Assessing the Impact of a Carbon Tax in Ukraine

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Abstract

Ukraine has one of the highest levels of CO_2 emissions per GDP in the world. However, the country committed itself to reduce emissions from stationary sources by 10% until 2015. To this end, the Ukrainian government passed a law to impose a carbon tax on the use of energy commodities. The tax was first levied in 2011 with a starting value of 0.1 Ukrainian Hryvnia (UAH)/ton of CO_2 and was gradually increased resulting in a current tax level of 0.26 UAH/ton of CO_2 (0.02 USD/ton of CO_2). Against this background the questions arise 1) whether such a low tax level can be expected to have any impact on CO_2 emissions at all and 2) which tax level would be consistent with the policy goal of a 10% emission reduction. Thus, using a computable general equilibrium (CGE) model for Ukraine, this paper assesses the impact of different carbon tax levels on the Ukrainian economy and the environment. The results confirm that the effects of the current tax level are negligible. In order to achieve the reduction target a carbon tax of around 40 UAH/ton of CO_2 would be necessary.

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Keywords: Carbon Tax; CGE; Environment; Ukraine

1 Introduction

With 0.98 kilograms CO_2/USD (PPP, 2005 prices) in 2011 Ukraine has one of the highest CO_2 emissions per GDP in the world (IEA; 2013).[1] This level is well above the Non-OECD average (0.55 kilograms CO_2/USD) and even higher than the value for major polluters like the USA (0.40 kilograms CO_2/USD) and China (0.78 kilograms CO_2/USD). However, the Ukrainian government committed itself to improve this situation by ratifying the United Nations Framework Convention on Climate Change (UNFCCC) in 1997 and the Kyoto Protocol in 2004. For this purpose, Ukraine announced in the Law of Ukraine[2] from December 21, 2010, that emissions from stationary sources should be reduced by 10% by 2015 and by 25% by 2020 compared to the emission level of 2010. One of the measures to achieve this is to tighten the regulatory framework for the taxation of environmental pollution.[3] Accordingly, in 2010 the Ukrainian government passed a law to gradually implement a carbon tax on energy commodities used by stationary sources. The tax was first levied in 2011 with a starting value of 0.1 Ukrainian Hryvnia (UAH)/ton of CO_2, and was increased step-by-step up to 0.2 UAH/ton of CO_2. After amendments with respect to the tax level in 2011 (0.22 UAH/ton of CO_2) and 2012 (0.24 UAH/ton of CO_2) the current value is equal to 0.26 UAH/ton of CO_2 (0.02 USD/ton of CO_2).

Compared to the level of carbon taxes in other countries (e.g. India: 0.80 USD/ton of CO_2, Chile: 5 USD/ton of CO_2, Sweden: 150 USD/ton of CO_2) the tax in Ukraine is extremely low. This raises the question about the environmental and economic effects of the carbon tax in Ukraine. For instance, comparing the tax on the use of one ton of coal (0.36 UAH) to the average coal price in 2008 (446 UAH/ton), the National Ecological Centre of Ukraine (NECU) concludes that the tax will not stimulate a reduction in coal combustion and related CO_2 emissions (NECU; 2010). However, they argue that the tax has some advantages over alternative instruments like an emission trading system as it is relatively easy to implement and does not require further legislative and institutional changes. So the main challenge is to find the appropriate tax level leading to a reduction in CO_2 emissions. This calls for a quantitative assessment of the impact of alternative tax levels on the Ukrainian economy and environment, which, to the best of our knowledge, is still lacking in the literature. Using a computable general equilibrium (CGE) model for Ukraine, different carbon tax levels are evaluated with respect to their effect on changes in CO_2 emissions, GDP and welfare.

[1] Among the Former Soviet Union countries only Kazakhstan (1.22 kilograms CO_2/USD), Uzbekistan (1.29 kilograms CO_2/USD) and Turkmenistan (1.45 kilograms CO_2/USD) have a higher level of CO_2 emissions per GDP (IEA; 2013).

[2] The law is entitled "On the Fundamental Principles (Strategy) of Ukraine's State Environmental Policy for the Period until 2020."

[3] This is not the only way to reduce emissions in Ukraine. Another important issue in this regard is to tackle the problem of high energy subsidies as they foster energy consumption and therefore increase emissions (Deutsche Beratergruppe; 2014).

The paper is organized as follows. Section two provides the key model features. The data work is described in section three, followed by the section on the simulations and results. The last section concludes.

2 Modeling approach

Following Meng et al. (2013) and Fraser and Waschik (2013) we use a static CGE model for Ukraine[4] to simulate the impact of different carbon tax levels. The model assumes perfect competition and constant returns to scale and is characterized by zero profits for producers, clearance of the commodity and factor markets and balanced budgets for the model's agents. It includes 38 industries[5] and commodities because each sector is assumed to produce only one homogeneous good. Among those are the following six energy commodities: coal/peat, crude oil, coke products, refined petroleum, gas and electricity/heat.[6]

As the focus of this paper is on the use of energy in production, the nesting structure of domestic output in Frey and Olekseyuk (2014) is adjusted to allow for substitution possibilities between energy commodities used in production. The modified model structure is presented in Figure 1.

