Spatial-economic-ecological model for the assessment of sustainability policies of the Russian Federation

Project 213091

D8
Description of the links between the three dimensions of sustainability within the model

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Table of contents

Index of Figures

Index of Tables

1. The model framework

1.1 Sustainability and SUST-RUS

The main objective of the SUST-RUS project is to create and implement an integrated modeling framework for analysis of sustainability of the Russian economy on regional level. The standard definition of sustainability is: "Assuring that the needs of the present generation can be met without compromising the ability of future generations to meet their own needs." In general, however, this definition is too broad to be used as a basis for applied modeling and impact assessment.

Sustainability is a difficult and complex concept, as it should be analyzed at the level of an entire system, rather than its composing sub-systems, including the analysis of the trade-offs between different sustainability dimensions.

Therefore in many applications, researchers measure sustainability along the lines of economic, environmental and social functioning of a system. This is often defined as people, planet, prosperity (3P) or economy, environment and equality (3E) in practical applications. Our SUST-RUS model is characterized by the objectives of the EU definition of sustainable development. This development strategy defines sustainability according to 4 themes, rather than 3 themes[1]:

1. Environmental protection
2. Social equity and cohesion
3. Economic prosperity
4. Meeting international responsibilities

The final integrated model incorporates a set of flexible modules built around each EU sustainable development theme, that enable the user to isolate the effects of several policy alternatives and make consistent counter-factual scenario or (in broader terms) policy analysis.

The modeling framework used by the SUST-RUS model, is the general equilibrium methodology. General equilibrium, as a methodology, is a common denominator for a wide range of approaches in theoretical and applied economics, which explain the behavior of supply, demand and prices in a whole economy with many interacting markets. These markets evolve to a single overall equilibrium, with a price setting such that supply equals demand, hence 'general equilibrium'. When applied, general equilibrium models are often implemented in special software packages, such a GAMS or MATLAB, to allow solving the often complex systems of equations they consist of. This explains the term 'computable' general equilibrium or CGE.

The choice of the SUST-RUS project, to use the general equilibrium methodology, can be motivated from the objectives and concept of interrelatedness specific for the study of sustainability. General equilibrium methodology, as a holistic approach, is especially well suited for an integrated analysis of sustainability.

Citing Böhringer C., Löschel A (2006):
In general, there is no specific model, which fits all requirements for comprehensive sustainability impact analysis, but rather a package of models or methods depending on the policy measure or issue to be assessed and the availability of data.

[1] EU-SDS: EU sustainable development strategy (Source, year).

During the development of the model, we took this into account and made SUST-RUS into a flexible model, where the user has the choice to compare various assumptions related to the labor market, interregional or international trade balance and use of tax revenue. Also one is able to activate or deactivate parts of the model that are not of direct interest for some policy programs. Our goal was to allow the researcher a large variety of methods within the model to study sustainability of Russia or if necessary to introduce updates or variations upon the basic model code.

This deliverable is structured to allow the reader to gain insight in the existing links between the SUST-RUS modules. In the rest of this chapter we explain how the integrated modeling framework of SUST-RUS was built up and how one can use the model to evaluate progress to sustainability in Russia. We show how the sustainability indicators, discussed in Deliverable 4.1 are essential in understanding the interrelation between model elements.

In chapter 2 we give information on the type of model closures and modeling choices a researcher can make, when using SUST-RUS. Also we include a short practical manual to help researchers to introduce new scenarios and compare the results of one or multiple runs of the model with relative ease. Chapter 3 consists of a set of simple policy scenarios, using the system of indicators to analyze interrelatedness of policy objectives.

1.2 Developing the model

In the first year of the project the economic module of the SUST-RUS model was developed, building from a very simple model with three sectors and three regions, with only a limited representation of international and domestic trade, towards an increasingly complex model. In Table 1 the first steps in the development of the economic module are shown.

Table 1: Development of the economic module

Model version	Features	Database
SUST-RUS 0.1	3 regions 3 active sectors No international trade No interregional trade	Preliminary database (baseline equal to 2001) supplied by CEFIR
SUST-RUS 0.2	3 regions 3 active sectors International trade No interregional trade	Preliminary database (baseline equal to 2001) supplied by CEFIR
SUST-RUS 0.3	7 regions 21 sectors (OKVED classification) International trade Interregional trade in goods	Preliminary database (baseline equal to 2001) supplied by CEFIR
SUST-RUS 0.4	7 regions 32 sectors (NACE classification) International trade Interregional trade in goods	Economic database supplied by CEFIR and calibrated in cooperation with TML

By the middle of the second year, the economic module was finalized and ready for testing. In Table 2 we summarize how the model was further developed, adding the social, environmental and international trade modules step-by-step, while at the same time performing tests on the database of the model. The most recently available socio-economic, trade data and environmental data were used to produce the final

SUST-RUS dataset. The model is calibrated for 2006, which is the most recent year for which a full database could be constructed.

