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

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Assessment of the model reliability and sensitivity analysis

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1. Sensitivity analysis

1.1 Introduction

This deliverable is dedicated to the analysis of sensitivity (SA) and uncertainty (UA) of the SUST-RUS model. The SUST-RUS model is a spatial computable general equilibrium model for the Russian Federation on the level of 7 Federal regions.

According to Saltelli et al. (2000) sensitivity analysis is the study about the relations between the input and the output of a model. In this deliverable, we take a broad view on what input actually is. We extend the item 'input' to uncertainties on model parameters and model structure.

Uncertainty and *sensitivity* analyses are two sides of the same coin. In uncertainty analysis we analyze the reliability of the results and conclusions of a certain model, assessment procedure or a similar quantitative framework in the presence of changes in its parameters. It basically states: "Are your results still reliable, taking into account that you have uncertainty on the parameters of your model?" Sensitivity analysis is a bit more refined. Given that we know that our model parameters contain uncertainties, we want to determine what the important parameters are. Mainly: what is really driving our model results, given that we feed it the same input?

While it is often claimed that sensitivity and uncertainty analysis are critical to interpret results and verify reliability of complex models, it is quite remarkable to see that it is often low on the priority list of modelers. The reason for this may be that sensitivity analysis can be cumbersome and requires (when performed adequately) a large set of simulations. Also it can be claimed that sensitivity analysis can be confronting and may lead to additional criticism on the performed modeling efforts.

Sensitivity analysis may be performed in a number of ways.

- **Local methods**: Deviations from the point estimates of a parameter set, often perturbing only one parameter at a time. Results are compared to the baseline simulation.
- **Elementary effects method (Morris sensitivity):** The set of parameters is randomly perturbed within a range of variation and a given distribution[1]. For a given set of parameter values p and a given set of simulations r, one parameter is changed at a time. The local effect of each simulation is calculated. The total sensitivity is calculated as the sum of the square of the average of the local effects and the square of the standard deviation in local effects. Often used in combination with variance methods.
- **Regression methods**: ex-post analysis of model results, using standard econometric techniques such as OLS (ordinary least squares) on the model results, given the parameter inputs. Requires a large amount of model simulations to be reliable
- **Variance methods**: focused on finding the source of variance in the model results (ANOVA analysis: analysis of variance method). Variance can be decomposed to find the elementary effect (the effect of the parameter change) and the interaction effects (effect of parameter on other parameters). Several algorithms are available for experiment design and variance calculation, of which the Sobol (1967) and Fourier Amplitude Sensitivity Test or FAST (Cukier et al. 1973, Saltelli and Bolado 1997, Saltelli et al. 1997) methods are the most famous ones.

[1] Commonly a uniform or a normal distribution with a preset range of variation

In general, local methods dominate the field of sensitivity analysis for general equilibrium modeling. Researchers prefer to apply random shocks to a limited set of parameters which may or may not affect the results of the model. This often involves a limited set of runs and parameters. In general the interaction effect of different parameters is not included or only to a marginal degree. Local methods are cheap in terms of requirement, but lack in reliability and completeness.

In her Ph. D thesis Mohora M. C. (2006) describes the methodology for global sensitivity analysis of CGE models. This type of analysis is relatively uncommon for CGE models, but has been proved to be important and justified, given the large uncertainties involving CGE model construction and estimation. In a first step, a Morris screening sensitivity test (Morris, 1991) is performed and is used to select the most influent parameters. In a second step, a Sobol analysis is used for uncertainty and sensitivity analysis.

More recently, Hermeling and Mennel (2008) provided a systematic approach to conduct a sensitivity analysis within a CGE frame. The paper formalized deterministic and stochastic methods used for sensitivity analysis. It presented the numerical algorithms to apply the methods, in particular, an improved version of a Gauss-Quadrature algorithm, applicable to one as well as multidimensional sensitivity analysis. The advantages and disadvantages of different methods and algorithms were discussed as well as their applicability. Alexeeva-Talebi et al. (2012) revolved their sensitivity analysis for the global model PACE around three types of unobserved heterogeneity at the sub-sectoral level: trade elasticities, energy consumption and technology specifications. Drawing on the example of border tax adjustments, they found that for all given technology specifications and variation in energy shares, the biggest differences emerge if we vary the Armington elasticities. Even a moderate variation in Armington elasticities can change the magnitude and the sign of the effects at the sectoral level.

The sensitivity analysis performed in the framework of the SUST-RUS project combines a local method and the Morris method of global sensitivity analysis. Experiments with the Sobol method were performed, but due to the large amount of simulations necessary for an adequate analysis, it was decided to use the results of the Morris sensitivity analysis. The choice of methodology is motivated, based on the possibility of its practical implementation in the SUST-RUS model.

1.2 Methodology

It is difficult to perform a sensitivity analysis on a complex model like SUST-RUS. This complexity is due to the huge amount of inputs and outputs that are used and generated by the model. This section will therefore deal with this problem and discuss ways to reduce this complexity to a more manageable level.

Our model can be thought as a process using vector of inputs *M* and generating a vector of outputs *N*. In what follows, the symbol δ_i, $i = 1,2,\ldots,m$, represents inputs of data into the model. With the term data, we understand a very complex set of inputs, which entail the social accounting matrix, trade database, labor market database and inputs necessary for policy simulations. Part of the inputs (we denote them as x_j, $j = 1,2,\ldots,n$, represent a subset of model parameters, such as the elasticities used in the production sector, the elasticity of the labor market, the Stone-Geary 'minimum consumption' and even elements of the general structure of the model[2].

[2]An example of this could be a model closure (fixed of flexible exchange rate).

The outputs are the values of variables that are calculated during the work of our model. In this section, we consider relative and absolute changes in each variable of the model, as well as indicators calculated from the initial database (D4.1).

It is impossible to apply uncertainty analysis on each variable of such a complex model. Therefore we choose to work on a subset of the model, which we assume to be representative for the whole SUST-RUS model. First we define the function f , which is a map from inputs to outputs of our model, keeping ceteris paribus conditions for all inputs, except from the set of exogenous parameters. This means that we will run our SUST-RUS model with exactly the same 'data', but with changes to the exogenous parameters. We consider function f as having only limited set of outputs y , which are taken or calculated from the whole set off outputs N . Namely, as outputs y we consider only several specific indicators, which can be used as 'proxy' for the behavior of the entire system. In the subsequent sections, we will apply only 2 such outputs: Social welfare and GDP. Specifying the model in such a way, we can study the effect of changing one or several parameters on the chosen indicator(s), given the data and the background of the simulation. So we write

