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Multivariate Sensitivity Analysis with a Very Large CGE Model

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Contents

Foreword

The purpose of this technical paper is to illustrate a fast and frugal in terms of model iterations approach of conducting the deterministic multivariate sensitivity analysis with a very large and complex non-linear model. This technique can be applied to any model that is written in GAMS. With a pedagogical purpose we provide the detailed explanations of the algorithms and the full listings of computer codes that were developed to implement the multivariate sensitivity analysis exercise.

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Abstract

The purpose of this technical paper is to illustrate a computationally cheap approach of conducting the multivariate sensitivity analysis with a very large and complex non-linear model RHOMOLO.

We evaluated model responses to the different combinations of the following input data a) elasticity parameters that define behavioural responses of RHOMOLO b) labour- and total factor productivity parameters that characterize technology and c) scenario perturbations that represent policy decisions with regard to fiscal transfers. Such selection of scenario perturbations is of particular importance in the context of the EU Cohesion policies that are evaluated with RHOMOLO: in accordance with a number of objectives, fiscal contributions enter the model being translated into the factor productivity shocks.

In order to bypass the dimensionality curse we resorted to the deterministic approach, assigning three levels to each input parameter and implemented the exercise in two steps:

One-at-a-time variation of fifteen elasticity parameters for the different combinations of three scenario shocks permitted to attribute the highest influence ranking to the elasticities that define possibilities of substitution between labour and capital, among the domestic and imported goods and to the wage curve elasticity. For the influence ranking we employed the standard elasticity index and the Hoffman&Gardner sensitivity index.

All-at-a-time variation of the most influential elasticity parameters and scenario shocks demonstrated that the total factor productivity and labour productivity shocks are the main drivers of model results, showing strong individual and weak interaction effects. Quantification of the individual and interaction effects of multivariate scenario perturbations was based on a three-level factorial design approach.

We developed the algorithms for the parallel execution of the multiple instances of RHOMOLO that permit all computations to be finished in five hours.

Our approach can be applied to virtually any static or dynamic model that is programmed in GAMS requiring minor modifications in the model code.

With a pedagogical purpose we provide the detailed explanations of algorithms and the full listings of computer codes that were developed to implement this multivariate sensitivity analysis exercise.

The comprehensive sensitivity analysis of the individual and interactions effects allows prioritize the econometric estimations of the most influential parameters, thus increasing precision of policy impact assessment.

Keywords: multivariate sensitivity analysis, parallel processing, factorial design, CGE model.

1 Introduction

While computable general equilibrium (CGE) models are the established tool to analyse the welfare impacts of policies whose effects are transmitted through multiple markets, they are also known to suffer from parameter uncertainty. This problem is particularly severe for regional models because of the lack of regional data, and hence, reliable econometric estimates (Partridge and Rickman, 1998). In particular, uncertainly relates to the behavioural parameters, such as the elasticities of substitution and transformation which are the key parameters to capture responses of a CGE model to scenario perturbations.

Whereas modellers often lack data to run reliable econometric estimates, a common practice is to adopt the values of parameters in question from other models or econometric studies. Although borrowing parameters is a sensible starting point in any modelling exercise, the parameters obtained in studies that are not related to the region, topic and time horizon of investigation, may have reduced applicability in a specific policy context.

For example, econometric methods used to estimate the values of elasticity parameters may not be compatible with the nesting structure of cost functions that are employed in a CGE model. Indeed, the elasticities on lower nests of cost functions can depend on the elasticities of higher nests; however, it is difficult to pin down their joint probability distribution. As a result, the covariation between elasticity parameters that are collected from different sources is often not accounted for.

Therefore, comprehensive sensitivity analysis is necessary for prioritizing the econometric estimations of crucial input parameters and improving the precision of impact evaluation.

Considering a very high computational cost of conducting a global sensitivity analysis with a large model, a common approach is to investigate the sensitivity of model output to a small subset of input parameters for one or several scenario perturbations (Hermeling 2013, Hertel et al 2007, Webster et al 2008). However, for understanding the distributional effects of model responses, it is important to examine the interaction effects between and among the input parameters and scenario perturbations, thus conducting a multivariate sensitivity analysis (Saltelli A. et al, 2010, Abler et al. 1999).

In order to address this important issue, we investigate the responsiveness of the multi-regional dynamic computable general equilibrium model RHOMOLO[1] (Mercenier, 2016) to the different combinations of structural parameters that characterize: a) behavioural preferences (elasticities of transformation/substitution), b) technology (factor productivity parameters), and c) policy decisions (allocation of fiscal transfers) thus performing the multivariate sensitivity analysis (MSA).

This sensitivity analysis exercise resorts to a deterministic approach that does not require prior knowledge about the probability density functions of input parameters under investigation. This is the only feasible option considering RHOMOLO's dimensions and a big number of exogenous input parameters[2] (Mercenier et al 2016, Álvarez-Martínez M.T. and López-Cobo M., 2016).

We employed the factorial experiment technique to investigate the individual effect of each factor on the response indicator, as well as the effects of interactions between factors on the response indicator (Anderson et al, 2015).

The importance ranking of input parameters, and estimates of individual and interaction effects and that are obtained by this exercise allow us to prioritize econometric estimations of the most influential parameters, what is particularly important for large and complex non-linear models like RHOMOLO.

The structure of paper is as follows. Section 2 presents the set-up of MSA exercise. Section 3 contains a detailed explanation of the algorithms and computer codes that were developed to implement the MSA. Section 4 presents the results, and Section 5 offers conclusions. The listings of computer codes and illustrations are provided in the Annexes.

[1] RHOMOLO-v2 covers 267 NUTS2 regions of the EU27 and each regional economy is disaggregated into five NACE Rev. 1.1 sectors and one national R&D sector

2 The current version of RHOMOLO has 269 regions, 6 sectors, 2 types of capital and 3 types of labour

2 The setup of the multivariate sensitivity analysis exercise with the RHOMOLO model

The main area of RHOMOLO application is evaluation of EU Cohesion policies and EU investment support policies (Mercenier, 2016). In accordance with a number of objectives, fiscal contributions enter the model being translated into the factor productivity shocks. Values of elasticity parameters regulate the behavioural responses of RHOMOLO. With this in mind, we focus the current MSA exercise on testing the model sensitivity to the key input factors that are the fiscal transfers, factor productivity, and elasticity parameters.

The list of elasticity parameters that were selected for the MSA is provided in Table 1.