Table 2: Stepwise integration of other modules

Model version	Features	Database
SUST-RUS 0.5	7 regions 32 sectors (NACE) International trade to EU and ROW Interregional trade in goods and services	Economic database supplied by CEFIR and calibrated in cooperation with TML Improved interregional trade data supplied by CEFIR
SUST-RUS 0.6	Integration with social module -Labour market with different skill levels -Unemployment with wage curve -Social indicators (Gini/Poverty) -Different household types	SUST-RUS 0.5 with -Demand of skills/occupations at the level of economic sectors (ILO data) -Average wage by skill/occupation level (RLMS) -Labour / capital income by household type (RLMS) -Endowment of skills/occupation by household type (RLMS)
SUST-RUS 0.7	Integration with environmental module -Energy use -Emissions of main pollutants -Abatement cost curves -Emissions trading system, energy taxes	SUST-RUS 0.6 with - Preliminary database developed by ZEW
SUST-RUS 0.8	Integration with international module -FDI in recursive dynamic system -Extended Armington function -Export and import taxes -Trade balance and foreign reserve system -Trade margins on international trade	SUST-RUS 0.7 with -Database on international trade based on GTAP 7 and World trade database -Improved Exiopol database and recalibration of model
SUST-RUS 0.9	Fully integrated model with -Mayor update on energy database and emissions	SUST-RUS 0.8 with -Improved database on energy and emissions based on different sources including the IEA and ROSSTAT databases (Ter-11 database) for Russia -Improved data on abatement curves based IIASA GAINS-Europe model estimations
SUST-RUS 1.0	Fully integrated model with trade, environmental and social module -Health impact module (link between social and environment) -Monopolistic competition of domestic and foreign firms -Improved handling of multiple closures, simulations and sensitivity analysis	SUST-RUS 0.9 with additional -improvements and calibration in trade and energy module based on sensitivity analysis and debugging -data for health impact module -data for monopolistic competition module

1.3 Measuring sustainability

1.3.1 Sustainability indicators

In Deliverable 4.1, we discuss the indicator framework applied within the SUST-RUS model. We claim that the indicator framework is the key to understanding the interrelationships between the economic, environmental, social module and international trade module. For a full description of each indicator and its calculation we refer to p.28-34 of D4.1. Tables, summarizing the calculation of each indicator have been added to the Appendix of this deliverable on pages 22, 23 and 24. Our sustainability indicators are chosen to improve the knowledge of the modeler on the results of the model, evaluate policy scenarios which desire to improve sustainability of the economy and discover possible problems within scenarios or model results.

We arrange indicators by dimension of sustainability, but admit that the distinction is somehow arbitrary, as the main challenge of measuring sustainability is the interrelatedness between model dimensions and hence between indicators. In fact, the indicators specific for international and interregional trade (trade openness, current account, foreign investment and international trade in GDP) are often classified as a part of the economic dimension.

Many of our indicators are weighted by the level of real GDP in the economy, making them interrelated with economic developments and domestic production. The values of the sustainability indicators for the baseline of the model on national level are given in Table 3 below. Sustainability indicators are available on national level and for each region.

Table 3: Sustainability indicators – baseline values (2006)

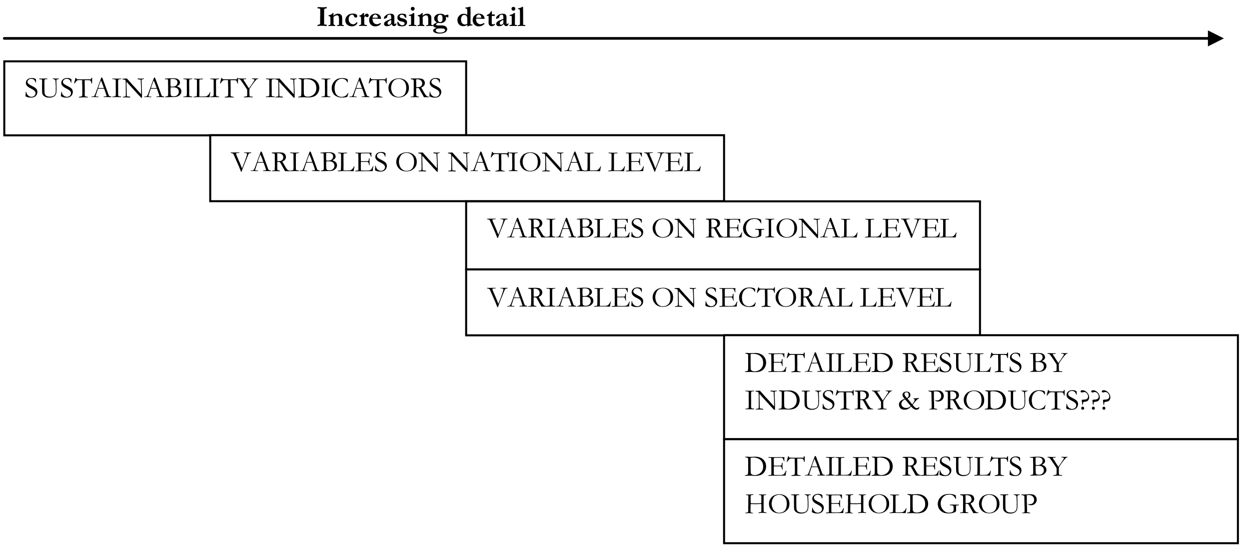
Sustainability Dimensions	Base Case
ECONOMY	
Real GDP per capita (billion rubles)	0.186
Herfindahl index	6.939
Investment (by GDP)	0.227
Price index (base price)	1.000
Public savings (by GDP)	0.148
Tax revenues (by GDP)	0.382
TRADE (ECONOMY)	
Interregional trade value (by GDP)	0.235
Current account (by GDP)	0.081
Foreign investment (by GDP)	0.017
International trade openness	0.491
ENVIRONMENT	
CO2 emission (Mtonnes/ GDP)	0.061
Electricity consumption (monetary value as ratio of GDP)	0.055
Fossil fuel consumption (monetary value as ratio of GDP)	0.082
NOX emissions (ktonnes/ GDP)	0.154
PM emissions (ktonnes/ GDP)	0.112
SOX emissions (ktonnes/GDP)	0.188
SOCIAL EQUITY	

Atkinson index (ε=3[2])	0.526
Consumption budget (by GDP)	0.502
Gini coefficient	0.394
Kakwani index	-0.004
Poverty intensity[3]	0.788
Unemployment rate	0.061
Unemployment Low skilled	0.162
Unemployment Medium skilled	0.052
Unemployment High skilled	0.031

1.3.2 Applying the indicator framework

For the analysis of SUST-RUS results we suggest applying a hierarchical approach, illustrated in Figure 1. The sustainability indicators are at the topmost level of analysis and have been constructed to take into account the overlapping elements of sustainability. Of course, it is often not enough to simply report the change in sustainability indicators. Therefore, the model reports the base case, simulated, relative change and change in absolute value of all variables used in the model on national, regional and sector level. The highest level of detail available is on the level of sector and region and by household group[4].