$$y = f(x_1, \ldots, x_n)$$

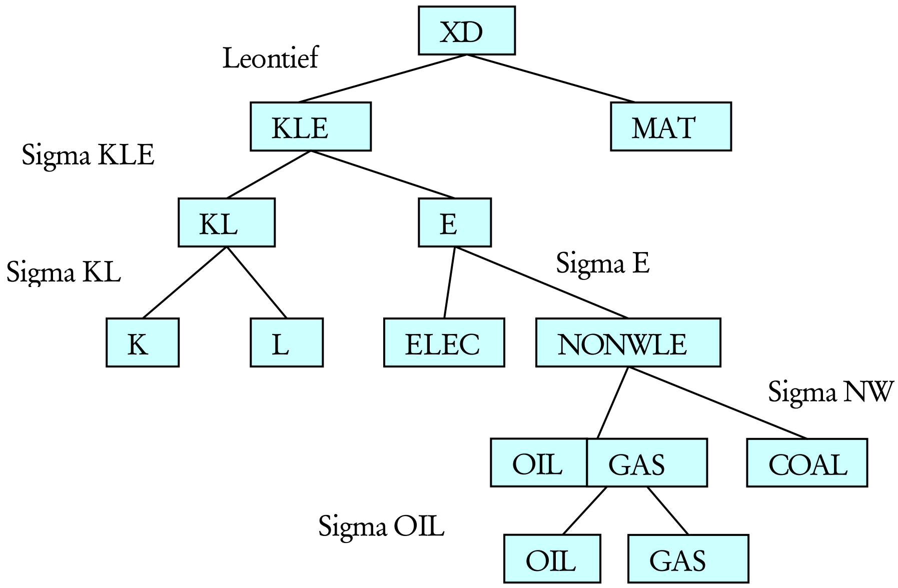
ignoring all other inputs δ_i and outputs $N \setminus \{y\}$.

We have chosen the parameters below as subjects for our sensitivity analysis. These parameters are the elasticity of the inputs to the economic sectors and the elasticity of the international and interregional trade. These are the main parameters of the model.

Table 1: List of parameters with description

Parameter name	Description
Sigma KLE	Elasticity of substitution between capital-labour and energy bundle
Sigma KL	Elasticity of substitution between capital and labour
Sigma E	Elasticity of substitution between electricity and fuels
Sigma NE	Elasticity of substitution between gas/oil bundle and coal
Sigma OIL	Elasticity of substitution between gas and oil inputs
Sigma A	Armington elasticity of demand
Sigma T	CET elasticity of export demand
Sigma A1	Interregional trade elasticity (Armington)

Figure 1: Technological nesting in the production process



The values of these parameters, as well as the disaggregation of the production technology, were based on the multi-country CGE model of PACE (see Deliverable D3.1). Point estimates were available on the level of the production sectors, however in SUST-RUS they are dimensioned along sectors and regions. As we did not have any additional information to determine these parameters on regional level, we had to assume that the elasticity of substitution was equal among regions. The total amount of parameters under study is equal to the amount of parameters, multiplied with the number of sectors and regions. In total this comes down to 1792 parameters. This is a very high number of parameters, which creates a barrier to fully assess the sensitivity of the model. To circumvent making an unreasonable number of simulations, while at the same time, avoiding an incomplete analysis, we choose to combine 2 approaches

1. Local method with small variations from point estimates on the level of sectors and regions
2. More detailed Morris screening method on the level of sectors

We choose a dual approach, as local methods alone cannot capture correlation between parameters and are largely insufficient to handle uncertainty analysis. The Morris method was applied for processing joint uncertainty and sensitivity analysis, but due to the higher amount of simulations necessary to perform this analysis, we have chosen to only apply the variation on the level of the sectors.

Type of sensitivity analysis	Set-up	Simulations	Dimension	(Dis)advantages
Local method	Each elasticity receives 2 shocks from its initial point (-0.03 and + 0.03)	3584	Sector and region	+ limited amount of simulations + based on initial sample + easy to implement + regional differences - only ceteris paribus effects

Morris sensitivity analysis	The model is initiated with a randomized set, after which one parameter receives a shock of 0.01 from its initial value. This is performed 9 times per parameter.	4608	Sector[3]	+ interrelation between parameters - larger amount of simulations necessary - regional differences could not be included

The local sensitivity analysis is performed on the basis of the point estimate of each parameter. Each parameter receives a 'backward' and 'forward' shock equal to 0.03 from its initial value. The elementary effect of the parameter is calculated as

$$\varepsilon = [f(x_1 x_2,..,x_i,..x_n) - f(x_1 x_2,..,x_i + \Delta,..x_n)]/\Delta$$

With Δ equal to the shock introduced and x_i equal to the parameter under study. All parameters x_i, except from the parameters under study, remain equal to the point estimate based on the PACE model. This method therefore leads to the calculation of 2 elementary effects per parameter: a forward and backward effect. We define ε_- as the backward effect and ε_+ as the forward effect.

We define the average of both effects as

$$\mu = (\varepsilon_- + \varepsilon_+)/2$$

and standard deviation as

$$\sigma = \sqrt{(\varepsilon_- - \mu)^2 + (\varepsilon_+ - \mu)^2}$$

The total variability for each partner is defined as $S_i = {\mu_i}^2 + {\sigma_i}^2$. Given a set of parameters, we can calculate the share of variability in the total set as $R_i = \frac{S_i}{\Sigma S_i}$.

A Morris sensitivity analysis has one important difference. In the case of the Morris global sensitivity analysis, we base our sensitivity analysis on a random draw from a subset (*h*) of parameters. We have chosen to use a uniform distribution with 5 levels, and ranges equal to minus ½ times the point estimate and plus ½ times the point estimate from PACE.

$$Range_i = [-0.5 \cdot x_i, +0.5 \cdot x_i]$$

The value of each parameter is randomly drawn from a uniform distribution with this range.

For each parameter 9 runs were performed which leads to 9 estimates for elementary effects. The calculation is very similar to the one of the local effect (cfr above) however we do not use the point estimate from the baseline simulation as a reference for the calculation.

$$\varepsilon_{i,r} = [f_h(x_1,x_2,..,x_i,..x_h) - f_h(x_1,x_2,..,x_i + \Delta,..x_h)]/\Delta$$

[3]The Morris screening analysis was only performed on the level of the sectors. It was assumed that the parameter would change in the same way in each region.

Similar to the local method, we define the average and standard deviation of the elementary effects as principal measure of variability.

Because of the large amount of simulations necessary for this analysis, the regional dimension was ignored[4]. The parameter of each region was changed in the same direction. Therefore this method does not give any detail on regional variability of the change in parameter.

2. Results

2.1 Set-up of the sensitivity analysis.

We perform a local method and a Morris sensitivity analysis on the basis of 2 static simulations. In the **'emission tax'** scenario, we introduce a tax on carbon dioxide emissions of 1 euro or 38 rubles per ton. The income from the tax is attributed to the savings of the government.
The **'international energy price'** scenario is based on an exogenous reduction in the price of gasoline, gas, oil and coal on the international market with 1% of its initial value.

These scenarios were chosen for their relative simplicity and their potential to give insights into the main mechanisms of the model. The emission tax scenario gives insights into the elasticity of inputs to production, while the energy price scenario is more focused on the international market. For each simulation, we present the output the effect on social welfare (equivalent variation in billions of rubles) and GDP (gross domestic product). The disaggregated results however are presented only based on social welfare.