Table 1 Selection of elasticity parameters for multivariate sensitivity analysis

Elasticity parameters	Notation	Baseline value
Transformation of R&D/non-R&D high-skill labour supply	Sig_FacSupLab_H	1
Substitution between different household consumption goods	Sig_ConHou	1.2
Substitution between different public goods	Sig_ConGov	0.3
Substitution between primary factors and intermediate inputs	Sig_ZS	0.2
Substitution between intermediate goods	Sig_XS	0.25
Substitution between aggregate labour and capital	Sig_QS	1
Substitution between private and public capital	Sig_KapS	2
Substitution between different labour skill groups	Sig_LabS	2
Knowledge externality parameter	KnowK_Ext	0.0053
Substitution at the upper level of investment technology	Sig_EuroInv	3
Substitution at the lower level of investment technology	Sig_Inv	1.3
Substitution between goods from different regions	Sig_ArmS	2
Wage curve elasticity	WgeCurveElast	0.01
Transformation of EU capital between regional markets	Sig_EuroKap	3
Substitution between goods in R&D consumption	Sig_Arm_RnD	3

Source: Values of elasticity parameters that are employed in the RHOMOLO model

Given that public policy funding is earmarked for different objectives, in order to clear the experiment out the complex interaction effects, we tested two alternative scenarios for achieving factor productivity gains without prior investments (ShockTotFacProd and ShockLabProd). Under the third scenario we tested the case when investments were not aimed at productivity gains (ShockIncTransf).

The scenario perturbations for the MSA are listed in Table 2.

Table 2 Selection of scenario shocks for the multivariate sensitivity analysis

Model Shocks	**Baseline value**
ShockTotFacProd	
- A 1% increase of total factor productivity in all sectors of all regions relative to the baseline value; - 1% decrease of total factor productivity in all sectors of all regions relative to the baseline value.	1 (no total factor productivity improvements)
ShockLabProd	
- A 1% increase of labour productivity in all sectors of all regions relative to the baseline value; - 1% decrease of labour productivity in all sectors of all regions relative to the baseline value.	1 (no labour productivity improvements)
ShockIncTransf	
- All NUTS2 regions contribute part of their household income to raise the cumulative household income of the Least Developed Regions (LDRs) by 1%; - LDRs transfer 1% of their cumulative household income to all NUTS2 regions. In both cases each NUTS2 region contributes/receives funding in proportion to its GDP. Each LDR contributes/receives funding proportionally to the share of its population in the cumulative population of LDRs.	0 (no donations no contributions)

Source: author's selection of scenario-set up for the current MSA exercise with the RHOMOLO model

In accordance with the deterministic approach of MSA, we established three levels for each elasticity parameter (baseline value, +10%, - 10%) and for each scenario shock (baseline value, +1%,-1%)[3].

Since the combination of baseline values of scenario shocks (see Table 2) describes the unperturbed situation of the economy on which elasticity parameters have no impact, it was excluded from the analysis.

In order to investigate how all possible combinations of three scenario perturbations (see Table 2) excluding the baseline combination would impact model results we need to run RHOMOLO 26 (3 in the power of 3 less one) times. To investigate the interactions across fifteen elasticity parameters (see Table 1) for a single scenario shock we would have to run the model 14348907 (3 in the power of 15) times. Accounting for all possible combinations of elasticity and scenario shocks parameters requires running RHOMOLO 373071582 times (14348907 times 26). Clearly, this number of computations is unmanageable with the model of the dimensions of RHOMOLO that has long simulations time.

With the goal to bypass the dimensionality curse we implemented the MSA exercise in two steps:

At the ***first step*** we ran RHOMOLO for all possible combinations of the three scenario shocks (excluding the baseline) changing one elasticity parameter per model run. To vary each of the 15 elasticities 2 times[4] while keeping the values of the rest of the elasticities fixed at their baseline values, required 30 model runs. To repeat this procedure for 26 combinations of

[3] A more powerful sensitivity test could be conducted if the input parameters were varied by a factor of their standard deviations, but these measurements are unknown. Other sources of model uncertainty (the choice of nesting structure of cost functions, temporal and spatial variability, etc.) are not considered in this study. Sensitivity analysis with respect to all parameters of complex models is virtually impossible because of the enormous number of model solutions and a very long computation time.

[4] To avoid the repetition of the baseline values of elasticity parameters

scenario shocks required 780 model runs. This step permitted to sort the elasticity parameters by their influence on model output.

At the ***second step*** we performed computer simulations with RHOMOLO for all possible combinations of the most influential elasticity parameters repeating it for the 26 combinations of scenario shocks. Having selected three elasticity parameters with the highest influence on the results, we ran the model 702 times (27 combinations of elasticities and 26 combinations of scenario shocks). This step permitted to rank the combinations of scenario shocks capturing their individual and conjoint influence on model results.

Since the MSA with a very large and complex multiregional CGE model RHOMOLO is highly time- and CPU- consuming, the multiple model runs were executed as 40 parallel processes on a virtual machine with 40 processor cores and 192 GB of physical memory. Within each parallel process a given number of model runs is executed sequentially. When all model runs are completed, the results are automatically merged into the Excel Pivot tables, as in Di Comite et al (2016).

3 Programming the multivariate sensitivity analysis exercise: step by step guide

Since our approach and the model codes can be easily applied to any model that is written in GAMS, in this section we provide step-by step explanations of how the MSA exercise was programmed.

This paper also serves a pedagogical purpose of facilitating the entry into the Windows batch scripting[5] and batch execution of GAMS programs. In order to understand certain parts of the computer codes the reader would need to have an advanced knowledge of GAMS programming language (McCarl 2017) and a basic knowledge of Windows batch scripting. This work can be seen as an extension to the approaches of Rutherford (2007) and Kalvelagen (2012). The full listings of the batch script and GAMS program code created to perform the MSA are provided in the Annex 1 and Annex 2.

We start with the detailed explanation of the key elements of the parent batch script that executes the multiple instances of RHOMOLO.

3.1 Parallel execution of multiple model instances in a batch script

Each step of the MSA exercise is executed with a double mouse click on the parent batch script RunSSA4CGE.cmd (its program code is provided in Annex 1). Since the MSA procedure is fully automated, after launching the RunSSA4CGE.cmd no more user intervention is required. When all model runs for a given step of MSA are finished, the RunSSA4CGE.cmd automatically merges the results into Excel pivot tables.

The RunSSA4CGE.cmd begins with providing the paths to the model folder and to the GAMS executable gams.exe (lines 2 and 4, Annex 1)[6]. Lines 6−9 set the directories for storing the results of multiple model runs (SSA\Temporary_SSA) and the Excel pivot tables (SSA\PivotTables_SSA). Lines 11−13 delete the results of previous model runs. Line 15 sets the number of available processor cores on the virtual machine.

Lines 17−24 define the model settings, where a user can select between running RHOMOLO in static or in dynamic environment, provide the last year of dynamic horizon, set the type of competition and functioning of labour markets.

We heavily used environment variables, as they permit to pass the selected settings from the batch script into the model code. All values that were defined in the GAMS code with GAMS control variables can be reset in a batch script.

The script continues (lines 26−34) with introducing the coefficients to vary the baseline values of elasticities (+/-10%) and scenario perturbations (+/- 1%).