Figure 1: Analyzing SUST-RUS results



In this deliverable we mainly use the sustainability indicators for our analysis, as we wish to pay attention to the interplay within the different modules in the integrated model.

1.4 Interaction between model dimensions

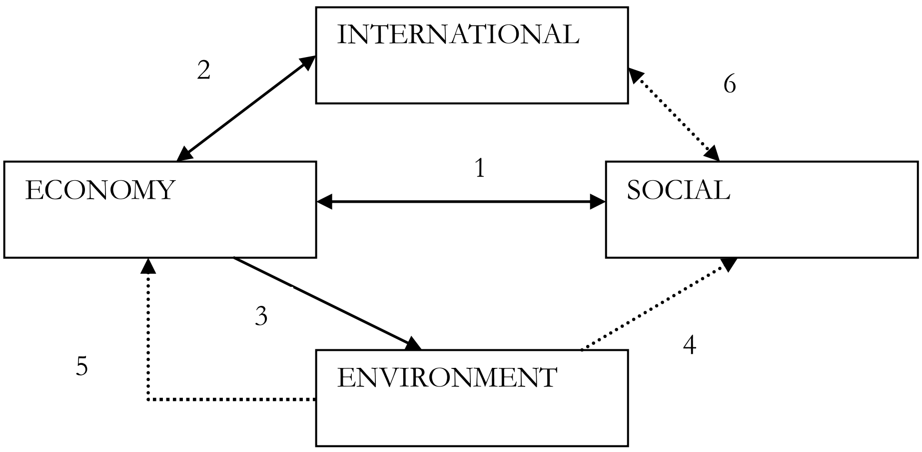
1.4.1 Representation of the interaction between modules

Figure 2 represents interlinks between the SUST-RUS modules in practical terms. We consider three main links (1, 2 and 3) and three optional links (4, 5, 6). Links 1 and 2 represent the functioning of the social,

[2] ε is equal to the inequality avoidance parameter, inherent to the Atkinson index. For more information see appendix page 24.
[3] Poverty intensity is defined as the ratio of the average income of low income households (QL) to the poverty line. The poverty line is equal to 60% of the average household income.
[4] Meaning low income (QL), middle income (QM) and high income (QH) households

international and economic modules. Link 3 is the connection between economy and environmental functioning. Link 4 represents the impact of environment to health. Link 5 is an optional link from environment to economy. This link can be either driven by policy or by adverse health impacts to labor in a region. SUST-RUS contains a simple cap-and-trade scheme for emissions, which has been implemented based on the GEM-E-3 and PACE model. The SUST-RUS model does model a (limited) effect on labor, due to environmental damage, within the health module. Environmental damages to economic capital were not integrated in the basic version of SUST-RUS. They could be integrated in a model-based study, for example by introducing exogenous shocks to capital or by calculating 'damage coefficients' of emissions on capital in certain regions.

Figure 2: Interaction and links between modules



Regarding the links between the economic, international and social module (1 & 2), the Russian economy demands labor force of different skill levels, taxes are collected based on household income and capital income is transferred to capital owners. Goods and services are traded with several countries and firms can invest domestically or in the foreign market. In the same way, households have different preferences for consumption goods on national and international level and supply their labor skills based on the perceived wage rate. A direct link between the international and social module is absent within the SUST-RUS model (6), it could be introduced when taking into account international migration.

The link between the economic and the environmental part (3) is modeled in accordance with the state-of-the-art approach. The economy demands energy carriers, which produce damaging emissions when consumed by industry or by households. The main polluters of the Russian economy are the energy and heat producers and the basic metals sector.

New policy measures, for example the introduction of energy taxes, cap on emissions, emissions trading or specific environmental taxation will have a direct effect on the economy (5). The link between environment, exposure to emissions and health (4) has been considered in the health impact module of the model and presented in Deliverable 5.1. For more details we refer to D5.1. The health impact module can be activated within the model code.

2. Model manual

2.1 Setting up the model for simulations

The integrated model was developed to handle a large variety of policy issues for sustainability impact analysis and can be set-up according to the best fitting assumptions. From the start of the model development it was decided to give the modeler a large freedom in adapting the model to his or her needs. Also the SUST-RUS model allows running the model several times, with different assumptions on closure, capital accumulation and government behavior.

This is shown in Table 4, which resumes the main closure options of the model. The modeler has to make a choice in each column to obtain a functioning model for a specific analysis. Each assumption has its advantages and disadvantages and should be chosen in accordance with theoretical considerations.

Table 4: Overview of model closures[5]

International closure	Government	Households/labor market	Investment/Capital market
Current Account balance	**Budget balance**	**Labour supply**	**Investment balance**
Flexible exchange rate	Flexible savings	Fixed labor supply in each region	Fixed investment demand
Flexible foreign savings	Flexible consumption	Fixed price of labor	Fixed capital
Exchange rate as numeraire	Flexible foreign debt	Unemployment according to wage curve	Simulation with capital accumulation
	Redistribution via transfers/lump-sum taxes		
	Tax incentives		

The basic set-up of the model as underlined in the Table 4 are the following:

- **International closure:** Flexible foreign savings
- **Government:** Flexible public savings
- **Households/Labor market:** Unemployment modeling via wage curve
- **Investment/Capital market:** Capital accumulation

Besides the choice in closures, the modeler can (de)activate a set of extra modules. This can be done, to avoid overloading the model with elements that are not specific for the type of simulation performed.