The supply side of the Ukrainian economy is represented by a multi-level production function. The value-added-energy bundle and intermediate inputs are combined at the top level nest to produce domestic output. Intermediate inputs are either produced domestically or imported. Value-added is generated by combining the primary factors of production (skilled and unskilled labor, capital and sector-specific capital)[7] according to a Cobb-Douglas technology. The energy bundle is split into electricity and a non-electric-energy bundle, which is obtained by the use of energy commodities based on a constant elasticity of substitution (CES) function. Energy and non-energy producers are assumed to differ with respect to the substitutability of energy commodities. Table 1 presents the respective model elasticities, some of which are taken from Pavel et al. (2004).

The resulting output can be sold on domestic or foreign markets according to a constant elasticity of transformation (CET) function. Domestic demand is comprised of domestic sales and imports as described by a CES function. This means that consumers regard domestically produced and imported commodities as imperfect substitutes (Armington; 1969). Accordingly, Ukraine's exports and imports are aggregated into

[4]For a detailed model description see Frey and Olekseyuk (2014).

[5]See Table 5 in Appendix A for information about the sectoral aggregation.

[6]Renewables are not considered here as they are still of minor importance in Ukraine.

[7]Labor is assumed to be fully employed. Sector-specific capital is used in the state-owned mining (a04) and pipeline transportation (a24P) sectors.

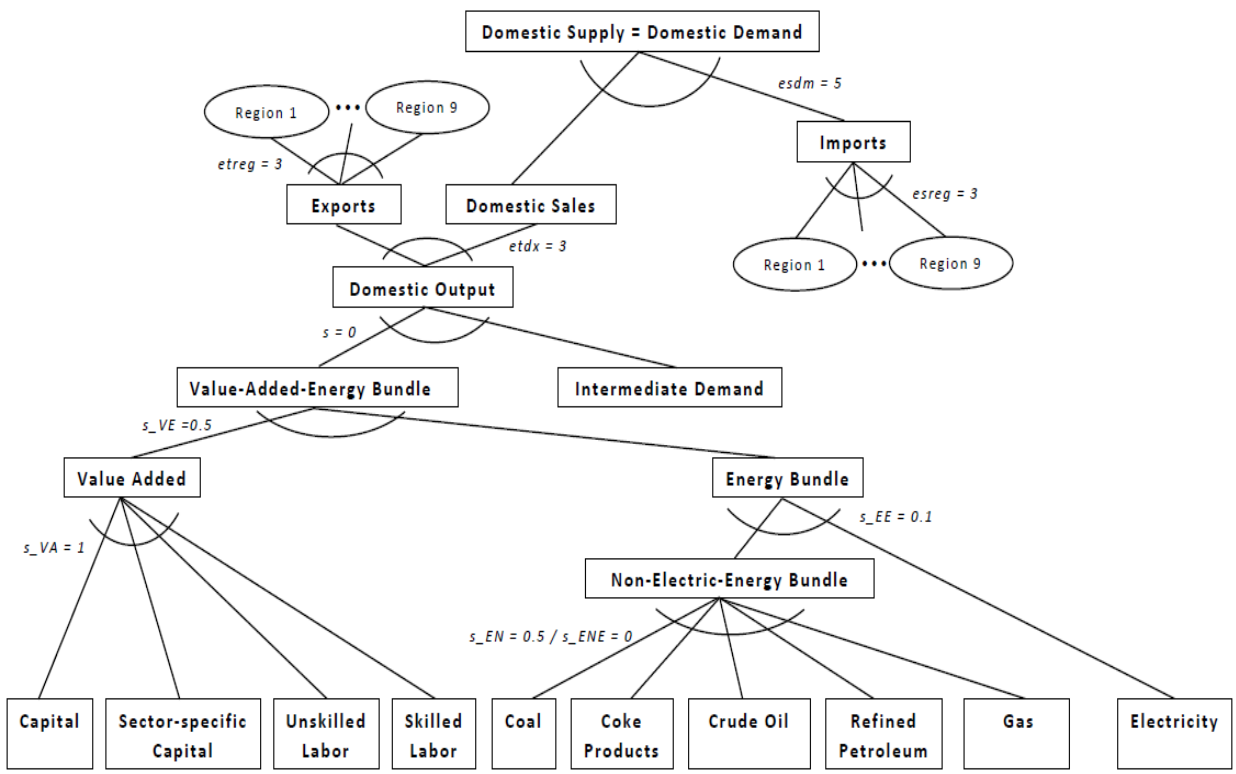

Figure 1: Model structure

Parameter	Value	Description
s	0.0	Elasticity of substitution between value-added-energy bundle and intermediate inputs
s_VA	1.0	Elasticity of substitution between primary factors: capital and labor
s_EN	0.5	Elasticity of substitution between energy commodities (except electricity), non-energy producers
s_ENE	0.0	Elasticity of substitution between energy commodities (except electricity), energy producers
s_EE	0.1	Elasticity of substitution between non-electric-energy bundle and electricity
s_VE	0.5	Elasticity of substitution between value added bundle and energy bundle
esdm	5.0	Armington elasticity of substitution between imports and domestic goods
etdx	5.0	Elasticity of transformation between domestic production and exports
esreg	3.0	Elasticity of substitution between import origins
etreg	3.0	Elasticity of transformation between export destinations

Table 1: Model elasticities

the following nine trading regions: EU15,[8] EU12, other Europe, Asia, Africa, America, Commonwealth of Independent States (CIS), Russia and the rest of the world (ROW).