In the line 37 the user selects between performing the first or the second step of MSA. Specifically, "set LoopChanging1ElasticityAtAtime=YES" launches implementation of the first step of MSA. Analysis of the results of the first step of MSA permits to determine the most influential elasticity parameters that are used at the second step.

The second step of MSA is activated with the command "set LoopChanging1ElasticityAtAtime=NO". In the line 40 the most influential elasticity parameters are selected and the lines 42-46 export them to the newly created file Combinations2Run.gms. This is done in order to separate the most influential elasticities, different combinations of which are tested on the second step of MSA from the elasticities that are hold fixed at their baseline values.

Lines 49−52 pass the selected model settings, the step of the MSA and the coefficients that are used to vary the baseline values of elasticities and scenario shocks parameters to the GAMS file SSA4CGE.gms and launch the GAMS execution of SSA4CGE.gms.

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[5] Batch scripting is a convenient instrument to automate the execution of repeatable tasks. A batch script is a series of command contained in a text file with extension .BAT or .CMD. They are executed by the command interpreter with a double click and can be edited in any text editor including the GAMS-IDE. Good web-sites for grasping the basics of Windows batch scripting are www.ss64.com, www.dostips.com, www.robvanderwoude.com, https://steve-jansen.github.io/guides/ windows-batch-scripting.

[6] A path to gams.exe has to be provided only when PATH environment variable for GAMS is not set.

The main functions of SSA4CGE.gms (Annex 2) are to create 40 parallel processes (RunPara1.cmd, RunPara2.cmd,…,RunPara40.cmd), distribute RHOMOLO runs among them, and write the code for merging the results into the file Pivot_SSA.gms. The syntax of SSA4CGE.gms is analysed in detail in the following sub-section.

After the completion of the SSA4CGE.gms, the line 61 of the parent script RunSSA4CGE.cmd (Annex 1) launches the 40 parallel processes (RunPara1.cmd, RunPara2.cmd,…,RunPara40.cmd). Each parallel process executes consecutively allocated to it model runs.

A known shortcoming of Windows batch scripting is that a parent script may not wait for all parallel child processes to complete. We developed a special delay procedure to prevent that RunSSA4CGE.cmd starts merging the results before all model runs are finished. According to the procedure when each of 40 parallel processes terminates allocated to it model runs, it writes its number to the file X.txt and closes down. The parent batch script RunSSA4CGE.cmd checks every 59 seconds the number of lines in X.txt (lines 63-69), when it finds 40 lines, it launches the Pivot_SSA.gms to merge the results of model runs into Excel pivot tables (lines 70−73).

The screenshots that illustrate the parallel batch execution of multiple RHOMOLO runs and the delayed execution procedure are provided in Annex 3 and Annex 4.

3.2 Distribution of multiple model runs among the parallel batch processes

Below we explain in detail the key elements of the GAMS code SSA4CGE.gms. Its full listing is presented in Annex 2.

Lines 3-5 set the directories to place the results of individual model runs and Excel pivot tables. Lines 7−14 establish the default model settings, step of the MSA and a counter of model runs. The default values are overwritten with the values that are set in the parent batch script.

If the second step of MSA is activated ($ifi %LoopChanging1ElasticityAtAtime%==NO), the GAMS file Combinations2Run.gms that contains the names of elasticity parameter to be varied all-at-a-time at the second step of MSA is imported into SSA4CGE.gms (lines 16-17). Lines 19-33 set the default values of elasticity parameters that are not subject to variation at the second step of MSA.

Lines 35-46 establish the default coefficients to vary the elasticity parameters and scenario shocks.

Next, using the $Evalglobal command the alternative values of scenario shocks are computed (lines 48−53), and the sets of their values are constructed, as show the lines 55−60. In the same manner the alternative values of elasticity parameters are calculated (lines 62−109).

When the first step of MSA is activated with the statement $ifthen %LoopChanging1ElasticityAtAtime%=="YES", line 111) a single set of alternative values of all elasticity parameters has to be constructed. However, a problem arises if some elasticity parameters have the same values, because GAMS sets cannot have repetitive entries (McCarl 2017). Taking into account the fact that GAMS set elements are strings, we overcame the problem of repetitive set entries by adding different number of zeroes to the fractional part of set elements, as shown by lines 114−127. Then it was straightforward to construct the subsets of alternative values for each elasticity parameter (lines 130−145).

When the second step of MSA is activated ($ifi %LoopChanging1ElasticityAtAtime%==NO, line 147), the alternative values of the most influential elasticity parameters are computed (lines 148−162) and the sets of their alternative values are constructed (lines 164−178). These sets consist of three elements for the elasticities to be varied, and of one element for the elasticities that are held fixed at a baseline value.

Further on, subject to the activated step of MSA, the SSA4CGE.gms loops over the sets of alternative values of elasticity parameters and scenario shocks, constructing different combinations of their values (lines 185−189). Employing the "put" commands, the SSA4CGE.gms writes each combination to a corresponding batch file j.bat (lines 181−184 and 190−228). The number of BAT files is equal to the number of combinations (i.e. 780 on the first step and 702 on the second step of MSA).

When launched, the batch file j.bat executes RHOMOLO for a given combination of elasticity parameters and model chocks saving the results in the corresponding file j.gdx, placing the GDX file in the folder SSA\Temporary_SSA. An example of the batch file that is created on the second step of MSA is provided in Annex 5.

Lines 231-236 compute the number of model runs (%NuRuns%) as number of combinations of elasticity parameters and scenario shocks.

Sequentially, since the MSA computations are run in parallel on the virtual machine with 40–processor cores (Annex 3, Annex 4), we developed an algorithm that allocates model runs (%NuRuns%) among the 40 (%CPUS%) parallel processes, producing the set assign(cjob,jj), as illustrated by the lines 238−246.

Lines 249−259 create the files RunPara1.cmd, RunPara2.cmd,…,RunPara40.cmd that, when launched by the parent batch script RunSSA4CGE.cmd, run in parallel. Lines 252−253 in accordance with the set assign(cjob,jj) attribute to each CMD process a certain number of BAT files. When each parallel CMD process finishes the consecutive execution of allocated to it batch files, it writes its name into the file X.txt (line 257) and closes down (line 258). Functioning of the delayed execution procedure is illustrated with screenshot in Annex 4.

3.3 Merging the results of individual model runs and report generation

At the last step, the SSA4CGE.gms creates the file Pivot_SSA.gms, writing in it the GAMS code for merging the results of model runs into Excel pivot tables (lines 263−343, Annex 2). The Pivot_SSA.gms is placed to the directory SSA\PivotTables_SSA. As it was explained above, the parent batch script RunSSA4CGE.cmd launches the Pivot_SSA.gms when all model runs that are associated with the first or second step of MSA are finished. This procedure is illustrated with the screenshot in Annex 4.