Some of the elements in Table 5 are activated by default in the SUST-RUS model. These are: the extended Armington functions (International module), the abatement curves for pollutants (Environmental module), trade and transport margins on interregional trade (Economic module), Impact of emissions on health and expenditures (Social module).

[5] Underlined items are referring to the default set-up of the model.

Table 5: Overview of extra modules

International module	Environmental module	Social module	Economic module
Extended Armington-function for imports and exports to EU & ROW countries	Emissions trading	Impact of emissions on health and expenditures on health services	Monopolistic competition module
Extension of monopolistic competition to foreign firms	Abatement curves for NOx and SOx	Migration between regions / International migration[6]	Trade and transport margins on interregional trade

2.2 Running the model

2.2.1 Introducing a new scenario

When doing a new simulation one should perform the following steps

1) **Obtain information:** on the type of simulation, the background and goal of the policy. In the case of fiscal policy/taxation one should try to get information on the height of the tax, compensating mechanisms and revenue recycling.
2) **Check the model:** Which parameters/variables does the policy affect? Is it necessary to introduce new features? Which type of model set-up is necessary for this type of analysis? Do we need to use the optional modules? Is a static model run enough or do we need a dynamic-recursive run? Is the data detail sufficient for the intended analysis?
3) **Implement the policy:** Create a new scenario file, which contains all the necessary parameter changes and calculations to be performed within the model run.
4) **Run the model:** …and if it doesn't work, check what is wrong (reiterate step2)
5) **Check the model results:** Use the scheme developed in paragraph 1.3.2. First check the sustainability indicators, then aggregated results on regional and national level. If of relevance check how individual sectors and households react to the policy change in each region. If the results are in line with theoretical considerations (expectations) , then go to step 6. Otherwise go back to step 2.
6) **Do sensitivity analysis:** Are the model results robust? What happens if we make changes to the model structure or if we change something to the exogenous parameters? Or make changes to the set-up of the policy? Repeat step 5 and in the worst case, go back to step 2.
7) **Report results:** consistent with the model results and the analysis performed.

3. Using the integrated model

3.1 Sustainability impact analysis with the integrated model: expected outcomes

In this chapter we use and verify the use of the SUST-RUS model for sustainability impact analysis, focusing on the interaction between the model subsystems. We use the framework of sustainability indicators to indicate the important interlinks between model elements.

[6] Preliminary model code to handle migration (both interregional and international) are introduced in the recursive framework, but have only been applied in a few test cases. Optimally, they would be based on econometric research.

Table 6 gives an overview of 3 policy simulations that can be performed with the model and what effects we can expect. We distinguish the impacts on the economic, international trade, environmental and social subsystems.

In paragraphs 3.2, 3.3 and 3.4, we show actual results from policy runs performed with the SUST-RUS model. Paragraph 3.5 concludes this chapter and evaluates the performance of the model to our expectations.

All simulations performed with SUST-RUS in this chapter[7] use the following set-up:

1) Fixed exchange rate and flexible foreign savings account;
2) A GDP deflator is used as the numeraire;
3) Government budget is balanced by decreasing or increasing public savings;
4) The model runs are performed in a static simulation;
5) No lump-sum distribution of new tax income to households, tax income is added to the government savings;
6) Both the monopolistic competition and health impact modules are activated.

Table 6: Expected effects of policy simulations in chapter 3

Simulation	Dimension	Effects
Taxation and redistribution	ECONOMY	Tax income increases Investment decreases Productivity decreases Price decreases
	ENVIRONMENT	Ambivalent for different indicators
	TRADE	Decrease in imports Decrease in current account
	SOCIAL	Income distribution changes Disposable income and consumption Household savings decrease Unemployment increases
Environmental taxation	ECONOMY	Tax income increases Production cost increases Labor? Capital? Productivity decreases Investments decrease Energy demand decreases
	ENVIRONMENT	Reduction in emissions Abatement
	TRADE	Increased export of energy carriers Decrease in imports Increase in current account
	SOCIAL[8]	Reduction in exposure to emissions Unemployment increases

[7] Unless differently stated within each paragraph

[8] Social effects depend on the set-up of the policy. When the tax revenues are (partially or fully) redistributed to households, social effects may vary according to the type of redistribution.

Investments in transport or trade infrastructure	ECONOMY	Investments increase Costs of service decreases Improved accessibility Agglomeration of activities Productivity increases
	ENVIRONMENT	Ambivalent for different indicators
	TRADE	Increase in interregional trade
	SOCIAL	Unemployment decreases

3.2 Social policy: increasing income taxes with 5% by household group

We show the interrelation between social and economic indicators by using the sustainability indicators of the SUST-RUS model. We perform 3 simulations: a regressive, a neutral and a progressive change in income taxes. In practice, we increase the income tax of the low (QL), medium (QM) or high (QH) income households with 5%. In Table 7 we show the results in relative change (%) vs. BaU (business as usual) for all social indicators. The increase in income tax is undifferentiated by region.

The social indicators were extensively discussed in Deliverable 4 of the SUST-RUS project. A review of the calculation and use of the social indicators as they figure in the model, is presented in Table 15 in the appendix on page 23.

Table 7: Change in social indicators for each household group

SOCIAL (% change vs. BaU)	QL	QM	QH
Atkinson	3.09	0.63	-4.02
Consumption budget	-0.33	-0.65	-1.51
Gini	0.00	-0.02	-0.06
Kakwani[9]	-110.91	-61.91	177.28
Poverty Intensity	-0.01	-0.02	-0.05
Unemployment	0.00	-0.01	-0.45
Unemployment Low skill	-0.01	-0.02	-0.27
Unemployment Medium skill	0.08	0.14	-0.05
Unemployment High skill	-0.33	-0.61	-2.61
Welfare	-0.21	-0.42	-0.95
Welfare Low income	-1.69	0.02	0.04
Welfare Medium income	0.01	-1.69	0.05
Welfare High income	0.01	0.03	-1.59

From the table 7 we can draw the following conclusions:

- The Atkinson indicator for inequality is more sensitive to changes in the lower part of the income[10] distribution than the Gini coefficient. The Gini coefficient recognizes the neutral tax change as inequality reducing, while the Atkinson index still reports a rise in low-income inequality.