The consumption side consists of public consumption, investment and intermediate consumption and final consumption by households. The four types of households (rural/urban, poor/non-poor) derive utility from the consumption of goods and services, which is financed by income from labor and capital endowments[9] and received transfers.

CO_2 emissions are proportional to the use of energy commodities in production.

3 Data

As the purpose of this paper is to analyze the economic and environmental consequences of a carbon tax in Ukraine, the economic data is complemented by detailed data on intermediate and final use of energy commodities. In addition, information on CO_2 emissions from fuel combustion is used.

[8] EU15 comprises the EU countries prior to 2004. EU12 refers to the countries of the 2004 and 2007 enlargement of the EU.

[9] Non-poor households are endowed with both capital and labor (skilled and unskilled) whereas poor households are only endowed with unskilled labor.

3.1 Economic data

A social accounting matrix (SAM) for the year 2007[10] forms the main database for the CGE model. It is based on the Ukrainian national accounts and input-output tables at basic and consumer prices published by the State Statistics Service of Ukraine. National data sources also provide information on indirect taxes and subsidies, labor remuneration, household expenditures and tariff lines. Trade statistics are taken from the UN Comtrade database.[11] As "crude oil" and "natural gas" are not reported separately in the original SAM, a disaggregation of the respective industry/commodity is necessary. Therefore, supplementary data on energy consumption in Ukraine is needed.

3.2 Energy data

Following Wissema (2006) and McDougall and Lee (2006), the following steps are carried out in order to prepare the energy data: preparation of energy volume data, energy price data and energy data in monetary units and disaggregation of energy industry/commodity "crude oil/natural gas" in the SAM.

The main purpose of the first step is to convert the available energy volume data for the year 2007 in such a way that its structure coincides with the model structure. This is done by grouping the fuels reported in the Energy Balances of Non-OECD Countries (IEA; 2010) into the energy commodities included in the model. Furthermore, the SAM and the IEA sectors are matched. As the Energy Prices and Taxes of Non-OECD Countries are no longer published by the IEA, the information on energy prices in Ukraine has to be extracted from different sources (e.g. national commissions) in the second step. Combining the outcome of the first two steps results in energy data reported in monetary units. In the last step, this data is used to disaggregate the sector/commodity "crude oil/natural gas" in the SAM based on value shares in a "natural gas" and a "crude oil" part. The separated part on "natural gas" is added to the already existing sector/commodity "manufactured gas", while "crude oil" from now on forms a separate sector/commodity.

3.3 Emission data

Country-specific CO_2 emission factors for Ukraine are computed as follows (GAEIU; 2013):

$$\text{emission factor } (CO_2/\text{ton}) = \text{carbon oxidation factor} * \text{net calorific value } (\text{TJ/ton}) * \text{coefficient of carbon content } (\text{C/TJ}) * \text{molecular weight ratio of } CO_2 \text{ to C } (CO_2/\text{C})$$

[10] As the carbon tax was first introduced in 2011, we could not take this or one of the following years as the base year because this would imply that the carbon tax is already included in the benchmark data. To further avoid the influence of the world economic crises, we chose 2007 as the base year for our analysis.

[11] For a detailed data description see Frey and Olekseyuk (2014).

The resulting CO_2 emission factors[12] are reported in Table 2. In order to calculate Ukraine's emissions from fuel combustion for the base year 2007, the energy volume data is multiplied with the respective emission factors.

Energy commodity	Emission factor (ton of CO_2/TOE)
Crude oil	3.03
Refined petroleum[a]	2.97
Gas	1.54
Coal/peat	4.27
Coke products	5.06

Source: Own calculation based on GAEIU (2013)

Table 2: Emission factors for Ukraine

[a]This is a weighted average of diesel, LPG and motor gasoline (A-95).

4 Scenarios and simulation results

The base year for Ukraine's emission reduction target (10% by 2015) is 2010. However, our model is calibrated for the year 2007. As emissions were already reduced between 2007 and 2010, the target of 10% compared to the level of 2010 corresponds to a reduction of 22% based on the level of 2007. Since we are interested in the reductions in CO_2 emissions associated with different carbon tax levels, we perform a couple of tax simulations ranging from the existing tax level of 0.26 UAH/ton of CO_2 to 40 UAH/ton of CO_2 (see Figure 2).

Specific carbon taxes are implemented in the CGE model as ad-valorem equivalents. Those are calculated by dividing CO_2 emission factors by energy prices. The resulting data is multiplied with the specific carbon taxes to obtain the tax rates in percent. Differences in prices and emission factors are also reflected in different ad-valorem taxes, ranging for example between 3.54% for refined petroleum and 29.38% for coal for a specific tax level of 40 UAH/ton of CO_2. As the carbon tax in Ukraine is only raised on CO_2 emissions from stationary sources, the simulated ad-valorem taxes are only imposed on the model sectors a01-a18.

The introduction of a carbon tax generates additional tax revenues. Analyzing different alternatives to recycle carbon tax revenues in Scotland, Allan et al. (2014) conclude that a positive economic effect on top of reduced CO_2 emissions might occur, if the tax revenue is used to lower other existing taxes. Accordingly, the additional tax revenues generated in this model are used to reduce the indirect tax rate. This implies

[12]Using conversion factors, the calculated emission factors in CO_2/ton are converted into CO_2/ton of oil equivalent (toe).