Given our definition of variance as $S_i = {\mu_i}^2 + {\sigma_i}^2$, with μ as the average of the elementary effects and σ as the standard deviation, we represent the majority of the output of the sensitivity analysis as $R_i = \frac{S_i}{\sum S_i}$. This normalization was applied as it is additive among different parameters, sectors and regions. Also it greatly simplifies the understanding of the sensitivity analysis and its comparison with different simulations and methodologies. In the case of the Morris-sensitivity analysis we show the output the average elementary effect of each sector-parameter pair in tables 11 and 17. We are only able to introduce uncertainty analysis in the case of the Morris sensitivity analysis. Histograms of social welfare and gross domestic product are presented to illustrate the variability of the end-result after a large amount of simulations.

[4] Disaggregating the effect on regional level would multiply the amount of simulations by 7, which was difficult to handle from a practical perspective.

2.2 Emission tax

2.2.1 Local method

Table 2: Individual effect of 10 most influential parameters on social welfare (SWF)

Sector	Commodity	parameter	Region	ε1	ε2	μ	μ̂	S	μ̂+S	share
sec4	Gas	sKL	Urals	-1.94	-2.02	-1.98	3.92	0.00	3.92	0.25
sec22	Electr_gen	sKLE	Central	-1.49	-1.55	-1.52	2.30	0.00	2.30	0.15
sec3	Coal	sKL	Urals	-0.83	-1.03	-0.93	0.87	0.02	0.89	0.06
sec22	Electr_gen	sKLE	Volga	-0.90	-0.94	-0.92	0.85	0.00	0.85	0.05
sec24	Wholesale	sT	Central	0.73	0.72	0.73	0.53	0.00	0.53	0.03
sec16	Basic metals,	sKLE	Siberia	0.66	0.67	0.66	0.44	0.00	0.44	0.03
sec16	Basic metals	sKLE	Urals	0.66	0.67	0.66	0.44	0.00	0.44	0.03
sec22	Electr_gen	sKLE	Siberia	-0.57	-0.59	-0.58	0.34	0.00	0.34	0.02
sec8	Textile	sKL	F-E	0.40	-0.40	0.00	0.00	0.32	0.32	0.02
sec8	Textile	sA1	F-E	0.40	-0.40	0.00	0.00	0.32	0.32	0.02

Table 3: Individual effect of 10 most influential parameters on gross domestic product (GDP)

sec	Commodity	Parameter	Region	ε1	ε2	μ	μ̂	S	μ̂+S	share
sec4	Gas	sKL	Urals	-4.19	-4.35	-4.27	18.26	0.01	18.27	0.32
sec3	Coal	sKLE	Urals	-2.03	-2.52	-2.28	5.19	0.12	5.31	0.09
sec3	Coal	sKL	Siberia	-1.48	-1.62	-1.55	2.40	0.01	2.41	0.04
sec23	Construction	sKLE	Central	1.41	1.47	1.44	2.07	0.00	2.07	0.04
sec12	Coke	sT	Central	-1.25	-1.27	-1.26	1.58	0.00	1.58	0.03
sec4	Gas	sKLE	Urals	-1.07	-1.08	-1.07	1.15	0.00	1.15	0.02
sec23	Construction	sKLE	Urals	1.03	1.07	1.05	1.10	0.00	1.10	0.02
sec22	Electr_gen	sKLE	Central	-1.01	-1.05	-1.03	1.06	0.00	1.06	0.02
sec16	Construction	sKL	Urals	0.96	0.98	0.97	0.94	0.00	0.94	0.02
sec17	Machinery	sA1	Central	0.91	1.01	0.96	0.92	0.01	0.93	0.02

From tables 2 and 3 we can conclude that by far the most influential parameter is the elasticity of substitution between capital and labour (sKL) of the gas sector in Urals (region 5 in the model). The elasticity of the capital–labour-energy bundle (sKLE) in the electricity and gas generation sector and the capital-labour elasticity of the coal mining sector are next by importance. These three parameters together capture about 50 % of the measured variability. All 10 parameters together cover nearly 80% of the local variability of the set.

Looking at the direction of the effects, we see that increasing the elasticity of capital-labour in the gas and capital-labour-energy in the electricity generation sector has a significantly negative effect on GDP and social welfare (equivalent variation). The effect is opposite for the basic-metals sector. This is caused by the input-preference of each sector. Increasing the elasticity of capital-labour-energy for the basic metals sector leads to a relatively bigger shift to labour, improving social welfare. This is not true for the energy sector.

Table 4: Overall effect on Social Welfare (SWF) by region

Parameters	Central	NW	South	Volga	Ural	Siberia	FE	Total
sKL	**0.04**	0.01	0.00	0.01	**0.33**	0.01	0.03	**0.44**
sKLE	**0.20**	0.03	0.01	**0.07**	**0.06**	**0.05**	0.01	**0.43**
sE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.01**
sNE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
sOIL	0.02	0.00	0.00	0.01	0.00	0.00	0.00	**0.04**
sA	0.00	0.00	0.00	0.00	0.00	0.00	0.01	**0.01**
sT	**0.04**	0.00	0.00	0.00	0.01	0.01	0.00	**0.06**
sA1	0.00	0.00	0.00	0.00	0.00	0.00	0.02	**0.02**
Total	**0.29**	**0.05**	**0.02**	**0.10**	**0.40**	**0.08**	**0.06**	**1.00**

Table 5: Overall effect on GDP by region

Parameters	Central	NW	South	Volga	Ural	Siberia	FE	Total
sKL	**0.07**	0.03	0.01	0.04	**0.45**	0.06	0.01	**0.66**
sKLE	**0.07**	0.01	0.01	0.03	0.04	0.02	0.02	**0.21**
sE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.01**
sNE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
sOIL	0.02	0.00	0.00	0.01	0.00	0.01	0.00	**0.05**
sA	0.00	0.00	0.00	0.00	0.00	0.00	0.01	**0.02**
sT	0.02	0.00	0.00	0.00	0.01	0.01	0.01	**0.05**
sA1	0.00	0.00	0.00	0.00	0.01	0.00	0.00	**0.01**
Total	**0.18**	**0.05**	**0.02**	**0.09**	**0.51**	**0.10**	**0.05**	**1.00**

Given tables 4 and 5 we can conclude that the Central and Urals region are having the most influence on the overal result. The South region has an insignificant contribution. Only considering GDP, we see that over 50% of the variability can be attributed to the Urals region, of which 45% only to the elasticity of capital and labour.

For social welfare the main determinants are the elasticity of capital-labour-energy in the Central, Urals and Volga region and the capital-labour elasticity in the Urals region.

In table 6 below, we aggregate the ratio of variability over all parameters, only looking at sectors that have the most influence on the overal result. From the table we can conclude that the electricity generation sector and the trade sector in the Central region and the coal & gas mining sector, as well as the metallurgy sector in the Urals region have a large influence. The textile sector in the Far-East (FE) causes some unwanted variability. This might be caused by a data related error.

Comparing again with the results of table 7, we can confirm that most of the variability is due to the elasticity of capital-labour-energy in the basic metals and electricity generation sectors and the elasticity of capital-labour in the gas and coal sectors. Of the trade elasticities, only the Constant elasticity of transformation (CET) of trade has some influence on the end result.