[9] The Kakwani index in the basecase is slightly negative (regressive taxation). To avoid interpretation errors, we switch the signs of the relative changes in this indicator. The interpretation of the indicator remains, the more positive the indicator, the more progressive the tax system.
[10] This is caused by the high level of inequality avoidance (e=3) chosen to calculate the Atkinson index.

- The Kakwani index as measure for progressivity of the tax system indicates the effect of the increased income taxes. The tax changes in the low and medium income households are recognized as regressive while the changes in the high income households are progressive.
- The change in welfare of each household group relative to their income is more or less equal. In absolute terms, the total welfare loss of the medium and high income households is more pronounced.
- Negative side effects on the labour market are only to be seen for the medium income households. As the income tax is imposed on total income (capital and labour income), it does not have an important secondary effect on work incentives. It is not a tax on labour, but on total income. For a tax on high income households with large capital incomes, participation to the labour market even increases, as labor is taxed relatively less.

Table 8: Change in economic and trade indicators in case of increase in income tax

ECONOMY (% change vs. BaU)	**QL**	**QM**	**QH**
GDPcapitaReal	-0.04	-0.08	-0.17
Herfindahl	-0.01	-0.01	-0.04
Investment	-0.10	-0.16	-0.29
Public Savings	0.04	0.08	0.17
Tax Revenues	0.40	0.79	1.85
TRADE (% change)	**QL**	**QM**	**QH**
Foreign Invest	0.04	0.08	0.17
Current Account	0.37	1.02	1.22
Trade Integration???	-0.06	-0.10	-0.18
Trade Openness	-0.02	-0.08	-0.02

This leads to the following results:

- The increase in income taxes leads to lower investments in the domestic economy especially when taxing high income households. The importance of foreign investments in the economy grows, due to lower domestic investment and a decrease in GDP.
- The reduction in income leads to lower demand for goods and services. This leads to lower prices on the domestic market and a decrease in import demand
- The increase in tax revenues is the largest in absolute value when increasing the tax on high income households, as is the decrease in economic production in absolute terms
- The current account surplus increases, due to lower demand for import products, in particular when taxing medium and high income households.

We can summarize our findings by calculating the ratio of the change in GDP and welfare to the change in collected tax revenue (in absolute values). This dimensionless ratio is sometimes referred to in literature as the 'marginal cost of public funds' (MCF) (Dahlby, 2008) or as an example of a 'conversion factor' (DG Regio, 2008)[11]. It can be interpreted in the following way:

On average, 1 extra ruble of tax revenue collected by a change in the income tax for this particular household, will lead to a corresponding change in GDP (or welfare) equal to this factor. If our MCF on welfare is equal to -1.10, this means that collecting 1 ruble of revenue by the corresponding policy leads to a decrease in consumer welfare of 1.10 rubles.

[11] See 'Guide to cost-benefit analysis for investment projects', DG Regio (2008), by TRT

The interpretation of the MCF on GDP is slightly different, as taxes on value added and final consumption are an integral part of the GDP indicator[12].

This means that:

$$MCF_{GDP} = \frac{\Delta GDP}{\Delta Tax} = \frac{\Delta GDP_{nonTax} + \Delta Tax}{\Delta Tax} = 1 + \frac{\Delta GDP_{nonTax}}{\Delta Tax}$$

This means that MCF_{GDP} can be interpreted as efficiency losses due to taxation[13]. The difference between social welfare and GDP arises as social welfare is based on consumption of households and improvements in health conditions, while GDP is based on total value added income and income for the public sector. Measuring social welfare through equivalent variation does not take into account changes in public savings, unless lump-sum distribution is active.

Table 9: Change (in billion rubles) in GDP, Welfare and Tax revenues (vs. BaU)

	GDP	Welfare	Tax Revenues	MCF_GDP	MCF_Welfare
QL	-11.33	-39.89	35.82	-0.316	-1.114
QM	-21.81	-79.02	71.59	-0.305	-1.104
QH	-44.13	-179.18	169.36	-0.261	-1.058

Although it is not at the core of our attention, we wish to point to the fact that all indicators are also available on the regional level. The SUST-RUS is able to disaggregate the effects and show interregional disparities, if this is in the interest of the model user. To economize the space, we have chosen not to report the regional effects.

[12] GDP is calculated as Income Capital + Income Labour + Consumption taxes + Export taxes + Capital tax + Income tax or alternatively as Production – Intermediate use + Consumption taxes + Export taxes

[13] Meaning that when MCF_GDP = -0.3, for each ruble raised the non-tax part of GDP decreases with 1.3 rubles.

3.3 Environmental policy: tax on carbon dioxide emissions

The results below are based on a simulation introducing an emission taxes on carbon dioxide (CO_2) of 1 euro (or 38 rubles) per ton. We focus on the linkage between environmental, social and economic policy goals and use the sustainability indicators to indicate how the environmental module fits within the model framework. The results (in relative changes) for all sustainability indicators are introduced in Table 10.