The lines 275−279 load from the file 1.gdx the sets which define model horizon (T) and list of NUTS2 regions (Reg). This is needed to restore after merging the domains of model response indicators.

Next, the sets of elasticity parameters and scenario shocks are defined with the control variables (281−283).

After that the command in the line 286 merges all GDX files that contain the results of individual model runs into a single composite file merged.gdx.

By GAMS default (McCarl 2013), after merging the GDX files, in the composite file merged.gdx the domains of all symbols become redefined over the additional set Merged_set_1 that contains the names of all merged GDX files.

Consecutively, from the composite file merged.gdx we import the sets Merged_set_1, Elasticities(Merged_set_1,%Elasticities%), Shocks(Merged_set_1,%Shocks%), and load the GDP projections (lines 288−302).

The set Merged_set_1 contains the numbers of all model runs. The set Elasticities(Merged_set_1,%Elasticities%) puts in correspondence the number of a model run with the corresponding combination of elasticity parameters. The set Shocks(Merged_set_1,%Shocks%) combines the number of a model run with corresponding combination of scenario shocks. We employed GDP projections at regional and EU level as model response indicators.

To analyse the results, the domains of the loaded GDP estimates have to be redefined over the sets of elasticity parameters and scenario shocks instead of the Merged_set_1. For this purpose, we constructed the set ElasticitiesShocks(Merged_set_1,%Elasticities%,%Shocks%) which associates the number of each model run with the corresponding combination of elasticity parameters and scenario shocks, lines 306-307. Summation over this tuple set (lines 311−316) permitted to redefine the domains of GDP estimates, swapping the Merged_set_1 with the corresponding sets of elasticity parameters %Elasticities% and scenario shocks %Shocks%.

Lines 322−343 which follow illustrate the standard GAMS procedure of creating Excel pivot tables. An example of the pivot table that contains the results of the second step of MSA is provided in Annex 6.

3.4 Modifications in the model code to pass through the current combination of the tested parameters

The only modifications of the model code that are needed to run the MSA were the following:

a) All parameters subject to the sensitivity analysis have to be defined as control variables so that their values can be modified from the batch file, as shown in the example below:

```
Sig_FacSupLab_H(Reg)          =  %Sig_FacSupLab_H%  ;
TFP0.FX(Reg,Sec)              =  %ShockTotFacProd%  ;
```

b) The combinations of the current values of elasticity and shock parameters, the model response indicators, and the sets, over which they are defined, have to be uploaded to the corresponding GDX file, as shown below:

```
$if not set  ActiveRun          $set ActiveRun          0

set Elasticities /

"%Sig_FacSupLab_H%"."%Sig_ConHou%"."%Sig_ZS%"."%Sig_QS%"."%Sig_XS%".
"%Sig_KapS%"."%Sig_LabS%"."%Sig_Inv%"."%Sig_ConGov%"."%Sig_ArmS%".

"%Sig_EuroInv%"."%Sig_EuroKap%"."%Sig_Arm_RnD%"."%KnowK_Ext%"."%WgeCurveElas
t%" /;

set Shocks / "%ShockTotFacProd%"."%ShockLabProd%"."%ShockIncTransf%" /;

Execute_Unload '%TempDir%\%ActiveRun%' Elasticities, Shocks, T, Reg, RealGDP, RealGDPe,
RealGDPeuE;
```

In the code sample above the control variable %ActiveRun% defines the number of a current model run. It is assigned in SSA4CGE.gms (line 197, Annex 2) and is passed to the RHOMOLO model code RunCGE.gms through the every batch file j.bat which executes RHOMOLO for a given combination of elasticity parameters and model shocks, as illustrated in Annex 5.

4 Discussion of the results

To proceed with analysis of the results obtained on the first step of MSA we had to select among a dozen importance measures and sensitivity indexes (Hamby, 1995, Pannell, D.J. (1997).

Given that different indices may attribute distinct influence rankings to the same input parameters, the Hoffman&Gardner sensitivity index (Hoffman and Gardner, 1983) that calculates the difference in model output varying the input parameter from its minimum value to its maximum value was found to be the simplest and the most reliable sensitivity measure (Hamby 1994, 1995).

For the thorough analysis we combined the Hoffman&Gardner sensitivity indices with the standard elasticity indices (Pannell, 1997)[7], and computed the average, pick, and the standard deviation values. For the current exercise we limited our analysis to the projections of EU GDP, calculating the average values over the different combinations of scenario shocks. The results are presented in Table 3:

Table 3 Influence ranking of elasticity parameters for the different combinations of scenario shocks

	Max	Min	Average	Standard Deviation	Standard Elasticity index	Hoffman& Gardner Sensitivity Index
WgeCurveElast	2.6766	-2.6394	-0.0211612	1.616843	0.0023188	0.046376
Sig_ArmS	2.7410	-2.7041	0.0023552	1.643364	0.0000290	0.000579
Sig_QS	2.7298	-2.6921	0.0023989	1.646648	0.0000277	0.000553
Sig_EuroInv	2.6644	-2.6289	0.0024139	1.647282	0.0000031	0.000062
Sig_ConHou	2.6665	-2.6309	0.0024141	1.647282	0.0000022	0.000045
Sig_KapS	2.6646	-2.6291	0.0024133	1.647263	0.0000006	0.000012
Sig_LabS	2.6644	-2.6289	0.0024138	1.647282	0.0000003	0.000006
Sig_Inv	2.6643	-2.6289	0.0024139	1.647282	0.0000001	0.000002
Sig_EuroKap	2.6643	-2.6289	0.0024139	1.647282	0.0000000	0.000000
Sig_Arm_RnD	2.6643	-2.6289	0.0024139	1.647282	0.0000000	0.000000
KnowK_Ext	2.6643	-2.6289	0.0024139	1.647282	0.0000000	0.000000
Sig_FacSupLab_H	2.6644	-2.6289	0.0024139	1.647286	-0.0000001	-0.000001
Sig_XS	2.6646	-2.6292	0.0024139	1.647283	-0.0000001	-0.000003
Sig_ConGov	2.6645	-2.6290	0.0024139	1.647282	-0.0000002	-0.000004
Sig_ZS	2.6654	-2.6300	0.0024138	1.647282	-0.0000007	-0.000015

Source: computer simulations with the RHOMOLO model. Evaluation in terms EU GDP in 2020 relative to the baseline projections Elasticity indices were calculated in absolute terms, the rest of indices- in terms of average per cent deviation from the baseline projections.

In our case, both the standard elasticity index and the Hoffman&Gardner sensitivity index attribute the highest influence ranking to the following three elasticities, see Table 3 above:

- Sig_QS- substitution between aggregate labour and capital;

[7] The standard elasticity index measures the percentage change in output divided by a percentage change in an input

- Sig_ArmS- substitution between goods from different regions;
- WgeCurveElast- wage curve elasticity.