Table 6: Sensitivity of social welfare indicator by sector and region (ratio of total variability)

Sectors	Central	NW	South	Volga	Ural	Siberia	FE	Total
Agr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fishing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coal	0.00	0.01	0.00	0.00	**0.06**	0.00	0.00	**0.07**
Gas	0.00	0.00	0.00	0.00	**0.25**	0.00	0.00	**0.26**
Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Food	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Textile	0.00	0.00	0.00	0.00	0.00	0.00	**0.05**	0.05
Leather	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pulp	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Coke	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Chemicals	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01
Rubber	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non_metal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Basic_metal	0.02	0.02	0.00	0.01	**0.03**	**0.04**	0.00	**0.12**
Machinery	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.02
Electrical_eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transport_eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other_manufacturing	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Electr_distr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Electr_gen	**0.16**	0.01	0.01	**0.06**	0.02	0.02	0.00	0.29
Construction	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.03
Trade	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Hotels	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Communication	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transport	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.03
Finance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Real_estate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Public	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Education	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Health	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	0.29	0.05	0.02	0.10	0.40	0.08	0.06	1.00

Table 7: Sensitivity of social welfare indicator by sector and elasticity (ratio of total variability)

Sectors	sKL	sKLE	sE	sNE	sOIL	sA	sT	sA1	Total
Agr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fishing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coal	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07
Gas	0.25	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.26
Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Food	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Textile	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.05
Leather	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pulp	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Coke	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Chemicals	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Rubber	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non_metal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Basic_metal	0.00	0.10	0.00	0.00	0.00	0.00	0.02	0.00	0.12
Machinery	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Electrical_eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transport_eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other_manufacturing	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Electr_distr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Electr_gen	0.00	0.26	0.00	0.00	0.03	0.00	0.00	0.00	**0.29**
Construction	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Trade	0.01	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.05
Hotels	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Communication	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transport	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.03
Finance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Real_estate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Public	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Education	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Health	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	0.44	0.43	0.01	0.00	0.04	0.01	0.06	0.02	**1.00**

2.2.2 Morris method

Table 8: Individual effects of 10 most influential parameters on social welfare

parameters	sec	μ	σ	μ²	S	μ²+S	Ratio
sKLE	Elect_gen	-12.54	4.48	157.15	20.07	177.22	0.19
sKLE	Basic_metal	8.90	0.51	79.12	0.26	79.38	0.09
sA	Petrol	-2.53	7.93	6.38	62.82	69.21	0.07
sKL	Gas	-7.82	0.92	61.20	0.85	62.05	0.07
sNE	Construction	1.92	5.75	3.68	33.03	36.72	0.04
sA	Electr_distr	1.92	5.75	3.68	33.03	36.71	0.04
sNE	Elect_gen	1.18	5.92	1.38	35.04	36.42	0.04
sOIL	Communication	1.76	5.26	3.09	27.71	30.80	0.03
sT	Coal	-1.77	4.80	3.14	23.04	26.18	0.03
sKL	Real_estate	1.79	4.74	3.21	22.46	25.67	0.03

Table 9: Individual effects of 10 most influential parameters on gross domestic product (GDP)

parameters	sec	μ	σ	μ²	S	μ²+S	Ratio
sA	Petrol	-31.08	90.53	966.06	8196.03	9162.09	0.26
sT	Coal	-22.06	56.52	486.63	3194.60	3681.23	0.11
sKL	Real_estate	20.00	56.55	400.17	3197.46	3597.63	0.10
sE	Communication	18.85	56.38	355.33	3178.22	3533.55	0.10
sT	Health	18.76	56.39	351.77	3179.62	3531.39	0.10
sKLE	Gas	14.04	54.62	197.16	2982.98	3180.14	0.09
sKLE	Elect_gen	9.44	53.46	89.12	2857.95	2947.07	0.08
sKL	Petrol	-9.73	29.50	94.68	870.18	964.86	0.03
sT	Gas	-6.05	24.24	36.64	587.73	624.37	0.02
sKL	Coal	-18.43	3.31	339.56	10.97	350.54	0.01

The basics of the Morris method are different from the local method used above. Elementary effects are now studied on the basis of random samples. The results are more difficult to interpret as those from the local method. Also, we lose the regional specification of the model. The range of variation (Standard deviation in tables 8 and 9) is quite high, which points to non-linearity in the parameter effects. Remarkably, the trade elasticities (Armington petrol, CET coal) are much higher and are might no longer be ignored. Referring to table 8, we see that the highest variation is still caused by the elasticity of capital-labour-energy in the generation of electricity and basic-metals sector and the capital-labour elasticity in the gas sector. Table 9 figures some more interesting results for GDP. The variability caused by the health, communications and real estate sector are quite remarkable here.

The direction of the effects is similar, though relatively bigger, than in tables 2 and 3. Again, increasing elasticity of capital-labour-energy for the energy sector has a pronounced negative effect on social welfare and GDP, while the opposite is true for the basic-metals sector.

Having a look at table 10 and table 11 and comparing these figures with Table 7 above, we see that the variability is much less pronounced in the sigma KL parameter, with higher shares for the sigma NW and sigma OIL parameters. Also the effect of sigma KLE is less pronounced. This can point to interaction effects between the elasticity of gas-oil and fuel products and the upper capital-labour-(energy) bundle. Trade effects are as well more pronounced, with higher contributions from the Armington elasticity of petrol and electricity.

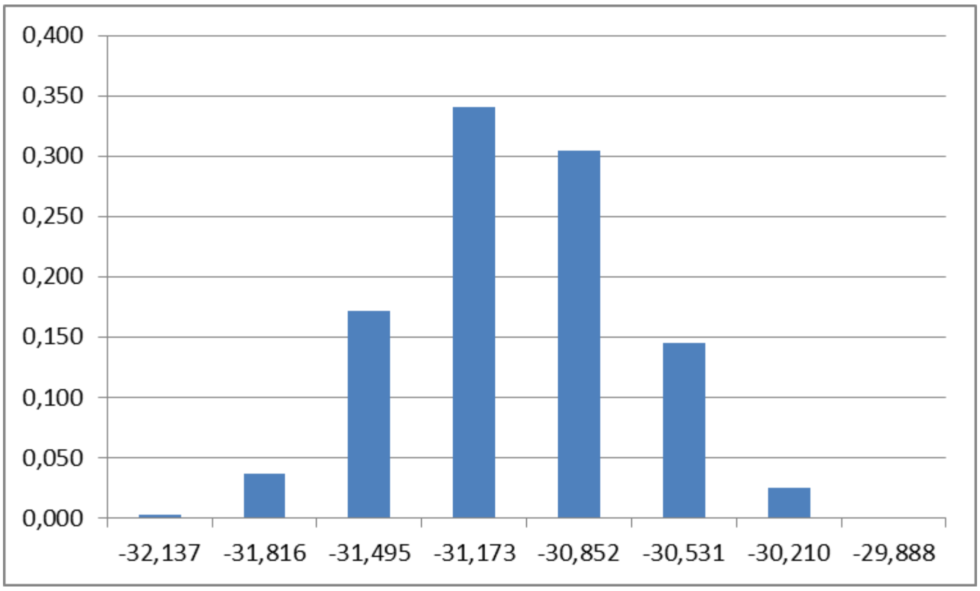
Table 10: Morris sensitivity on social welfare by sector and elasticity (ratio of total variation)