Table 10: Relative change in sustainability indicators, emission tax of 1 euro / ton (38 rubles /ton)

ENVIRONMENT	% (vs. BaU)
CO2 emissions	-4.56
Electricity consumption	-0.65
Fossil fuels consumption	-0.89
NOx emissions	-6.14
PM emissions	-4.46
SOx emissions	-3.66

ECONOMY	% (vs. BaU
GDP Capita Real	-0.23
Herfindahl	0.00
Investments	0.71
Public Savings	1.05
Tax Revenues	0.58
TRADE	**%**
Current Account	0.40
Foreign Investments	0.23
Trade Integration	-0.09
Trade Open	0.13

SOCIAL	% (vs. BaU
Atkinson	-0.07
Gini	0.00
Kakwani	0.46
Poverty Intensity	-0.02
Consumption Budget	-0.04
Unemployment	0.63
Unemployment LS	0.26
Unemployment MS	0.78
Unemployment HS	1.04
Welfare	-0.17
Welfare QL	-0.19
Welfare QM	-0.18
Welfare QH	-0.17

Our main conclusions from Table 10 are:

- **Environment:** The emissions tax is effective in reducing carbon dioxide emissions (-4.56 %) in terms of GDP. Additionally it reduces the use of fossil fuels and electricity, also leading to important reductions in NOx, PM and SOx emissions. From this we can conclude that the emissions tax leads to adjustments in energy demand and energy efficiency.
- **Economy:** The extra cost to industry is translated in lower real GDP (-0.23%). The collected tax increases public budget and hence domestic investment (+0.71%).
- **Trade:** The demand for energy in the domestic economy decreases and more primary energy goods (coal, oil, gas) are exported. Demand for imports decreases due to decreases in consumer budget. This leads to an increase in the current account surplus.
- **Social:** In welfare terms, low skilled households lose relatively more compared to their income; however this does not seem to have large side effects on inequality (Atkinson index -0.07%, Gini marginally positive). The emissions tax, according to the Kakwani index, is even slightly progressive. Unemployment increases relatively more for the high skilled than the low skilled, however, in absolute terms the increase in unemployment for low skilled is more important.

One question we can still ask ourselves is: "What happens when the government would use a lump-sum type of redistribution of tax revenues from the emissions tax?" and in particular "What is the effect on sustainability?"

We redo the simulation with exactly the same parameters as before, this time however we will allow the government to redistribute all the income from the emissions tax to the consumers. The government redistributes the revenue according to the same shares as the government transfers to consumers in the base case of the model. This means that emission tax revenue is redistributed progressively from low to high income households. In Table 11, we calculate the shadow price of the emission reduction, with and without the lump sum distribution.

Table 11: Shadow price of CO2 reduction (without and with lump sum distribution)

	Welfare	GDP	Tax revenues	CO2	Shadow price CO2 (rubles/ ton)	
	(billion rubles)	(billion rubles)	(billion rubles)	(Mega ton)	Welfare	GDP
No redistribution	-32.76	-60.68	34.85	-76.48	**428.37**	**793.35**
With lump sum redistribution	-1.08	-63.97	-3.62	-76.20	**14.17**	**839.48**

The results from Table 11 show the following important effects from the implemented redistribution mechanism.

1. Total tax revenues of the public authority end up negative when lump sum distribution is implemented. The reason for this is that the full revenues from the emissions tax are redistributed, but the losses in tax revenues from other sources (tax on capital, labour, taxes on intermediary goods, etc.) are not. This leads to a net loss for the government.
2. There is still a small overall reduction of welfare for consumers. This is mainly caused by income losses of high income households.
3. The reduction in GDP is higher, which is caused by efficiency losses due to the redistribution mechanism.
4. There is almost no difference in the CO^2 reduction potential of the emissions tax. This is because it is mainly a tax on industries and not on consumers.

We have to remark here, that we have not considered so called 'double dividend' mechanisms. With this we mean replacing distortionary taxes (labour tax, income tax) with taxes on emissions. In theory, this could lead to a lower shadow cost of welfare and a smaller effect on domestic production.

To conclude this paragraph we compare the social effects with and without the redistribution mechanism. We focus on these indicators because these are the most relevant for the type of simulation.

Table 12: Relative change in social indicators (with / without lump sum transfers)

SOCIAL (%)(vs. BaU)	**No lumpsum**	**Lumpsum**
Atkinson	-0.09	-0.16
Consumptionbudget	-0.04	0.25
Gini	0.00	-0.13
Kakwani	-0.58	-0.75
PovertyIntensity	-0.02	0.16
Unemployment	0.50	0.94
Unemployment Low skilled	0.18	0.41
Unemployment Medium skilled	0.63	1.16
Unemployment High skilled	0.79	1.44
Welfare	-0.17	-0.01
WelfareQL	-0.19	0.11
WelfareQM	-0.18	0.05
WelfareQH	-0.17	-0.05

The main conclusions we can draw from Table 12 are

1. The redistribution of tax revenues has positive effects on equality. It has a tendency to take income from high income earners to lower income households. Atkinson and Gini indices are reporting small decreases in inequality. The relative change in welfare for low and middle income households is actually positive. Only the high income households experience some decrease in welfare in this simulation.
2. Unemployment of all skill levels is higher than in the no-redistribution case, this reflects a rise in the voluntary unemployment of households due to the redistribution mechanism.

3.4 Trade policy: decreasing bi-regional transport costs of gas & oil

In this simulation we assume that we are able to improve the trade infrastructure between regions, decreasing trade costs between regions. We assume that the interregional transport costs of gas and oil transport between the Central region and the Urals region decrease with 10%. There are several possibilities how such an improvement could be induced. One example could be improved maintenance of gas and oil pipelines, another would be a reduction in charges.

Below, we present the relative change in sustainability indicators within the Central and Urals region and for the Russian Federation as a whole.

