-EU-ETS sectors. The hybrid regulation drives apart emission prices in the ETS and the non-ETS segments and thus induces excess cost of emission abatement. For the *POM* and *NEP* scenarios, we assume that the respective emission reduction targets are applied uniformly across all segments of the Swiss economy. This means that non-ETS industries in Switzerland must face a CO_2 tax which is sufficiently high to curb domestic emissions by 26% and 63% respectively compared to the *BaU* emission level.

3.2 Simulation Results

Taxes on CO_2 *and Electricity*

To achieve the CO_2 emission reduction targets in the non-ETS sectors of the Swiss economy, CO_2 emissions must be taxed at around 210 CHF/t CO_2 (equivalent to 50 Rp. per liter of gasoline or 55 Rp per liter of heating oil) in the case of *POM* and 1150 CHF/t CO_2 (equivalent to 2.75 CHF per liter of gasoline or 3.05 CHF per liter of heating oil) in the case of *NEP*. The magnitude of the CO_2 taxes reflects (i) the stringency of emission reduction, (ii) the difficulties of substituting away from carbon in production and consumption as captured through the empirical estimates on cross-price substitution elasticities, (iii) the absence of low-cost carbon backstop technologies (e.g. carbon capture and sequestration), and (iv) the missing access to international emissions offsets.

To meet the cutback target for electricity demand in the *POM* scenario, the consumer price of electricity must be taxed by around 24% whereas the tax goes up to 42% for the more ambitious *NEP* target. Note that energy-intensive industries are exempted from paying the electricity tax which drives up the tax for the remaining sectors of the economy given a fixed economy-wide reduction target for electricity consumption.

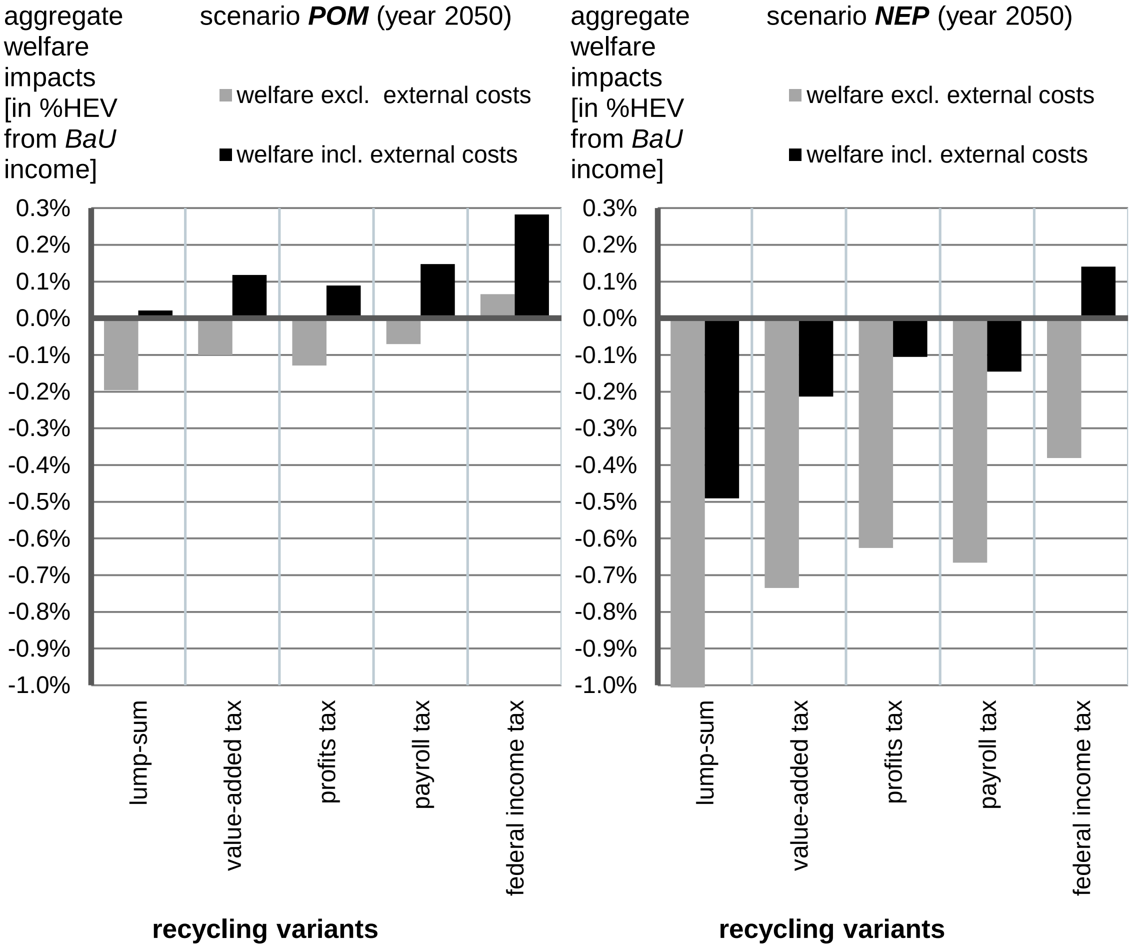
The recycling variant has hardly any impact on the level of the CO_2 tax while the electricity tax ranges between 39 % (recycling variant: lump-sum) and 49 % (recycling variant: profit tax) in the more stringent *NEP* scenario depending on the way additional tax revenues are recycled.