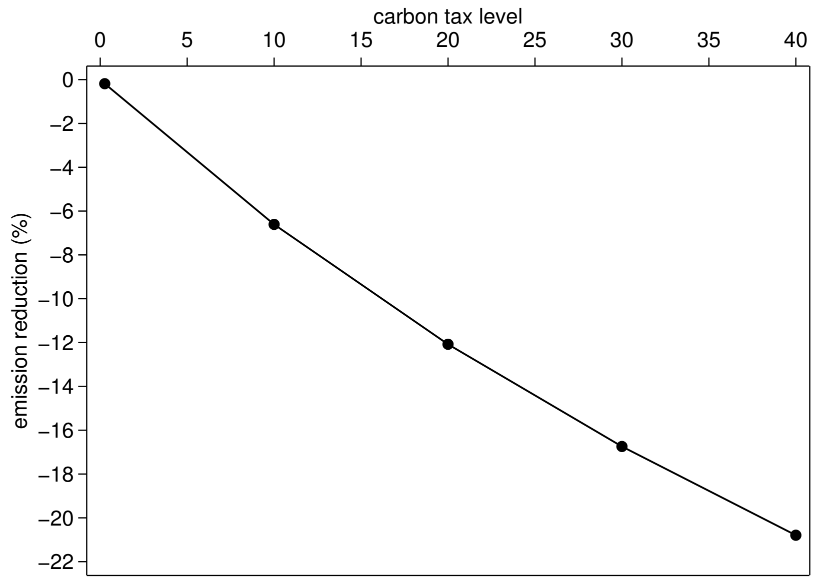

Figure 2: Different carbon tax levels and associated CO_2 emission reductions

that government expenditures are held constant.

Figure 2 depicts the impact of different carbon tax levels on CO_2 emission reductions in Ukraine. As expected, the current tax level of 0.26 UAH/ton of CO_2 results only in a very small reduction (0.19%) of CO_2 emissions. In order to meet the emission reduction target of 22%, a tax level of around 40 UAH/ton of CO_2 would be necessary. This level is equivalent to 3.46 USD/ton of CO_2 and comes within the limits of carbon taxes in Mexico and Chile.

Looking at the economic results presented in Table 3 one can see that the distortionary effect of a carbon tax can barely be offset by reducing the indirect tax rate. This is indicated by an increase, though a small one, of real GDP under all scenarios pointing to the existence of a double dividend. Thus, our result is in line with the findings of Fraser and Waschik (2013), who detect a double dividend for Australia if the tax revenue is used to lower consumption taxes.

Changes in domestic production lead to a decrease in the demand for capital and labor with the exception of sector-specific capital in pipeline transit (a24P)[13]. This becomes apparent in the negative effects on the respective real factor returns. However, the reduced indirect tax rate results in a drop of the consumer price index (CPI) for all types of households. This leads to a positive welfare effect (measured as the Hicks welfare

[13]The positive effect on sector-specific capital returns in pipeline transit (a24P) arises because this sector is not subject to carbon taxation and at the same time benefits from the drop in the indirect tax rate.

	0.26 UAH/t CO_2	10 UAH/t CO_2	20 UAH/t CO_2	30 UAH/t CO_2	40 UAH/t CO_2
Real GDP	0.00	0.02	0.04	0.07	0.10
Indirect tax	-0.2	-5.7	-10.2	-13.8	-16.8
Real wage rate for unskilled labor	0.0	-1.3	-2.4	-3.2	-4.0
Real wage rate for skilled labor	0.0	-1.1	-2.0	-2.7	-3.4
Real return to capital	0.0	-0.7	-1.2	-1.7	-2.0
Real return to capital in a04	-0.3	-8.8	-16.0	-22.0	-27.1
Real return to capital in a24P	0.1	3.7	6.6	8.7	10.3
Welfare urban household	0.0	0.2	0.3	0.3	0.3
Welfare rural household	0.0	0.2	0.3	0.4	0.5
Welfare urban poor households	0.0	0.2	0.4	0.5	0.5
Welfare rural poor households	0.0	-0.2	-0.4	-0.6	-0.8

Table 3: Economic results (changes in %)

of equivalent variation) for all but rural poor households. For those households the negative effect of reduced factor returns dominates the positive impact of a decreased CPI.

The most striking result concerning the changes in the sectoral output (see Figure 3) occurs in the textile industry (a08), which more than doubles its output. This is mainly due to the fact that the value of taxed energy commodities used in production does only account for 1% of the overall value of intermediates. In addition, this sector does not employ any coal, on which the highest carbon tax is imposed but benefits from the reduction of the indirect tax rate. As expected, output is mostly reduced in the energy producing and energy intensive industries like metallurgy (a14) and mining and quarrying (a06). The biggest drop arises in the manufacturing of coke products (a10) because this sector uses the relatively highly taxed energy commodity coal/peat most intensively.