Having obtained the influence ranking of elasticity parameters, on the second step of the MSA exercise we performed all-at-a-time variation of Sig_QS, Sig_ArmS, WgeCurveElast and the scenario shocks.

In order to quantify the individual and interaction effects of multivariate scenario perturbations we employed a three-level factorial design approach (Anderson, 2003, Anderson and Whitcomb, 2015, Saltelli and Annoni, 2010, Box, 1978):

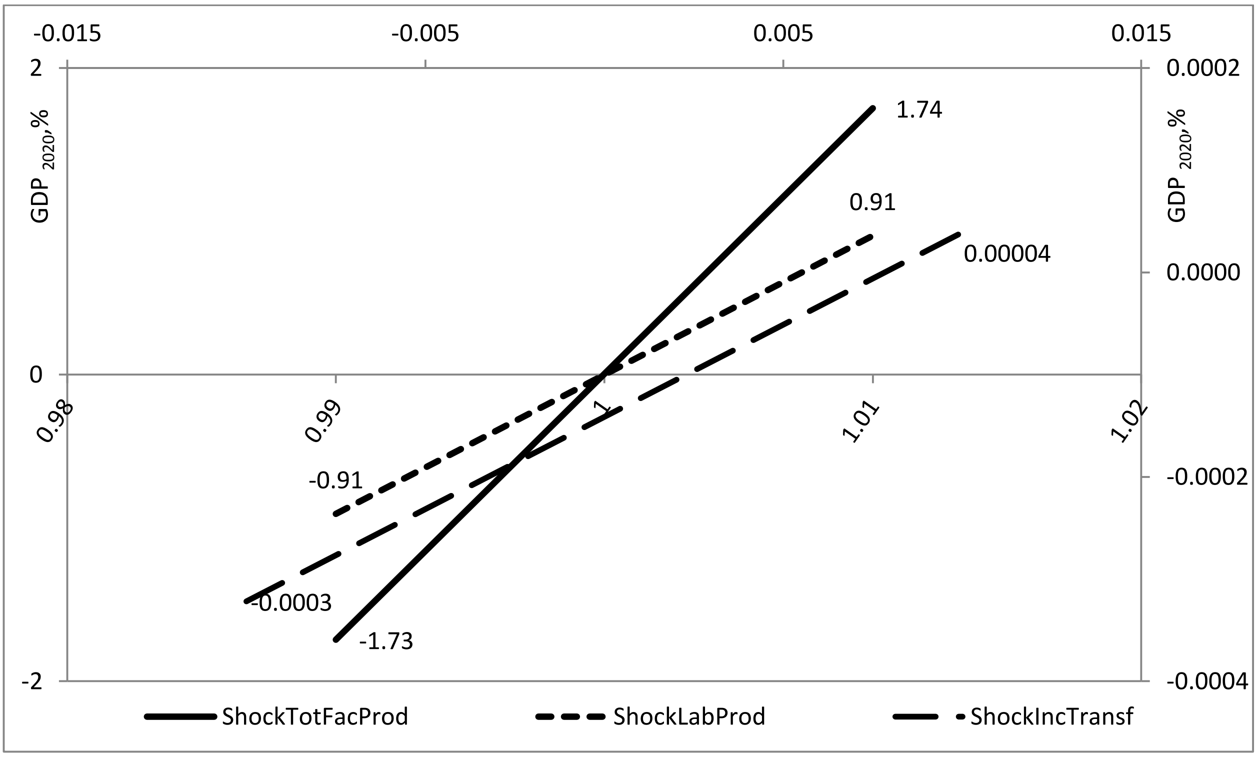
-the first-order individual effects of each model shock were computed as average change in model response when moving a shock parameter from its low level to its high level holding the values of two other shocks fixed at their baseline values;

-the second-order interaction effects were estimated as average change in model response when contrasting high and low levels of one shock at the different levels of another shock holding the values of the third shock fixed at its baseline value;

- the third-order interaction effects were calculated as two-way interaction of two shocks at each level of the third shocks.

Decomposition of scenario perturbations into the individual effects is presented below:

Figure 1. The first-order individual effects of scenario shocks

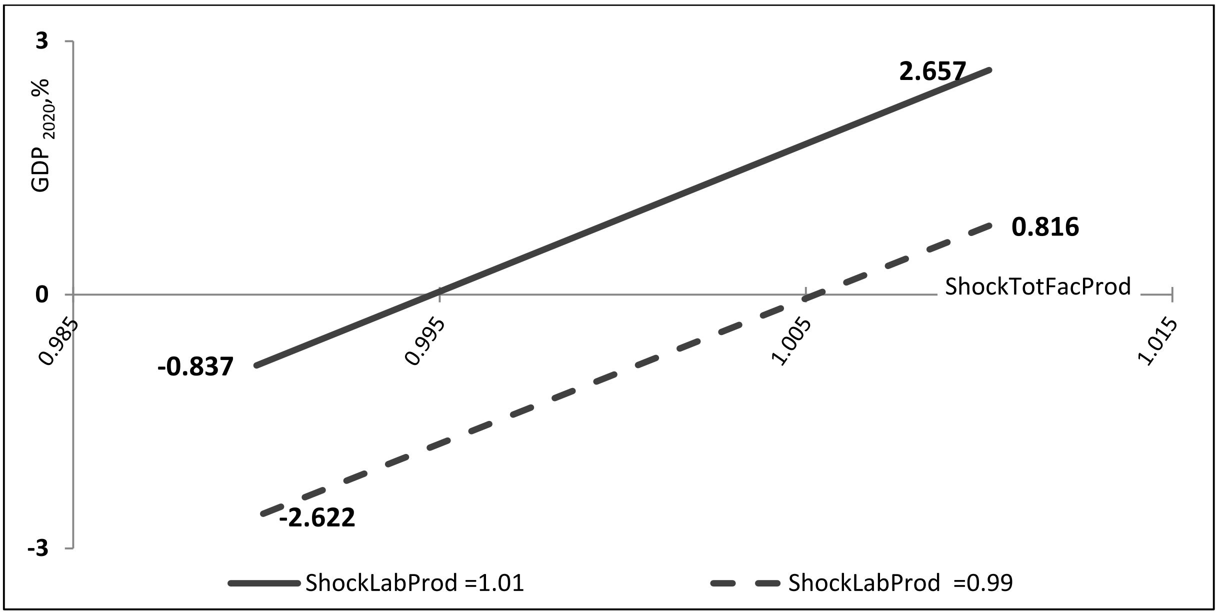


Source: computer simulations with the RHOMOLO model. Evaluation in terms of average per cent deviation of real EU GDP in 2020 relative to the baseline projections. On the primary axes were plotted the results for the ShockTotFacProd and ShockLabProd. On the secondary axes were plotted the results for the ShockIncTransf.