Table 13: Relative change in sustainability indices (vs. BaU): Central, Urals region and Russian Federation

ECONOMY	Central	Urals	Russia
GDPcapita Real	-0.19	0.04	-0.081
Herfindahl	0.06	0.09	0.028
Invest	0.16	-0.21	-0.069
Tax Revenues	0.07	0.09	0.001
TRADE	**Central**	**Urals**	**Russia**
Current account	-0.89	-0.27	0.113
Foreign Investments	0.19	-0.04	0.081
Trade Integration	0.41	0.48	-0.118
Trade Open	0.18	-0.18	0.041

ENVIRONMENT	Central	Urals	Russia
CO2 emissions	1.13	-0.27	0.223
Electricity consumption	0.30	-0.01	0.136
Fossil fuels consumption	0.49	-0.03	0.123
NOx emissions	1.52	-0.37	0.113
PM emissions	0.35	0.07	0.111
SOx emissions	0.34	0.03	0.099

SOCIAL	Central	Urals	Russia
Atkinson	0.01	0.26	0.083
Gini	0.00	-0.02	0.013
Poverty Intensity	0.00	0.01	0.002
Unemployment	0.04	-0.41	0.057
Unemployment LS	0.00	-0.18	0.013
Unemployment MS	0.07	-0.42	0.105
Unemployment HS	-0.01	-0.89	-0.025
Welfare	0.00	0.14	0.020
WelfareQL	-0.01	0.14	0.020
WelfareQM	-0.01	0.15	0.014
WelfareQH	0.00	0.14	0.022

From our sustainability indicators we can draw the following conclusions:

- **Economy**: The benefits induced by the reduction in transport costs are local and are mainly induced through redistribution from the national level. The economic benefit is for the producing region (Urals). There is no real benefit for the receiving Central region or on national level. GDP in Central region decreases to a quite large degree, the reason for this is a reduction in oil exports and a reduction in demand for trade and transport.
- **International:** There is a switch from international trade in resources to interregional trade in resources for the Urals region. However, the opposite takes place for the other regions, which become less competitive in interregional oil and gas exports. On national level this leads to an increase in current account surplus and slightly higher trade openness.
- **Environmental:** The Central region receives its fossil fuels at lower price, due to the reduced trade and transport cost. This leads to lower energy efficiency and higher emissions of carbon dioxide and other pollutants. The effect on the Central region dominates the reduction in emissions in other regions.
- **Social:** Overall slight increases in inequality. Unemployment within the Urals region decreases, but increases in the other regions. Small benefits for the highest income group, relative to the poor and medium income group.

3.5 Conclusion

In this chapter we loop on three general types of policy scenarios and use our sustainability indicators explicitly to perform an integrated analysis on the results. This illustrates the interrelatedness of the SUST-RUS sub-modules. These relatively simple policy simulations show why the SUST-RUS model is such a powerful tool for the analysis of the interdependent goals of sustainability.

Our first simulation is a social policy, namely an increase in income tax. While relatively straightforward, this simulation displays the sensitivity of SUST-RUS to the 'progressiveness' of the implemented tax mechanism. The link is made between the social and the macro-economic effects of income taxation. Also we show one can use the model to calculate an applied equivalent of the theoretical concept of 'marginal cost of public funds'.

Secondly, we move to environmental policy, more particularly the illustrative example of introducing a carbon dioxide emissions tax. We show that even at a low tax (1 euro or 38 rubles / ton) a significant reduction in emissions of not only carbon related, but also nitrate, sulfur and particulate matter can be triggered. Also it is a source of additional revenues for the public sector. However, at the same time the tax is reducing the growth in gross domestic product, mainly by increasing prices of electricity and manufacturing goods and reducing exports, albeit at a rather moderate rates

Thirdly, we show how the model can be used to evaluate the trade policy and infrastructure improvements. We show how a simple improvement in the infrastructure for interregional trade of gas and oil can be evaluated against social welfare and productivity on regional level. While small, the model identifies secondary effects of the improved trade link on the other regions, on socio-economic wellbeing, environment and international trade.

4. References

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Appendix

A. Running the model under different set-ups

To make comparing model results with different model set-ups easier, we have adapted a very useful tool developed by Thomas Rutherford[14] for systemic sensitivity analysis. This tool consists mainly of 2 separate gams files, i.e. qs.gms and qr.gms, which should be put in the same folders as the main model. The GAMS code in qs.gms generates and calls a set of alternate model simulations. The GAMS code in qr.gms writes the model results to a pivot report. The model can be initialized from a Windows .bat file.

Below, we give an example of a model simulation, invoking a scenario with different parameters

gams qs --p1="emis /'CO2', 'NOx', 'SOX'/" –p2="price /38, 50, 70/" --model=SUST-RUS-model --scenario=EMISTAX --calib=TRM --outdir=output

The .bat file starts by invoking the qs.gms file with different parameters. In this case we run the "Emissions Tax" scenario for CO2, NOx and SOx with a price of 38, 50 and 70 rubles per ton. The version of the model used is SUST-RUS-model.gms and the calibrated model includes transport margins.

The parameters used in the .bat file refer to environmental variables which are used in the specific scenario file or in the model code itself. A wide range of environmental variables can be introduced, which enables the modeler to make changes to parameters, scenario set-up or even model structure.

Some examples of environmental variables used in the model:

Changing exogenous parameters: $if not set sigmaA	$set sigmaA	15
Activating lump sum distribution: $if not set lumpsum	$set lumpsum	0
Putting a price on a tax or permit: $if not set price	$set price	1
Selecting emissions from a set : $if not set emis	$set emis	NOx

After running the model, the .bat file calls the qr.gams file, which writes model results to an excel file in a "pivot table friendly" format.

The code used is the following:
gams qr --item=report_sustain_main --domain="dim,sustain_main,indics,t" o=output\Sustain_main.lst

The item referred to in the .bat file should be an existing parameter or variable in the model. The domain should be in terms of clearly defined sets, which correspond to the real dimensions of the item. The code displayed above, invokes the report of the sustainability indicators for each model simulation.

We highly advise to use pivot-tables as a means to display and analyze the results of the SUST-RUS model. This offers the highest level of flexibility and insight and gives the researcher an additional advantage to aggregate results on different levels of detail, allowing for in-depth analysis.

[14] http://www.mpsge.org/qtool/

B. Sustainability indicators

The following tables contain the full overview of the sustainability indicators that figure in the SUST-RUS model, as they were presented in deliverable D4.