Welfare Impacts

Our central indicator for economic adjustment cost at the regional level is the Hicksian equivalent variation (HEV) in income which denotes the amount which is necessary to add to (or deduct from) the benchmark income of the household such that the household enjoys a utility level equal to the one in the counterfactual policy scenario on the basis of ex-ante relative prices.

Figure 5 reports aggregate welfare impacts for *POM* and *NEP* across the five recycling variants. Welfare aggregation across different households is based on a Benthamite utilitarian perspective where we add up money-metric utility with equal weights across all households. While this measure is a standard metric to quantify aggregate efficiency impacts of policy reforms it is agnostic about the distribution of cost.

Figure 5: Aggregate welfare impacts (in %HEV from BaU income)



Source: ECOPLAN, 2012b.

The efficiency implication of environmental tax reforms crucially depend on the stringency of reduction targets for CO_2 emissions and electricity demand as well as on the choice of the revenue-recycling strategy. The more ambitious the reduction targets the more unlikely it gets that swapping emission and energy taxes for broad-based income or consumption taxes will reduce the excess burden of raising public revenues. There are three general guidelines for exploiting potential inefficiencies of the initial tax system in the context of an environmental tax reform (i) the burden of the environmental tax should fall on factors whose initial taxation is associated with a relatively low marginal excess burden, (ii) additional revenues should be recycled to cut down taxes with a high marginal excess burden, and (iii) the tax base of the environmental tax should be large and subject to low demand and supply elasticities. Our simulation results point to a second (efficiency) dividend only for the case that CO_2 taxes and electricity taxes are sufficiently moderate (note that simple partial equilibrium reasoning suggests the excess burden of a tax to increase with the square of the tax rate) and additional revenues are used to cut marginal income tax rates. Lump-sum recycling performs worst in terms of efficiency since it foregoes the possibility to reduce other distortionary taxes:

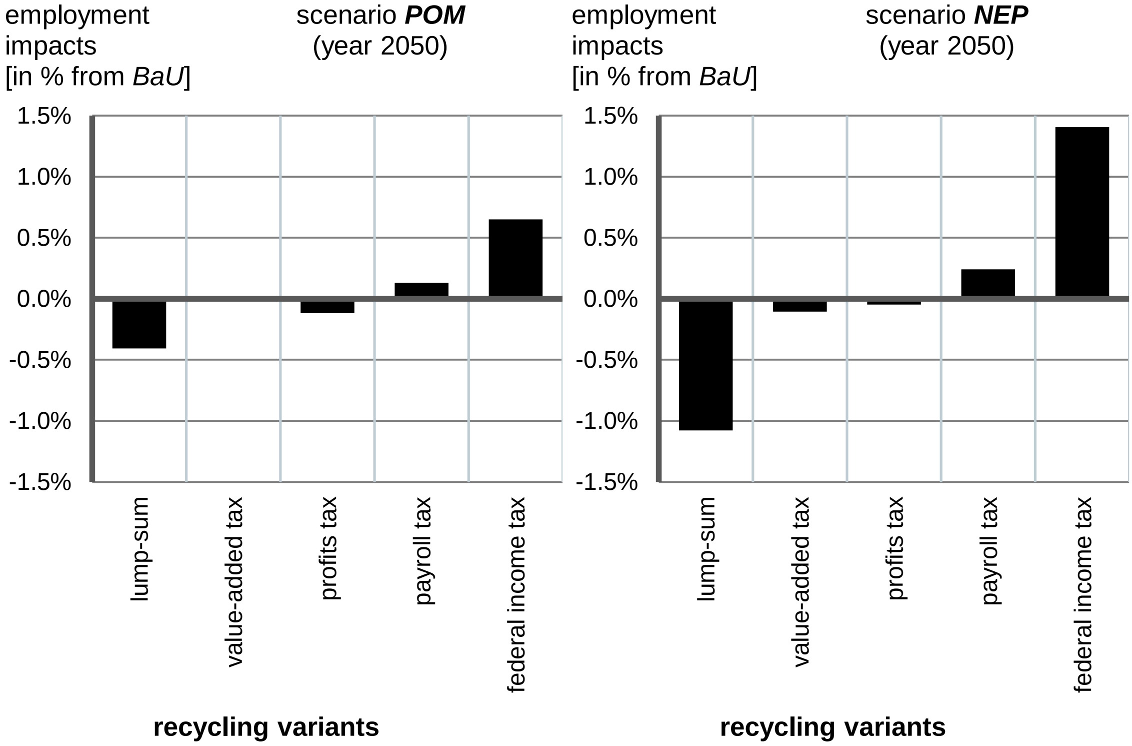
When tax revenues are recycled lump-sum, our central case estimates for the aggregate efficiency losses range from 0.2% for the case of *POM* to 1% for the case of *NEP*. The simulation results clearly highlight the importance of revenue recycling for ameliorating negative economic repercussions triggered by the taxation of CO_2 emissions and electricity consumption.