As illustrated in Figure 1, a symmetric 1% variation of the tfp coefficient has the strongest impact on GDP among all scenario perturbations. The first-order individual effect of ShockLabProd is almost twice weaker than that of ShockTotFacProd. The income transfer shock has rather insignificant individual effect. Overall, contrasting the high and low values of the scenario perturbations has quite symmetric response on model output.

The interaction plots in Figure 2 and Figure 3 illustrate the second-order interaction effects between the different pairs of scenario perturbations.

Figure 2. The second-order interaction effects of ShockTotFacProd with ShockLabProd

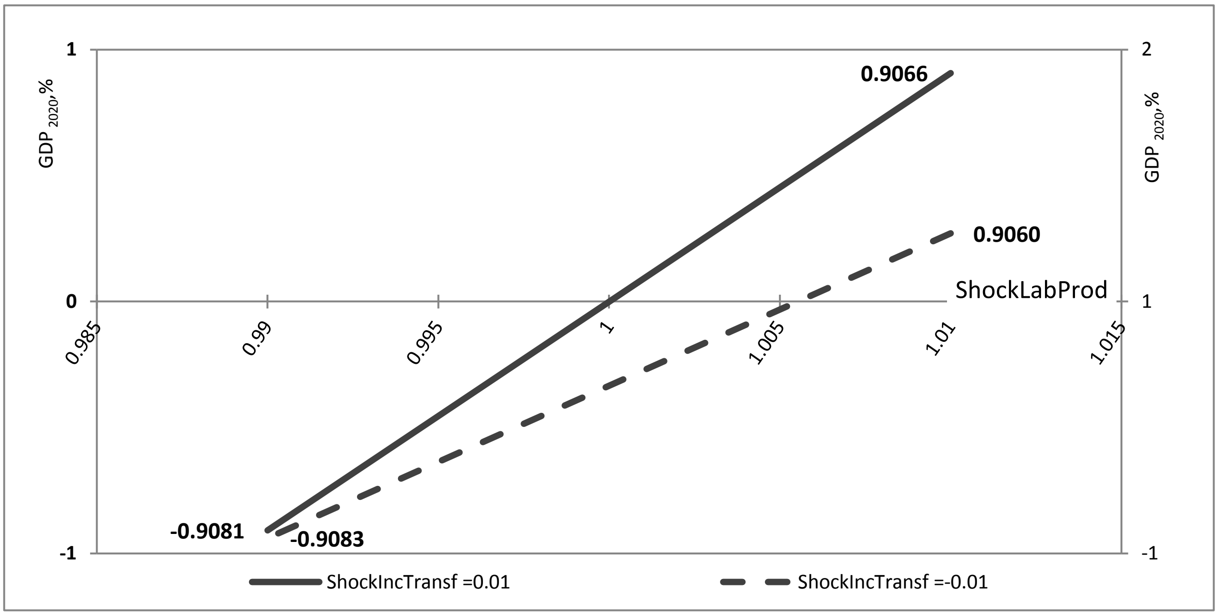


Source: computer simulations with the RHOMOLO model. Evaluation in terms of average per cent deviation of real EU GDP in 2020 relative to the baseline projections.

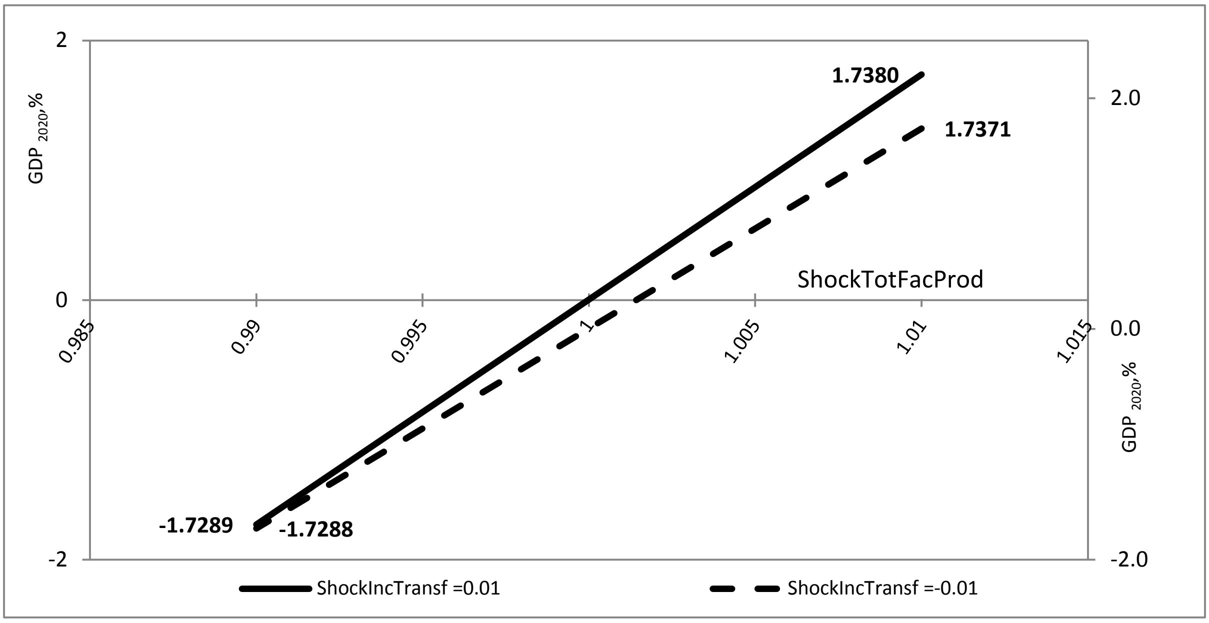
The almost parallel lines in Figure 2 indicate large effects of tfp and labour productivity shocks with insignificant interaction as ShockLabProd shows similar responses at the different levels of ShockTotFacProd. The maximum response is achieved at the highest levels of both shocks (2.657) and the minimum- at the lowest levels (-2.622). At the different (high-low) levels of these shocks, the response is stronger when ShockTotFacProd is at its high (0.816) and weaker when ShockTotFacProd is at its low level (-0.837), which manifests it dominance over the ShockLabProd.