Sectors	sKL	sKLE	sE	sNE	sOIL	sA	sT	sA1	Total
Agr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fishing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coal	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.05
Gas	0.07	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.10
Oil	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Food	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Textile	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01
Leather	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Wood	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pulp	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Petrol	0.00	0.01	0.00	0.00	0.01	0.07	0.00	0.01	0.09
Chemicals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Rubber	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non_metal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Basic_metal	0.00	0.09	0.00	0.00	0.01	0.00	0.01	0.00	0.11
Machinery	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Electrical_eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transport_eq	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.02
Other_manufacturing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Electr_distr	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.04
Electr_gen	0.00	0.19	0.00	0.04	0.02	0.00	0.00	0.00	0.25
Construction	0.03	0.00	0.00	0.04	0.01	0.00	0.00	0.00	0.08
Trade	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02
Hotels	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Communication	0.00	0.00	0.03	0.00	0.03	0.00	0.00	0.00	0.06
Transport	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.02
Finance	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Real_estate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Public	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Education	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.03
Health	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	0.18	0.33	0.04	0.09	0.08	0.15	0.11	0.02	1.00

Table 11: Morris sensitivity on social welfare by sector and elasticity (average value of elementary effects)

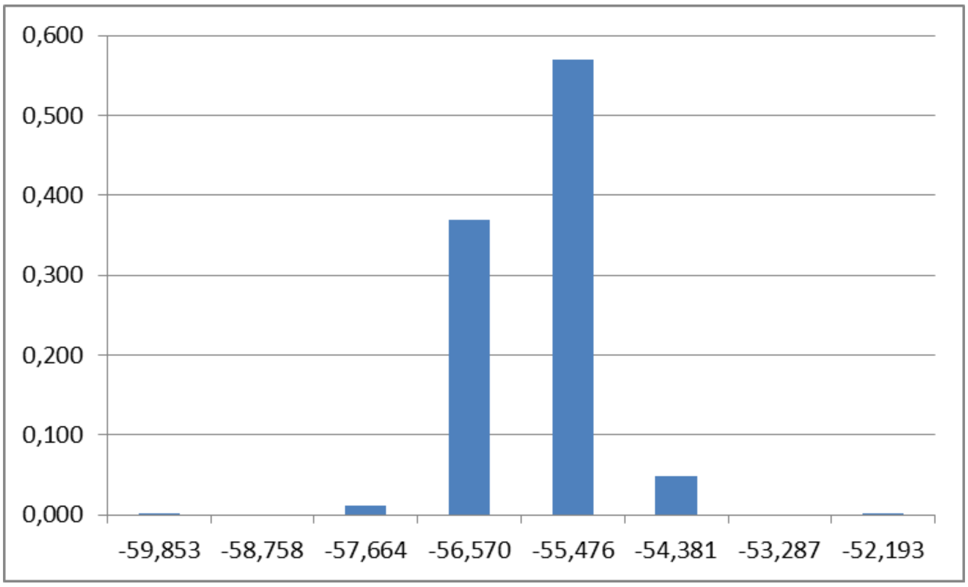
Sectors	sKL	sKLE	sE	sNE	sOIL	sA	sT	sA1	Total
Agr	-0.01	-0.20	0.04	0.00	0.00	0.00	0.00	0.00	-0.16
Fishing	-0.02	0.07	0.01	0.00	0.00	0.00	0.00	0.00	0.06
Coal	**-3.66**	-0.05	0.25	0.02	-0.05	-0.04	-1.77	0.04	-5.27
Gas	**-7.82**	0.03	-0.11	0.00	0.04	-0.23	-0.37	0.00	-8.46
Oil	-0.16	0.92	1.31	-0.01	0.00	0.02	-0.43	-0.01	1.64
Mining	0.10	1.40	-0.01	0.02	-0.06	-0.43	0.12	-0.06	1.09
Food	-0.02	-2.35	0.14	0.00	0.17	-0.05	-0.01	0.43	-1.70
Textile	-0.21	-0.35	0.01	0.00	-0.04	0.96	0.16	0.06	0.59
Leather	-0.80	0.06	0.02	0.00	0.00	0.48	0.00	0.00	-0.24
Wood	0.24	0.00	0.01	0.05	-0.04	-0.09	0.12	-0.35	-0.07
Pulp	0.24	1.90	-0.12	-0.02	0.21	-0.06	-0.45	-0.01	1.70
Petrol	-0.09	**-2.28**	-0.07	-0.29	0.94	**-2.53**	0.61	0.91	-2.79
Chemicals	0.18	0.95	0.09	0.78	-0.58	-0.26	0.31	0.61	2.08
Rubber	0.04	0.37	0.13	0.00	-0.10	0.16	0.17	0.00	0.77
Non_metal	-0.99	1.59	0.03	0.00	0.27	-0.09	0.04	-0.02	0.82
Basic_metal	0.73	**8.90**	-0.68	0.20	-0.75	-0.53	**3.38**	-0.16	11.09
Machinery	2.73	0.12	0.65	0.00	-0.19	-0.19	0.14	0.00	3.25
Electrical_eq	0.21	0.12	-0.38	0.00	0.03	-0.03	0.01	-0.14	-0.18
Transport_eq	0.24	0.01	0.05	0.18	0.06	1.69	0.01	0.01	2.25
Other_manufa	0.72	-0.08	0.17	0.00	-0.01	-0.52	-0.67	0.00	-0.39
Electr_distr	-0.28	0.50	0.29	-0.06	-0.19	1.92	0.21	0.00	2.40
Electr_gen	-1.00	**-12.54**	-0.56	1.18	**3.87**	0.00	-0.13	-0.13	-9.30
Construction	**5.03**	0.00	0.40	1.92	1.14	0.46	-0.01	0.00	8.94
Trade	-2.03	-1.26	0.39	0.00	-0.53	0.00	**3.29**	0.00	-0.14
Hotels	-0.25	0.01	0.19	-0.05	-0.01	0.00	-0.03	0.00	-0.12
Communication	-0.06	0.13	1.56	0.00	**1.76**	0.11	0.00	0.00	3.49
Transport	**-3.48**	-0.50	-0.01	0.02	**2.53**	0.00	-0.01	0.01	-1.44
Finance	1.79	0.68	0.12	-0.07	0.04	0.00	0.18	-0.01	2.74
Real_estate	-0.81	-1.41	0.24	0.11	0.23	0.00	0.00	0.00	-1.65
Public	0.08	1.28	0.55	0.00	0.00	-0.02	-0.03	0.14	2.01
Education	0.24	0.30	0.09	0.01	0.01	0.00	1.65	0.00	2.30
Health	0.03	0.05	-0.03	0.00	-0.14	0.00	-0.56	0.00	-0.65
Total	**-9.09**	**-1.64**	**4.79**	**4.00**	**8.62**	**0.72**	**5.93**	**1.32**	**14.65**

Figure 2 Uncertainty in change in social welfare (x-axis: billion rubles, y-axis: probability density)



min	-32.14
max	-30.21
average	-31.20

Figure 3 Uncertainty in change in GDP (x-axis: billion rubles, y-axis: probability density)



min	-59.85
max	-53.29
average	-56.39

Comparing the results of uncertainty analysis around social welfare and GDP in figures 2 and 3, we see that the randomized results for social welfare can be considered a normal spread with average equal to -31.20 billion rubles. GDP has a very large spread, but the result is concentrated between -55.48 billion rubles and -56.57 rubles.