In order to test the sensitivity of the results with respect to the substitution elasticities in production, the simulations are repeated with different changes in the substitution elasticities. The results are presented in Table 4. Doubling the substitution elasticities for the energy bundle (s_EN=1) and the value-added-energy bundle (s_VE=0.2) leads to a slightly higher reduction in CO_2 emissions as the relatively more expensive energy commodities can be substituted more easily. However, doubling the elasticity of substitution between electricity and the non-electric-energy bundle (s_EE=0.2) results in very small changes compared to the simulation with the initial substitution elasticities. The same holds for the sensitivity analysis concerning

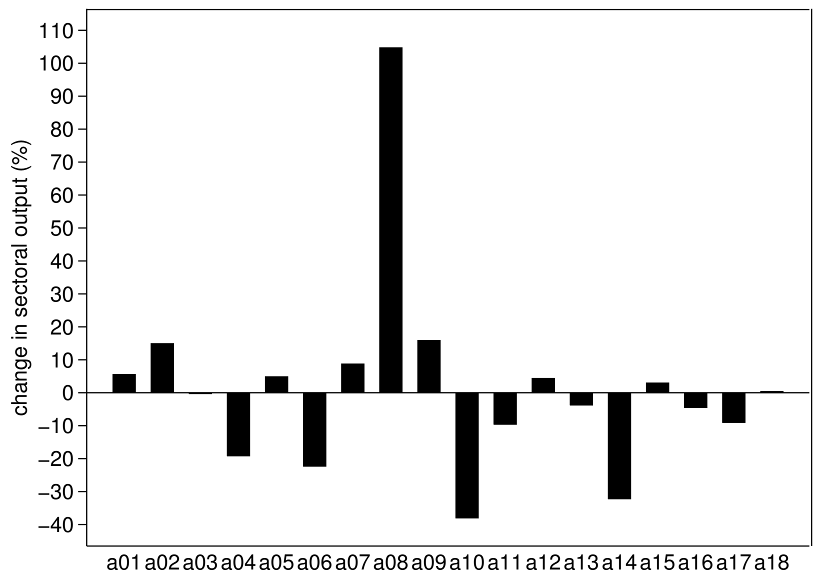

Figure 3: Changes in sectoral output for a tax level of 40 UAH/ t CO_2

the substitution possibilities of energy commodities used in energy production (s_ENE=0.1).

	Benchmark parametrization	s_EN=1	s_VE=0.2	s_EE=0.2	s_ENE=0.1
0.26 UAH/t CO_2	-0.19	-0.19	-0.20	-0.19	-0.19
10 UAH/t CO_2	-6.61	-6.88	-6.89	-6.62	-6.61
20 UAH/t CO_2	-12.08	-12.53	-12.56	-12.10	-12.08
30 UAH/t CO_2	-16.73	-17.31	-17.37	-16.77	-16.74
40 UAH/t CO_2	-20.79	-21.44	-21.53	-20.82	-20.79

Table 4: CO_2 emission reductions for different modified elasticity values (changes in %)

5 Conclusion

This paper analyzed the impact of alternative levels of an already existing carbon tax in Ukraine and the associated CO_2 emissions generated by stationary sources. As conjectured in the beginning, the current tax level of 0.26 UAH/ton of CO_2 does not result in a significant decrease of CO_2 emissions in Ukraine. Against the background of a national emission reduction target, we conclude that a reduction of 10% with respect to the emission level of 2010 may be achieved with a carbon tax of around 40 UAH/ton of CO_2. Although this tax level would be much higher than the current one, it would still be in the lower range of the carbon taxes existing in other countries. Assuming that the additional tax revenue is recycled through a reduction of the indirect tax rate, we can even constitute a welfare increase for three out of four household types and a small rise in real GDP indicating the existence of a double dividend. As this would favor consumers and sectors like the textile industry at the expenses of the energy producing sectors, the feasibility of such a carbon tax strongly depends on the power of the lobbying groups and the overall political will.

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A Appendix A

	SAM Sector		SAM Sector
a01	Agriculture	a21	Construction
a02	Forestry	a22	Trade and repair activities
a03	Fishing	a23	Hotels and restaurants
a04	*Mining of coal and peat*[a]	a24	Transport
a05	*Extraction of crude oil and natural gas*[b]	a25	Post and telecommunications
a06	Mining and quarrying	a26	Financial activities
a07	Food-processing	a27	Real estate activities
a08	Textile industry	a28	Renting
a09	Wood industry	a29	Computer and related activities
a10	*Manufacture of coke products*	a30	Research and development
a11	*Petroleum refinement*	a31	Other business activities
a12	Chemical industry	a32	Public administration
a13	Other non-metallic products	a33	Education
a14	Metallurgy, metal processing	a34	Health care and social assistance
a15	Machine building	a35	Streets cleaning and other utilities
a16	Other production	a36	Social activities
a17	*Electric energy, heat supply*	a37	Leisure activities
a18	*Gas supply*[c]	a38	Other activities
a20	Water supply	a24P	Pipeline transit

Source: Frey and Olekseyuk (2014)

Table 5: CGE model sectors

[a]The sectors in italics are the energy industries.

[b]This sector is disaggregated in "crude oil" and "natural gas" as part of the analysis.

[c]After the disaggregation of sector a05, the "natural gas" part is added to this sector to form the new sector "gas".