The second-order interaction effects between the ShockIncTransf and ShockLabProd (Figure 3, a) and between the ShockIncTransf and ShockTotFacProd (Figure 3, b) are illustrated below:

Figure 3. The second-order interaction effects of ShockLabProd with ShockIncTransf and ShockTotFacProd with ShockIncTransf shocks



a)



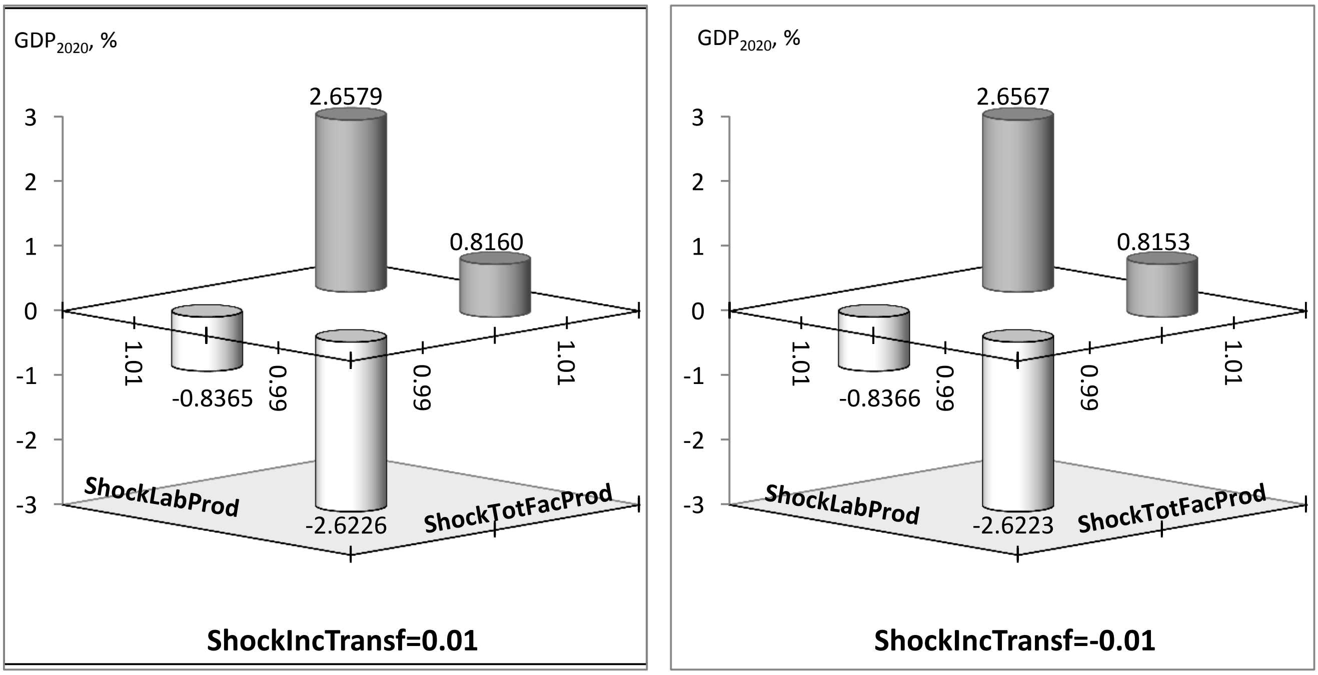
b)

Source: computer simulations with the RHOMOLO model. Evaluation in terms of average per cent deviation of real EU GDP in 2020 relative to the baseline projections. On the primary axes were plotted the results for ShockIncTransf=0.01.On the secondary vertical axis were plotted the results for ShockIncTransf=-0.01.

The almost coinciding, if plotted on the same axes, non-parallel lines in the interaction plots show that the ShockLabProd, and especially the ShockTotFacProd have large effects, although with little dependence on the level of ShockIncTransf, see Figure 3, a, b).

The third-order interaction of scenario shocks is very small, as the interaction effects of ShockLabProd and ShockTotFacProd nearly replicate each other at the different levels of ShockIncTransf, Figure 4:

Figure 4. The third-order interaction effects between ShockTotFacProd and ShockLabProd at the different levels of ShockIncTransf shock



Source: computer simulations with the RHOMOLO model. Evaluation in terms of average per cent deviation of real EU GDP in 2020 relative to the baseline projections.

Table 4 presents the combinations of elasticity parameters and scenario shocks that cause the most extreme fluctuations of GDP:

Table 4 The most extreme output responses

Sig_QS	Sig_ArmS	WgeCurveElast	ShockTotFacProd	ShockLabProd	ShockIncTransf	GDP, %
1.1	2.2	0.009	1.01	1.01	0.01	2.8279
1.1	2.2	0.009	1.01	1.01	0	2.8276
1.1	2.2	0.009	1.01	1.01	-0.01	2.8273
1.1	2.2	0.01	1.01	1.01	0.01	2.8121
1.1	2.2	0.01	1.01	1.01	0	2.8117
1.1	2.2	0.01	0.99	0.99	0	-2.7727
1.1	2.2	0.01	0.99	0.99	0.01	-2.7731
1.1	2.2	0.009	0.99	0.99	-0.01	-2.7852
1.1	2.2	0.009	0.99	0.99	0	-2.7856
1.1	2.2	0.009	0.99	0.99	0.01	-2.7860

Source: computer simulations with the RHOMOLO model. Evaluation in terms of average percent deviation of real EU GDP in 2020 relative to the baseline projections.

Based on the data in Table 4 we can draw a conclusion that the model is much more sensitive to the variation of the tfp and labour productivity parameters than to the changes in elasticities. The EU GDP reaches its minimum at the low levels of ShockTotFacProd, ShockLabProd and WgeCurveElast and at the high levels of ShockIncTransf, Sig_QS and Sig_ArmS. The EU GDP is at maximum at the high levels of all scenario shocks, Sig_QS and Sig_ArmS, and at the low level of WgeCurveElast. Interestingly, the five highest and five lowest GDP values are achieved at the maximum levels of Sig_QS and Sig_ArmS.

The analysis undertaken permits us to conclude that among the factors investigated within the framework of deterministic MSA the factor productivity parameters are the main drivers of model results.

Our approach proved to be computationally efficient, as each step of the MSA with 780 or 702 model runs takes around 2−2.5 hours to finish. To change the number of levels or to assign a different type of point estimates to the input parameters (e.g. zeros of Hermit or Legendre polynomials for a Gaussian Quadrature method, Hermeling et al 2008, 2013) requires marginal changes in the model code. Being robust and flexible, our technique and the codes can be used for virtually any static or dynamic model that is programmed in GAMS.

Considering that sensitivity of different response indicators can vary, an important direction of future research would be to test model responses in terms of different macroeconomic indicators (e.g. GDP, output, employment, real wages, net trade, household consumption and investments), so that correlation effects between different outputs are captured. Another important direction would be to decompose the response variability, constructing the variance based sensitivity indices (Saltelli A. et al, 2010, Sobol, 1990).

5 Conclusions

In this paper we presented a fast and frugal in terms of model iterations approach of conducting the multivariate sensitivity analysis of a very large and complex non-linear model.

One-at-a-time variation of each elasticity parameter for the different combinations of scenario shocks permitted to attribute the highest influence ranking to the elasticities that define possibilities of substitution between labour and capital, among the domestic and imported goods and to the wage curve elasticity.