2.3 International price of energy

2.3.1 Local method

Table 12: Effect of individual parameters on social welfare

sector	param	region	ε1	ε2	μ	μ^2	S	μ^2+S	share
Trade	sT	Central	-10.01	-18.57	-14.29	204.26	36.67	240.93	0.25
Health	sA	Siberia	0.00	-9.00	-4.50	20.27	40.54	60.81	0.06
Pulp	sKLE	Volga	8.99	-0.01	4.49	20.18	40.54	60.72	0.06
Services	sKL	Volga	8.94	-0.08	4.43	19.64	40.64	60.28	0.06
Machinery	sKLE	Volga	8.91	-0.10	4.40	19.40	40.55	59.94	0.06
Other	sKL	Central	0.14	-8.84	-4.35	18.92	40.30	59.23	0.06
Pulp	sA	Volga	-1.42	-8.96	-5.19	26.96	28.46	55.42	0.06
Machinery	sKL	Urals	8.21	-0.90	3.65	13.35	41.47	54.82	0.06
Transport	sT	Central	8.18	-0.83	3.68	13.52	40.54	54.06	0.06
Machinery	sT	Volga	8.17	-0.83	3.67	13.45	40.53	53.99	0.06

Table 13: Effect of individual parameters on gross domestic product

sector	param	region	ε1	ε2	μ	μ^2	S	μ^2+S	share
Trade	sT	Central	-20.12	-22.98	-21.55	464.28	4.09	468.36	0.55
Petrol	sT	Central	8.39	8.30	8.35	69.65	0.00	69.66	0.08
Petrol	sT	Volga	5.33	5.28	5.31	28.17	0.00	28.17	0.03
Machinery	sA	Central	5.04	5.10	5.07	25.73	0.00	25.73	0.03
Petrol	sT	Urals	3.78	3.73	3.75	14.10	0.00	14.10	0.02
Basic metals	sT	Urals	-3.37	-3.34	-3.36	11.27	0.00	11.27	0.01
Trade	sT	Urals	-3.27	-3.25	-3.26	10.62	0.00	10.62	0.01
Machinery	sKL	Central	-3.06	-3.41	-3.24	10.47	0.06	10.53	0.01
Petrol	sT	Siberia	3.23	3.19	3.21	10.30	0.00	10.30	0.01
Oil	sKL	Urals	-2.87	-2.92	-2.89	8.38	0.00	8.38	0.01

From tables 12 and 13 we can conclude that the effect of the trade elasticities is quite high, though very non-linear for the social welfare indicator. The machinery, pulp and transport sector have a high influence on the results. The effects on GDP are easier to interpret in this case. We see big influences for the trade sector in the central region. Also trade in petrol, machinery and basic metals have a big influence on the end result. The CET elasticity of the trade sector in the Central region is the main driver of both the social welfare and GDP effects.

In tables 14 and 15 we show disaggregated effects of the social welfare indicator, by sector & region and by sector & elasticity. Based on the tables we can conclud that the CET elasticity is the dominant parameter, followed by the Armington elasticity and the elasticity of the capital-labour and capital-labour-energy bundle. The transport, trade, machinery and pulp sectors have a strong influence on the social welfare results. The effect is strongest in the Central and the Volga region.

Table 14 Sensitivity of social welfare indicator by sector & region

Sectors	Central	NW	South	Volga	Ural	Siberia	FE	Total
Agr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fishing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coal	0.00	0.00	**0.05**	0.00	0.00	0.00	0.00	**0.06**
Gas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Food	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Textile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Leather	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pulp	0.00	0.00	0.00	**0.12**	0.00	0.00	0.00	**0.12**
Petrol	0.02	0.00	0.00	0.01	0.00	0.00	0.00	**0.04**
Chemicals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rubber	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non_metal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Basic_metal	0.06	0.00	0.00	0.00	0.00	0.00	0.00	**0.06**
Machinery	0.01	0.00	0.00	**0.12**	**0.06**	0.00	0.00	**0.19**
Electrical_eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transport_eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other_manufacturing	**0.06**	0.00	0.00	0.00	0.00	0.00	0.00	**0.06**
Electr_distr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Electr_gen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Construction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trade	**0.25**	0.00	0.00	0.00	0.00	0.00	0.00	**0.26**
Hotels	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Communication	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transport	**0.06**	0.00	0.00	0.00	0.00	0.00	0.00	**0.06**
Finance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Real_estate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Public	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Education	0.00	0.00	0.00	**0.06**	0.00	0.00	0.00	**0.06**
Health	0.00	0.00	0.00	0.00	0.00	**0.06**	0.00	**0.06**
Total	**0.47**	**0.00**	**0.06**	**0.32**	**0.07**	**0.07**	**0.00**	**1.00**

Table 15 Sensitivity of social welfare indicator by sector & elasticity

Sectors	sKL	sKLE	sE	sNE	sOIL	sA	sT	sA1
Agr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fishing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coal	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Food	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Textile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Leather	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pulp	0.00	0.06	0.00	0.00	0.00	0.06	0.00	0.00
Petrol	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
Chemicals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rubber	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non_metal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Basic_metal	0.00	0.00	0.00	0.00	0.00	0.06	0.01	0.00
Machinery	0.06	0.06	0.00	0.00	0.00	0.01	0.06	0.00
Electrical_eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transport_eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other_manufacturing	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Electr_distr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Electr_gen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Construction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trade	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00
Hotels	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Communication	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transport	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
Finance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Real_estate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Public	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Education	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Health	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00
Total	**0.25**	**0.13**	**0.00**	**0.00**	**0.00**	**0.20**	**0.42**	**0.00**

2.3.2 Morris method

Table 16 Individual effect of 10 most influential parameters on social welfare

parameters	sec	μ	μ^2	S	μ^2+S	share
sT	sec24	-15.90	252.91	1.22	254.13	0.13
sT	sec12	12.28	150.82	16.81	167.63	0.08
sE	sec23	2.08	4.33	75.38	79.71	0.04
sOIL	sec15	1.16	1.33	71.84	73.17	0.04
sKLE	sec27	2.98	8.88	49.80	58.68	0.03
sKL	sec17	-5.36	28.73	19.25	47.97	0.02
sE	sec19	0.71	0.50	33.66	34.16	0.02
sA	sec17	5.79	33.51	0.27	33.78	0.02
sKL	sec3	0.69	0.47	32.97	33.44	0.02
sT	sec19	2.59	6.69	26.64	33.33	0.02

Table 17 Individual effect of 10 most influential parameters on gross domestic product

parameters	sec	μ	μ^2	S	μ^2+S	Share
sT	sec24	-32.66	1066.48	4.92	1071.40	0.40
sT	sec12	23.07	532.16	8.68	540.84	0.20
sKL	sec17	-10.91	118.94	27.32	146.26	0.05
sA	sec17	10.74	115.28	0.54	115.82	0.04
sT	sec16	-9.87	97.44	0.59	98.03	0.04
sT	sec27	-7.48	55.93	1.17	57.10	0.02
sKL	sec3	6.64	44.03	2.93	46.97	0.02
sT	sec17	-6.38	40.70	0.17	40.86	0.02
sKLE	sec27	1.65	2.71	23.24	25.95	0.01
sKL	sec5	-3.88	15.02	10.31	25.33	0.01

The Morris sensitivity analysis gives a much more balanced result than the local sensitivity analysis. The CET parameters of the petrol and trade sectors are still dominant; however the effect of some smaller sectors (pulp sector) is not dominant and filtered out of the analysis.