Constraints on CO_2 emissions and electricity consumption go along with concerns on the external costs of energy production and consumption. While external effects have not been endogenized in SWISSGEM-E, it is possible to do an ex-post calculation on the monetary benefits from reducing negative external effects. Figure 5 reports how the total efficiency impacts changes when accounting for external cost reductions of the energy system (i.e., the first dividend of environmental tax reforms). For moderate CO_2 and electricity reduction targets (scenario *POM*) the overall efficiency implications are then positive throughout. With more ambitious targets (scenario *NEP*) the aggregate welfare impacts remain negative (except for the income tax reduction variant) but get substantially lower. Note that the external cost accounting in Figure 5 is limited to air quality, traffic accidents and traffic noise.

Employment Effects

Constraints on energy use via CO_2 and electricity taxes reduce labor productivity and thus exert a downward pressure on the real wage with negative implications on labor supply as a function of the labor supply elasticity. On the other hand, revenue recycling may more than offset the negative employment effects of additional environmental taxes. This is the case for reductions in payroll taxes and federal income taxes. For value-added tax recycling the negative and positive employment impacts of environmental tax reforms roughly cancel out whereas lump-sum recycling induces employment losses.

Figure 6: Employment impacts (in % from BaU)

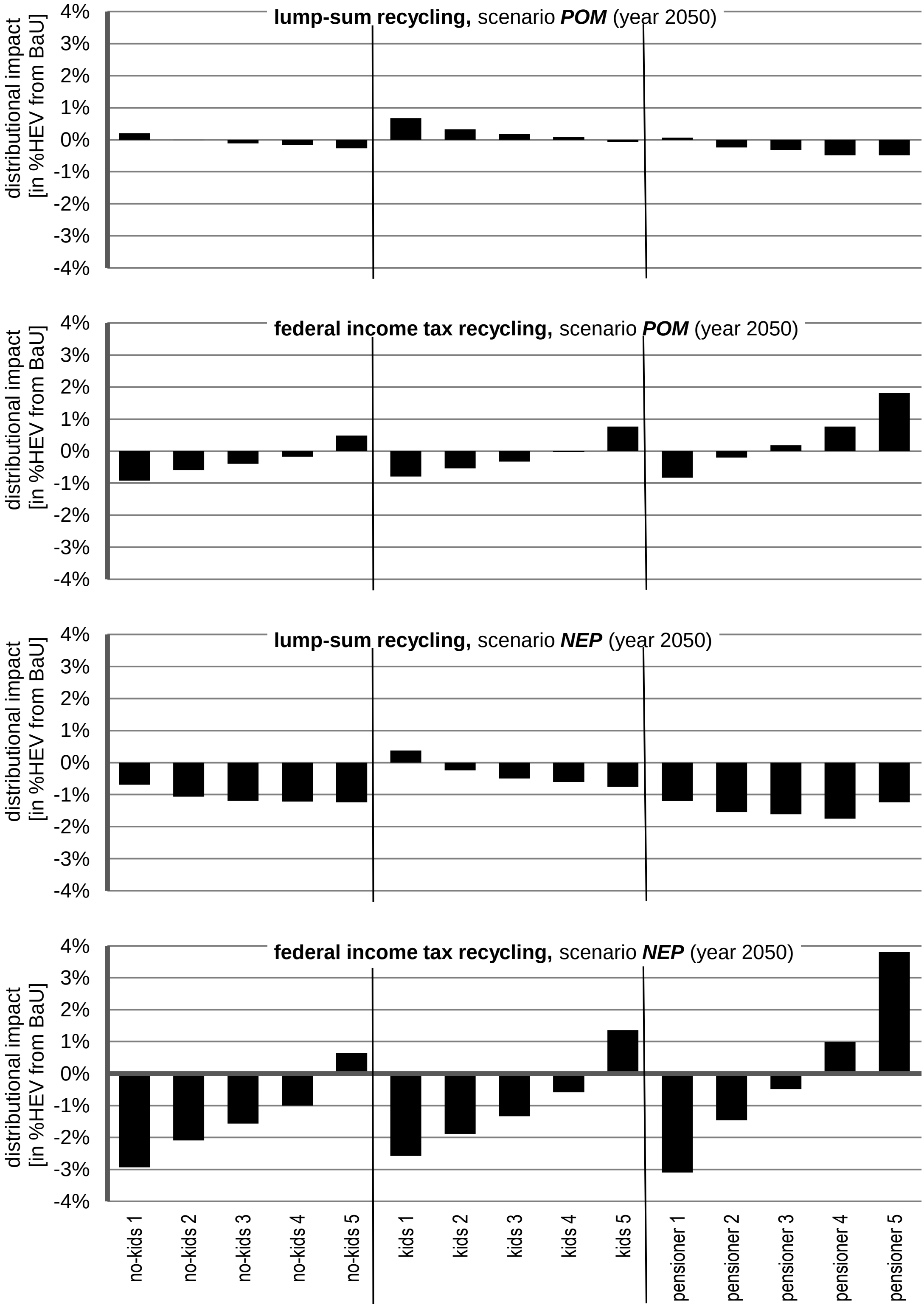


Source: ECOPLAN, 2012b.

Distributional Impacts

In policy practice, the appeal of environmental tax reforms will not only hinge on the magnitude of aggregate efficiency impacts but likewise on the incidence across households. If the market outcome does not deliver a Pareto improvement (thereby making some households worse off), then the critical issue of burden sharing arises. A central request for the design of environmental tax reforms in Switzerland is that income inequalities should not be further exacerbated. As a consequence, policy makers search for recycling strategies that are rather progressive than regressive. Among