Table 14: Economic indicators

Theme	Indicator	Level	Unit	Formula
Economic production	GDP per capita	National Regional Industry/Services	Monetary	GDP / POP_r
Trade balance	Current account deficit/surplus	National	Monetary	$E - M = T$ E = export M = import
Trade openness	(Export + Import) / GDP	National Regional	Unitless	$\frac{(E+M)}{GDP}$
Public budget	Public deficit/surplus by GDP	National	Percentage	$\frac{PB}{GDP}$ PB = public budget deficit/surplus
Investments	Investment share in GDP (FDI)	National Regional	Monetary	$\frac{I_{foreign}}{GDP}$
Price level	Change in relative price compared to baseline	National average Regional average Goods (by type)	Percentage	$\frac{P \cdot (1 + tc - sc)}{P^0 \cdot (1 + tc^0 - sc^0)}$ P = price tc = tax sc = subsidies
Government income	Tax revenues	National Regional	Monetary	TAXR (endogenous model equation)
Agglomeration and concentration	Herfindahl index for concentration Location coefficient	National Regional	Unitless	$HH_r = \sum_r (s_{i,r})^2$ $HH_i = \sum_i (s_{i,r})^2$ $s_{i,r}$ = share of production of sector i, in region r HH_i = concentration of firms HH_r = concentration of regional production
Integration within country economy	(Interregional export and import) / local production	By good Regional	Unitless	$\frac{\sum_i \left(\sum_{rr} XDDE_{i,r,rr} + \sum_{rr} XDDE_{i,rr,r} \right)}{\sum_i XD_{i,r}}$ [15]

[15] This is the aggregate index of economic integration (goods summed up), the index can (and will) also be calculated by good, in the case this is relevant.

				$XDDE_{i,r,rr}$ = interregional trade from region of origin r, to region of destination rr $XD_{i,r}$ = production of good i in region r

Table 15: Social indicators

Theme	Indicator	Level	Unit	Formula
Poverty	Amount of people defined as 'poor'	National Regional	Percentage of population	$\frac{n_{poor}}{\sum_r POP_r} = \frac{\sum_n 1 \mid Y_n \leq PovLine}{\sum_r POP_r}$
Poverty	Mean income of 'poor' household compared to poverty line (Intensity)	National Regional	Value between 0 and 1	$Y_{poor} / PovLine$ $Y_{poor} = IncomePoor$ $PovLine = PovertyLine$
Inequality in income distribution	Gini index	National Regional	Value between	$G = \frac{1}{2\mu} \cdot \sum_i s_i \sum_j s_j \lvert Y_i - Y_j \rvert$ $\mu = MeanIncome$ $Y = Income$ $s_i = SharePopulation$
Inequality in income distribution	Atkinson index (ε as inequality aversion parameter)	National Regional	Value between 0 and 1	$A(\varepsilon) = 1 - \left[\sum_i s_i \left(\frac{EV_i}{\mu EV} \right)^{1-\varepsilon} \right]^{1/1-\varepsilon}$ $s_i = IncomeShare$ $EV = EquivalentVariation$ μEV = Mean Equivalent Variation
Progressivity of tax system	Kakwani index (difference between concentration of tax payments and Gini index)	National Regional By good/service	Unitless	$\pi_k = C - G$ $C = \frac{1}{2\eta} \cdot \sum_i s_i \sum_j s_j \lvert TAX_i - TAX_j \rvert$ $\eta = MeanIncome$ $TAX = TaxPaid$ $s_i = SharePopulation$ $C = ConcentrationCurve$
Income	Change in household disposable income	National Regional	Monetary value Change	$\left(\frac{CBUD}{CBUD^0} - 1 \right) \cdot 100$ $CBUD$ = *Consumption Budget*
Unemployment	Unemployment rate	National Regional	Percentage	$\left(\frac{UNRATE}{UNRATE^0} - 1 \right) \cdot 100$ $UNRATE$ = *Unemployment Rate*

Welfare	Utility based index : equivalent variation (EV)	National Regional	Monetary value Percentage of income	$\left(\frac{U_{new}-U_{old}}{PEV_{old}}\right)\cdot\frac{1}{ScalU}=EV$ PEV = pricing index for utility ScalU = appropriate scaling index U = utility in new and old situation
Welfare	Social welfare (Bergson-Samuelson welfare function)	National	Monetary value	$SWF=\sum_r EV_r$ or (with inequality correction, cfr. Atkinson index) $SWF=\sum_r \frac{(EV_r)^{1-\varepsilon}}{1-\varepsilon}$ [16] ε = coefficient of inequality aversion

Table 16: Environmental indicators

Theme	Indicator(s)	Level	Unit	Formula
Climate change	GHG emissions by unit of GDP or by energy consumption	National Regional Industry	Tonnes	$\frac{\sum_{i,r} GHG_{i,r}}{GDP}$
Energy consumption	Gross inland energy consumption by fuel	National Regional Fuel type	Tonnes or value By GDP	$\frac{\sum_{i,r} OIL_{i,r}}{GDP}$ [17]
Energy	Electricity consumption by households	National Regional	KwH	$\frac{\sum_{i,r} ELEC_{i,r}}{\sum_r POP_r}$ POP_r = population
Energy	Final energy consumption	National Regional Sector	Tonnes By GDP	$\frac{\sum_{i,r} ENER_{i,r}}{\sum_r GDPR_r}$
Air pollution	Emission (damages) of several pollutants, including SOx, NOx, PM, etc.	National Regional Industry	Tonnes of pollutants	$\sum_{i,r} EMISSION_{type,i,r}$

[16] Note that if ε =0, the inequality corrected welfare function reduces to a sum of monetized utilities

[17] Can be oil, gas or coal or other energy input… Division by GDP is optional, but will help scaling with other indicators