B Appendix B (Energy data preparation)

The preparation of the energy data is required for two reasons. First, the initial industry/commodity "crude oil/natural gas" is disaggregated based on value shares. The necessary energy data in monetary units is obtained by combining two datasets: volume data and price data. The volume data in tons of oil equivalent (toe) comes from the International Energy Agency (IEA), but has to be adjusted to comply with the structure of the economic data. Compiling the price data is more elaborated, as some prices are regulated by law while others are determined by the market. Second, the energy volume data is also needed to calculate the baseline emissions.

B.1 Volume data

The Energy Balances (IEA; 2010) for Ukraine for the year 2007 constitute the starting dataset. This is modified in the following way:

- the following rows are deleted due to zero entries:
  international marine bunkers, petrochemical plants, gasification plants for biogases, nuclear industry, transfers, heat pumps (transformation processes), electric boilers (transformation processes), chemical heat for electricity production (transformation processes), coal liquefaction plants (transformation processes), blended natural gas (transformation processes), coal liquefaction plants (energy industry own use), liquefaction (LNG)/regasification plants (energy industry own use), gas-to-liquids (GTL) plants (energy industry own use), charcoal production plants (energy industry own use), world aviation bunkers (transport), world marine bunkers (transport), non-specified (other), non-energy use in transport
- the following columns are deleted due to zero entries:
  sub-bituminous coal, gas coke, oxygen steel furnace gas, industrial waste, municipal waste (renewable), municipal waste (non-renewable), biogases, biogasoline, biodiesels, other liquid biofuels, non-specified primary biofuels and waste, electricity/heat output from non-specified manufactured gases, heat output from non-specified combustible fuels, paraffin waxes, other hydrocarbons, gasoline type jet fuel, geothermal, solar photovoltaics, solar thermal, tide, wave and ocean, other sources, other recovered gases
- the following columns are discarded (see McDougall and Lee (2006)):
  additives/blending components, primary solid biofuels, charcoal, nuclear, hydro, wind
- the following rows are discarded (see McDougall and Lee (2006)):
  charcoal production plants
- international aviation bunkers and stock changes are summed up

- as motor gasoline and diesel used by households are included within the sector road, the following assumptions are made (based on McDougall and Lee (2006)) about which part of motor gasoline and diesel consumed by the road sector should be assigned to the residential sector: 50% (2748 toe)[14] of motor gasoline used in the road sector (5497 toe) is assigned to the residential sector, 25% (618 toe) of diesel used in the road sector (2471 toe) is assigned to the residential sector

- aggregation of energy commodities (columns):

IEA energy commodities	model energy commodities
anthracite + coking coal + other bituminous coal + lignite + patent fuel + BKB/peat briquettes + peat	coal/peat
coke oven coke + coal tar + coke oven gas + blast furnace gas	coke products
gas works gas	gas works gas[a]
natural gas + natural gas liquids	natural gas
crude oil	crude oil
refinery feedstocks + refinery gas + ethane + liquefied petroleum gases (LPG) + motor gasoline + aviation gasoline + kerosene type jet fuel + other kerosene + gas/diesel oil + fuel oil + naphtha + white spirit/SBP + lubricants + bitumen + petroleum coke + non-specified oil products	petroleum products
electricity + heat	electricity/heat

Table 6: Aggregation of energy commodities

[a]After the disaggregation of the initial model sector and comodity "crude oil/natural gas", gas works gas is combined with natural gas to the new model sector and commodity "gas".

- aggregation of energy sectors (rows: transformation processes and energy industry own use):

[14]Note that in the IEA Energy Balances table entries have positive or negative signs. Energy commodities used in the transformation processes or as energy industry own use are indicated by a negative sign as their use must be subtracted from total primary energy supply. After taking account of distribution losses and statistical differences, the remaining amount of each energy commodity should be equal to the sum of total final consumption. Therefore, the use of an energy commodity by any sector apart from the energy industries is indicated by a positive entry in the table. Because of this, in the following detailed description, positive and negative figures occur.

IEA energy sectors	model energy sectors
coal mines (energy industry own use)	coal/peat
blast furnaces (transformation processes) + coke ovens (transformation processes) + patent fuel plants (transformation processes) + BKB plants (transformation processes) + blast furnaces (energy industry own use) + coke ovens (energy industry own use) + patent fuel plants (energy industry own use) + BKB plants (energy industry own use)	coke products
gas works (transformation processes) + gas works (energy industry own use)	gas works gas
oil and gas extraction (energy industry own use) (part)	natural gas
oil and gas extraction (energy industry own use) (part)	crude oil
oil refineries (transformation processes) + gas-to-liquids (GTL) plants (transformation processes) + oil refineries (energy industry own use)	petroleum products
main activity producer electricity plants (transformation processes)+ autoproducer electricity plants (transformation processes) + main activity producer CHP plants (transformation processes) + autoproducer CHP plants (transformation processes) + main activity producer heat plants (transformation processes) + autoproducer heat plants (transformation processes) + own use in electricity, CHP and heat plants (energy industry own use) + pumped storage plants (energy industry own use)	electricity/heat