the five variants only lump-sum recycling is progressive, that is poorer households benefit more (or likewise lose less) than richer households. Figure 7 illustrates the differences in the incidence of *POM* and *NEP* across household groups for lump-sum transfers compared to reductions in the marginal income tax rate. Clearly, income tax reductions are less desirable from a distributional perspective. On the contrary, income tax reductions generate the most desirable outcome with respect to aggregate efficiency impacts. We thus have a trade-off between efficiency and distributional justice which could be further fine-tuned by mixing different recycling strategies rather than relying on pure strategies only.

Figure 7: Distributional impacts (in % HEV from BaU)



Source: ECOPLAN, 2012b.

4. Conclusions

Switzerland is committed to a drastic reduction of per-capita CO_2 emissions over the next decades as an inevitable contribution to global climate protection. At the same time, the nuclear disaster at Fukushima in 2011 let Switzerland decide to renounce on a nuclear option for CO_2 emission reductions in the electricity sector. Against this background, the Swiss energy policy strategy until 2050 envisages ambitious CO_2 emission reduction targets along with substantial cutbacks in electricity consumption.

Our CGE analysis shows that compliance with stringent CO_2 constraints requires high CO_2 taxes on economic activities which are not eligible for international emissions trading; likewise, electricity consumers are burdened with substantial electricity taxes. High CO_2 and electricity taxes will have negative implications for economic performance of the Swiss economy when we abstract in our accounting from the benefits of improved environmental quality. While environmental tax reforms are not likely to generate a second dividend, economic adjustment cost to a low carbon economy without nuclear energy remain modest and can be markedly reduced through revenue-neutral cuts of initial distortionary taxes. On the other hand, alternative recycling strategies pose a trade-off between efficiency and distributional justice which has to be resolved on normative grounds.

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