The overview of the Morris measure by sector and elasticity in table 18 confirms higher influence of the sigma E, sigma NE and sigma OIL parameters. The trade sector, petrol sector, coal, transport and construction sectors have a dominant effect on the end results. Larger CET estimates for the trade and transport sector lead to remarkably more negative effects on social welfare. This is counteracted flexibility in the imports (Armington estimates), especially for petrol and machinery.

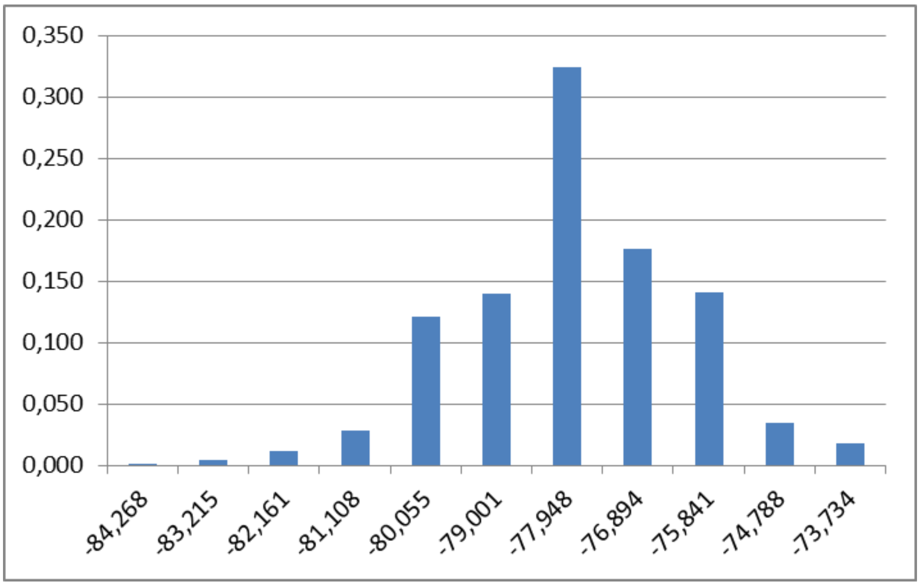
Table 18: Morris sensitivity on social welfare by sector and elasticity (ratio of total variation)

Sectors	sKL	sKLE	sE	sNE	sOIL	sA	sT	sA1	Total
Agr	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Fishing	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02
Coal	0.02	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.05
Gas	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.02
Oil	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Mining	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.02
Food	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
Textile	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Leather	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Wood	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02
Pulp	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.03
Petrol	0.00	0.00	0.00	0.00	0.00	0.00	**0.08**	0.01	**0.09**
Chemicals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Rubber	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.03
Non_metal	0.00	0.01	0.00	0.00	0.04	0.00	0.01	0.00	0.05
Basic_metal	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.04
Machinery	0.02	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.05
Electrical_eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transport_eq	0.00	0.01	0.02	0.00	0.00	0.00	0.02	0.01	0.05
Other_manufacturing	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.04
Electr_distr	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.02
Electr_gen	0.00	0.01	0.01	0.00	0.00	0.00	0.02	0.00	0.04
Construction	0.01	0.01	0.04	0.00	0.00	0.01	0.01	0.00	0.07
Trade	0.00	0.01	0.00	0.00	0.00	0.00	**0.13**	0.00	**0.13**
Hotels	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01
Communication	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transport	0.00	0.03	0.00	0.01	0.01	0.00	0.01	0.00	0.06
Finance	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.02
Real_estate	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Public	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.03
Education	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Health	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.02
Total	**0.13**	**0.13**	**0.11**	**0.04**	**0.09**	**0.10**	**0.36**	**0.04**	**1.00**

Table 19: Morris sensitivity on social welfare by sector and elasticity (average of elementary effect)

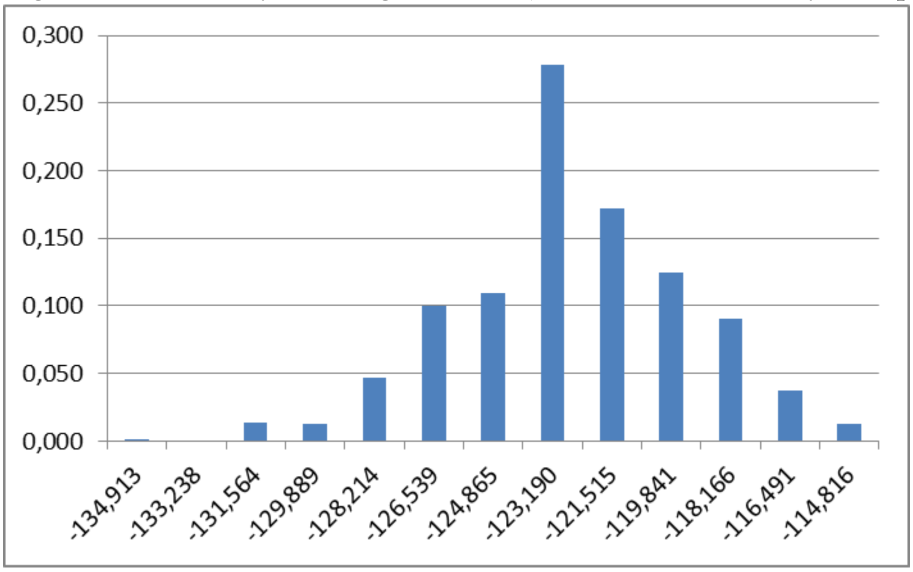
Sectors	sKL	sKLE	sE	sNE	sOIL	sA	sT	sA1	Total
Agr	-1.18	0.29	-0.09	0.00	0.00	0.84	-0.59	0.23	-0.50
Fishing	2.23	0.16	0.00	0.00	0.00	-1.40	-0.12	0.46	1.34
Coal	0.69	-0.72	0.43	-1.05	-1.30	0.22	-0.16	0.00	-1.91
Gas	-0.16	0.03	0.00	0.00	-0.48	0.16	0.74	-0.43	-0.14
Oil	-1.48	-0.93	-0.09	0.00	0.99	0.41	0.29	-0.01	-0.81
Mining	1.32	0.03	-0.01	0.00	-1.32	1.45	-0.71	0.54	1.29
Food	0.34	0.72	-0.02	1.11	-0.07	0.58	-1.00	0.00	1.65
Textile	-0.20	-1.22	-0.53	0.00	-0.01	1.52	0.00	0.06	-0.39
Leather	0.16	0.22	0.11	0.00	-0.01	0.15	0.34	-1.20	-0.25
Wood	0.36	0.00	0.83	0.69	0.38	0.39	-0.60	0.00	2.05
Pulp	1.68	0.46	-0.01	0.00	1.47	-0.75	-0.78	-0.01	2.05
Petrol	-1.04	-1.21	0.23	-0.02	-0.03	-1.08	**12.28**	1.06	10.19
Chemicals	0.75	0.10	-0.01	-0.11	-0.09	1.38	-1.63	-0.43	-0.04
Rubber	1.24	-1.49	0.03	0.00	-0.04	1.38	1.01	0.00	2.13
Non_metal	0.41	-0.94	0.00	-0.31	1.16	0.79	1.31	0.00	2.41
Basic_metal	2.49	-1.11	-1.05	-0.05	-0.26	2.06	**-4.21**	0.01	-2.11
Machinery	-5.36	-0.56	-0.66	-0.01	-0.08	**5.79**	**-3.38**	-0.02	-4.28
Electrical_eq	-0.29	0.01	-0.01	0.00	-0.21	0.03	0.37	0.00	-0.09
Transport_eq	-0.14	1.20	0.71	0.05	-0.03	0.62	2.59	-1.03	3.96
Other_manufacturing	1.62	-0.49	0.85	0.79	-0.01	-0.76	-0.75	1.35	2.60
Electr_distr	0.53	1.86	0.84	0.00	0.04	0.19	2.00	0.00	5.46
Electr_gen	-0.58	-0.53	-1.29	0.61	-0.12	0.00	2.41	0.78	1.27
Construction	-1.45	1.30	2.08	-0.01	0.00	2.17	0.65	0.35	5.10
Trade	-1.45	0.48	-0.05	0.21	-0.09	0.00	**-15.90**	0.00	-16.80
Hotels	-0.04	0.00	0.00	0.00	0.00	0.01	1.06	0.00	1.04
Communication	-0.02	0.06	-0.01	0.00	0.00	0.11	0.52	0.00	0.67
Transport	-2.03	2.98	-0.40	1.72	1.08	-0.14	-2.90	0.00	0.29
Finance	0.00	0.26	1.06	0.79	-0.10	1.60	0.00	1.05	4.66
Real_estate	1.48	1.96	-0.01	0.14	-0.04	0.00	0.00	0.00	3.54
Public	0.64	0.00	-0.13	0.00	0.00	3.58	-2.96	0.23	1.36
Education	-0.20	0.03	-0.38	-0.78	-0.01	0.01	-0.01	0.00	-1.34
Health	-0.04	-1.05	-0.03	0.00	-0.01	-1.05	-0.79	0.00	-2.97
Total	**0.27**	**1.87**	**2.40**	**3.78**	**0.79**	**20.27**	**-10.91**	**2.98**	**21.45**