Table 7: Aggregation of energy sectors

- disaggregation of the sector oil and gas extraction into crude oil and natural gas (following McDougall and Lee (2006)):

  all inflows of the commodity crude oil into oil and gas extraction are assigned to the industry crude oil (-3 toe) and all inflows of the commodity natural gas into oil and gas extraction are assigned to the industry natural gas (-1034 toe); the inflows of all other commodities are disaggregated in proportion to the production of crude oil (3327/22174=15%) and natural gas (18847/22174=85%): petroleum products (natural gas (-46 toe), crude oil (-8 toe)), electricity/heat (natural gas (-38 toe), crude oil (-7 toe))

- treatment of non-specified (transformation):
  split-up between all energy sectors in proportion to their own energy use (non-specified (transformation) for the commodity natural gas (-12 toe) is completely added to electricity/heat; non-specified (transformation) for the commodity petroleum products (-305 toe) is apportioned in the following way: electricity/heat (-96 toe), coke products (-1 toe), petroleum products (-208 toe))

- treatment of non-specified (energy):
  split-up between all energy sectors in proportion to their own energy use (non-specified (energy) for the commodity coal/peat (-1 toe) is completely added to electricity/heat (-1 toe); non-specified (energy) for the commodity natural gas (-2 toe) is completely added to oil and gas extraction (-2 toe); non-specified (energy) for the commodity petroleum products (-42 toe) is apportioned in the following way: coal/peat (-2 toe), oil and gas extraction (-3 toe), gas works (-2 toe), petroleum products (-24 toe), electricity/heat (-3 toe), coke products (-8 toe); non-specified (energy) for the commodity electricity/heat (-295 toe) is apportioned in the following way: coal/peat (-79 toe), oil and gas extraction (-5 toe), gas works (-1 toe), petroleum products (-15 toe), electricity/heat (-183 toe), coke products (-12 toe))

- treatment of distribution losses:
  summing-up with transformation and energy-industry own use (coal/peat (-20 toe), natural gas (-945 toe), crude oil (-19 toe), electricity/heat (-5391 toe))

- sectoral correspondence between IEA final consumption sectors and the model sectors (this table was created by the use of different correspondence tables):

<table>
<tr><th>IEA sectors (intermediate input and final demand)</th><th>model sectors</th></tr>
<tr><td>iron and steel + non-ferrous metals</td><td>metallurgy, metal processing</td></tr>
<tr><td>chemical and petrochemical</td><td>chemical industry</td></tr>
<tr><td>non-metallic minerals</td><td>other non-metallic products</td></tr>
<tr><td>transport equipment + machinery</td><td>machine building</td></tr>
<tr><td>mining and quarrying</td><td>mining and quarrying</td></tr>
<tr><td>food and tobacco</td><td>food processing</td></tr>
<tr><td>paper, pulp and print + wood and wood products</td><td>wood industry</td></tr>
<tr><td>construction</td><td>construction</td></tr>
<tr><td>textile and leather</td><td>textile industry</td></tr>
<tr><td>non-specified (industry)</td><td>other production</td></tr>
<tr><td>international civil aviation + domestic air transport + road + rail + international navigation + non-specified (transport)</td><td>transport</td></tr>
<tr><td>pipeline transport</td><td>pipeline transit</td></tr>
<tr><td>agriculture</td><td>agriculture | forestry</td></tr>
<tr><td>commercial and public services</td><td>water supply | trade and repair activities | hotel and restaurants | post and telecommunications | financial activities | real estate activities | renting | computer and related activities | research and development | other business activities | public administration | education | health care and social assistance | streets cleaning, other utilities | social activities | leisure activities | other activities</td></tr>
<tr><td>residential</td><td>households</td></tr>
</table>

Table 8: Correspondence between IEA and model sectors

- based on the sectoral correspondence (Table 8) two major changes are made with respect to the model sectors: the IEA sector agriculture/forestry is disaggregated in order to correspond to the model sectors agriculture and forestry (this is done by using the values of the energy commodity inputs in the activities agriculture and forestry in the SAM: coal/peat (all (25 toe) is assigned to agriculture), natural gas (all (134 toe) is assigned to agriculture), petroleum products (1298 toe out of 1382 toe are assigned to agriculture and 84 toe are assigned to forestry), electricity/heat (276 toe out of 282 toe are assigned to agriculture and 6 toe are assigned to forestry)); the same methodology is applied to disaggregate the IEA sector commercial and public services

- treatment of non-energy use:

  feedstock use in petrochemical industry is added to the chemical industry, non-energy use in other is apportioned between all sectors in other in proportion to their own energy use (Non-energy use industry/transformation/energy is apportioned between all sectors (but not the transport and other sectors) in proportion to their own energy use (non-energy use of the commodity coal/peat (792 toe) is added to electricity (-347 toe), coke products (-418 toe), coal mines (-2 toe), metallurgy (16 toe), non-metallic minerals (6 toe), mining and quarrying (2 toe) and food tobacco (1 toe); non-energy use of the commodity coke products (405 toe) is added to electricity (-32 toe), coke products (-206 toe), metallurgy (148 toe), mining and quarrying (2 toe) and non-specified industry (17 toe); non-energy use of the commodity natural gas (2 toe) is added to electricity/heat (-2 toe); non-energy use of the commodity crude oil (19 toe) is added to petroleum products (-19 toe); non-energy use of the commodity petroleum products (1398 toe) is added to electricity (-123 toe), coke products (-62 toe), gas works gas (-11 toe), petroleum products (-375 toe), coal/peat (-13 toe), natural gas (-17 toe), crude oil (-3 toe), metallurgy (136 toe), chemical (232 toe), non-metallic minerals (34 toe), machine building (29 toe), mining and quarrying (103 toe), food and tobacco (64 toe), wood industry (8 toe), construction (169 toe), textile and leather (1 toe) and non-specified (industry) (18 toe)), Non-energy use in other is apportioned between all sectors in other (non-energy use of the commodity petroleum products (6 toe) is added to residential (4 toe) and agriculture/forestry (2 toe))