Figure 4 Uncertainty change in SWF (x-axis: billion rubles, y-axis: probability density)



min	-84.27
max	-73.73
average	-78.36

Figure 5 Uncertainty in change in GDP (x-axis: billion rubles, y-axis: probability density)



min	-134.91
max	-114.82
average	-123.40

3. Conclusions

In this document we show the results of a sensitivity analysis performed on two important base scenarios, which can be building blocks of more detailed policy analysis for Russia. These scenarios are an introduction of a (low) tax on emissions of 1 euro per ton of CO2 and a reduction in the world price of energy carriers with 1%.We evaluate the effects on the primary indicators of social welfare and gross domestic product, in the presence of shocks to the elasticities of the production technology and international trade sector.

We decided to combine a local sensitivity analysis and a Morris sensitivity analysis for this purpose. A local sensitivity analysis was used to reveal effects on the level of regions and regions. The Morris sensitivity analysis was only performed on the level of sectors, to reduce the amount of model runs and complexity of the analysis. Therefore the local sensitivity analysis and Morris sensitivity analysis are not comparable, but complementary. Uncertainty analysis could only be performed on the basis of the Morris sensitivity analysis.

The sensitivity analysis demonstrates that the sensitivity of the overall results to parameter shocks is strongly concentrated in a few parameters and regions. In general a strong influence could be indicated for the trade sector in the Central region, the petrol and raw oil producing sectors in the Urals and Volga regions, the elasticity of capital-labour-energy bundle of the electricity and heating producing sectors and capital-labour elasticity of the gas sectors. The effect of parameters depends on the type of simulation. As could be expected, the primary energy sectors and gas sectors had a high relevance in the emissions tax base scenario. The effect of the CET and Armington trade elasticities was much more relevant in the 'energy price reduction scenario'. Increasing CET elasticities for export intensive sectors increased the negative GDP and welfare effects of the energy price scenarios. Larger Armington elasticities for import intensive sectors had a positive effect.

The uncertainty analysis revealed that the overall results in terms of social welfare and GDP are relatively robust, within the margins of variance applied in the analysis.

4. References

V. Alexeeva-Talebi, C. Böhringer, A. Löschel and S. Voigt (2012), The Value-Added of Sectoral Disaggregation: Implication on Competitive Consequences of Climate Change Policies, Paper presented at the Energy Modelling Forum – Workshop on Border Tax Adjustments.

Cukier, R. I., C. M. Fortuin, K. E. Shuler, A. G. Petschek, and J. H. Schaibly. 1973. Study of the sensitivity of coupled reaction systems to uncertainties in rate coecients. I Theory. The Journal of Chemical Physics 59: 3873{3878.

European Commission, 2009, Impact Assessment Guidelines (SEC 2009 92)

Hermeling, Claudia und Tim Mennel (2008), Sensitivity Analysis in Economic Simulations - A Systematic Approach, ZEW Discussion Paper No. 08-068, Mannheim.

Morris Max D., 1991, Factorial sampling plans for preliminary computational experiments, Technometrics Vol. 33, no.2

Mohora M. C. , 2006, ROMOD: a dynamic CGE model for Romania. A tool for policy analysis, Ph. D for Erasmus University Rotterdam

M. D. Morris Factorial Sampling Plans for Preliminary Computational Experiments, Technometrics, 33, 161-174, 1991.

Ravalico, J. K., H. R. Maier G. C. Dandy, J. P. Norton and B. F. W. Croke, 2005, A comparison of sensitivity analysis techniques for complex models for environmental management

Saltelli A., Tarantola S., Compolongo F.., 2000, Sensitivity analysis as an ingredient of modelling, European Commission, Joint Research Center (JRC), Institute for Systems Informatcs and Safety (ISIS)

Saltelli, A., and R. Bolado. 1997. Is there another way to compute Fourier Amplitude Sensitivity Test (FAST) Computational Statistics and Data Analysis Accepted.

Saltelli, A., S. Tarantola, and K. P.-S. Chan. 1997. A quantitativemodel independent method for global sensitivity analysis of model output. Submitted.

Saltelli A., 2002, Sensitivity analysis for importance assessment, Risk analysis Vol. 22, no.3

Saltelli A., 2005, Global sensitivity analysis: an introduction, European Commission, Joint Research Center (JRC)

Schwieger V., 2004, Variance based sensitivity analysis for model evaluation in engineering studies

Sobol',I.M. (1967), "Distribution of points in a cube and approximate evaluation of integrals". Zh. Vych. Mat. Mat. Fiz. 7: 784–802 (in Russian); U.S.S.R Comput. Maths. Math. Phys. 7: 86–112 (in English).