The resulting energy volume data is presented in Table 9:

supply and consumption (thousand toe)	coal/peat	coke products	gas works gas	natural gas	crude oil	petroleum products	electricity/heat
production	34404	20548	82	18847	3327	14988	30534
imports	8026	1255	0	42002	9857	5812	291
statistical differences	2188	6	-3	36	-1	-214	11
intermediate energy use by sector							
electricity/heat	17553	1687	55	21307	0	468	6989
coke products	21924	10891	24	4	0	207	108
gas works gas	0	0	0	0	0	41	11
petroleum products	0	0	0	1300	13278	1426	133
coal/peat	112	0	0	8	0	48	696
natural gas	0	0	0	1979	0	63	38
crude oil	0	0	0	0	22	11	7
metallurgy, metal processing	797	7784	0	6099	0	515	2908
chemical and petrochemical	4	22	0	5803	0	885	582
non-metallic minerals	332	18	0	2431	0	127	344
machine building	4	16	0	449	0	111	556
mining and quarrying	132	123	0	474	0	391	903
food and tobacco	48	1	0	307	0	242	410
wood industry	1	0	0	88	0	30	145
construction	8	0	0	66	0	643	128
textile and leather	2	0	0	7	0	5	42
non-specified (industry)	1	868	0	41	0	69	5604
transport	39	0	0	85	0	5071	822
pipeline transport	0	0	0	2854	0	12	82
water supply	3	0	0	6	0	1	397
trade and repair activities	14	0	0	79	0	21	272
hotels and restaurants	2	0	0	12	0	1	68
post and telecommunications	1	0	0	5	0	1	77
financial activities	0	0	0	1	0	2	13
real estate activities	6	0	0	73	0	3	447
renting	0	0	0	1	0	1	3
computer and related activities	0	0	0	0	0	0.5	3
research and development	2	0	0	7	0	1	14
other business activities	2	0	0	13	0	7	95
public administration	44	0	0	64	0	2	95
education	154	0	0	143	0	1	127
health care and social assistance	46	0	0	101	0	2	128
streets cleaning, other utilities	0	0	0	9	0	4	50
social activities	0	0	0	1	0	0.5	2
leisure activities	3	0	0	9	0	1	28
other activities	0	0	0	11	0	1	20
agriculture	25	0	0	134	0	1298	276
forestry	0	0	0	0	0	84	6
fishing	0	0	0	0	0	0	4
final demand incl. additions to stock							
residential	1441	2	0	13361	0	4063	7123
exports	1930	349	0	3	4	4262	1080
stock changes/int. aviation bunkers	-12	48	0	3550	-121	464	0

Table 9: Energy volume data

B.2 Price data

The prices for residential consumption of natural gas and electricity are set by the National Commission for State Energy and Public Utilities Regulation, Ukraine. Gas prices are graduated based on the consumption volume and the existence of a gas counter. As most households consume less than 2500 m^3 per year, the price associated with this consumption volume is taken for all households. Prices for electricity are differentiated according to the location of a household (urban or rural). Therefore, the price reported in Table 10 is a weighted average (share of rural population in 2007: 0.32, share of urban population in 2007: 0.68, source: State Statistics Service of Ukraine). Crude oil is sold by auctions. The prices for diesel, motor gasoline (A-95) and LPG are supposed to be market prices, which are calculated by taking the yearly averages over all prices available on the internet. The remaining prices are derived in the same way.

energy commodity	user	basic price (UAH per toe, excl. excise tax & VAT)
diesel	industry	3401.11
diesel	households	3857.68
motor gasoline (A-95)	industry	3427.27
motor gasoline (A-95)	households	4420.55
LPG	industry	2419.53
LPG	households	3840.54
crude oil	industry	2276.23
natural gas	industry	871.48
natural gas	electricity/heat producer	691.93
natural gas	households	341.93
coal	industry	580.73
coal	households	946.76
peat briquettes	households	804.38
coke	industry	2065.98
electricity	industry	3539.53
electricity	households	1918.61
heat	industry	1358.67
heat	households	1015.75

Table 10: Energy prices

Weighted averages of the prices reported in Table 10 are used to prepare the energy data in monetary units. For example, the price of refined petroleum is a weighted average of diesel, motor gasoline (A-95) and LPG. As information on import and export prices for energy commodities is hardly available, the values of imports and exports are not calculated by multiplying the energy volume with the respective price data, but are instead taken from the UN Comtrade database. However, there are two exceptions. The first concerns the data for crude oil and natural gas because these import and export values are not separately reported in this database. The second exception is the data for electricity as there is a zero entry in the UN Comtrade database but according to the IEA data some small amount of electricity is imported and exported. The missing data on imports and exports is taken from the website of the State Statistics Service of Ukraine.