All-at-a-time variation of the most influential elasticity parameters and scenario shocks demonstrated that the total factor productivity and labour productivity shocks are the main drivers of model results, showing strong individual and weak interaction effects.

The proposed approach permitted to rank the individual input parameters and their combinations by the order of influence on the results.

Being robust and flexible, our technique and the codes can be used for virtually any static or dynamic model that is programmed in GAMS requiring marginal changes in the model code.

Evaluation of the individual and interactions effects allows prioritize the econometric estimations of the most influential parameters, thus increasing the preciseness of policy impact assessment.

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List of abbreviations and definitions

CPU	Central processing unit
GAMS	General Algebraic Modelling Language
GDP	Gross domestic product
GDX	GAMS data exchange
LDR	Least Developed Regions
MSA	Multivariate sensitivity analysis
NUTS	Nomenclature of territorial units for statistics
NUTS2	The second level in the nomenclature of territorial units for statistics
TFP	Total factor productivity

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Annexes

Annex 1 The parent batch script for parallel execution of multiple model runs

```
::--------------------------------------------------------------------------------set path to the model location
cd "C:\Users\diukaol\Downloads\SSAJuly2017\CGEModel"
::--------------------------------------------------------------------------------set path to the gams.exe (if PATH environment variable is not set for GAMS)
 set GAMS="C:\PGM\GAMS\win64\24.8\gams.exe"
::--------------------------------------------------------------------------------set the directories to store the results of SA runs
set SSA=YES
set SSADir=SSA
set TempDir=%SSADir%\Temporary_SSA
set PivotDir=%SSADir%\PivotTables_SSA
::--------------------------------------------------------------------------------delete the results of previous runs
if exist %TempDir%\*                              ECHO Y | DEL   %TempDir%
if exist %PivotDir%\*                             ECHO Y | DEL   %PivotDir%
if exist %SSADir%\Combinations2Run.gms        ECHO Y | DEL   %SSADir%\Combinations2Run.gms
::--------------------------------------------------------------------------------set the number of processor cores on which to run the SA
set CPUS=%NUMBER_OF_PROCESSORS%
::--------------------------------------------------------------------------------set model settings:YES-dynamic;NO-static
set DynamicPolicyShocks=YES
::--------------------------------------------------------------------------------set the last year of model horizon
if %DynamicPolicyShocks%==NO   set LastYear=2010
if %DynamicPolicyShocks%==YES  set LastYear=2020
::--------------------------------------------------------------------------------set model settings:YES-flexible wages;NO-activate the wage curve
set FlexibleWages=NO
::--------------------------------------------------------------------------------set model settings:YES-imperfect competition;NO-perfect competition
set NEG=NO
::--------------------------------------------------------------------------------set multipliers for elasticities
set k1_elas="9/10"
set k2_elas="11/10"
::--------------------------------------------------------------------------------set multipliers for model shocks
set k1_IncTransf="1/100"
set k2_IncTransf="-1/100"
set k1_TotFacProd="9/100"
set k2_TotFacProd="11/100"
set k1_LabProd="9/100"
set k2_LabProd="11/100"
::--------------------------------------------------------------------------------YES-run SA for all combinations of model shocks changing 1 elasticity at a run
::--------------------------------------------------------------------------------NO-run SA for the selected combinations of elasticities and model shocks
set LoopChanging1ElasticityAtAtime=YES
if %LoopChanging1ElasticityAtAtime%==YES   goto LoopChanging1ElasticityAtAtime
::--------------------------------------------------------------------------------select the combinations of elasticities to run SA
if %LoopChanging1ElasticityAtAtime%==NO    set Run4Combinations=Sig_QS,Sig_ArmS,WgeCurveElast & goto Run4Combinations
::------------------------------------------------------------------ -------------pass the selected combination of the most influential elasticities to Combinations2Run.gms
:Run4Combinations
```

```
setlocal ENABLEDELAYEDEXPANSION
FOR  %%F IN (%Run4Combinations%) DO ( SET Vary_%%F=YES
echo $setglobal Vary_%%F !Vary_%%F!  >> %SSADir%\Combinations2Run.gms
                                                   )
:LoopChanging1ElasticityAtAtime
::--------------------------------------------------------------------------------pass the selected settings to SSA4CGE.gms
%GAMS% "%~dp0SSA4CGE.gms" --DynamicPolicyShocks=%DynamicPolicyShocks% --LastYear=%LastYear% --FlexibleWages=%FlexibleWages% --NEG=%NEG% ^
  --SSA=%SSA% --CPUS=%CPUS% --LoopChanging1ElasticityAtAtime=%LoopChanging1ElasticityAtAtime% --Run4Combinations="%Run4Combinations%"   ^
  --k1_elas=%k1_elas% --k2_elas=%k2_elas%    --k1_IncTransf=%k1_IncTransf%    --k2_IncTransf=%k2_IncTransf%      ^
  --k1_TotFacProd=%k1_TotFacProd% --k2_TotFacProd=%k2_TotFacProd%    --k1_LabProd=%k1_LabProd% --k2_LabProd=%k2_LabProd%   lo=2
::--------------------------------------------------------------------------------
if exist  SSA4CGE.log   move    SSA4CGE.log    %TempDir%\SSA4CGE.log
if exist  SSA4CGE.lst   move    SSA4CGE.lst     %TempDir%\SSA4CGE.lst
::------------------------------------------------------------------------------
IF %ERRORLEVEL% EQU 0   goto RunInParalel
IF %ERRORLEVEL% NEQ 0   goto Error
::------------------------------------------------------------------------------run in parallel
:RunInParalel
FOR /L  %%G IN (1,1,%CPUS%) DO  ( start  %TempDir%\RunPara%%G.cmd  )
::------------------------------------------------------------------------------delayed execution procedure
set file=%TempDir%\X.txt
set /a counter=0
:WaitAll2Finish
PING -n 60 127.0.0.1>nul
  @echo  Wait for all model runs to finish
  for /f %%F in ( ' type %file% ^|find /c /v   " "  '  ) do set /a counter=%%F
  if %counter% NEQ %CPUS%        goto WaitAll2Finish
  if %counter% EQU %CPUS%        goto ProducePivotTables
:ProducePivotTables
@echo Now all model runs are finished! Start merging the results and producing the pivot tables!
%GAMS%  %PivotDir%\Pivot_SSA.gms  lo=2
  if exist Pivot_SSA.log    move  Pivot_SSA.log    %PivotDir%\Pivot_SSA.log
  if exist Pivot_SSA.lst     move  Pivot_SSA.lst    %PivotDir%\Pivot_SSA.lst
  if exist    merged.gdx    move     merged.gdx    %PivotDir%\merged.gdx

IF %ERRORLEVEL% EQU 0   pause
IF %ERRORLEVEL% NEQ 0   goto Error
:Error
@echo   Look for a mistake!
 ::--------------------------------------------------------------------------------delete the GAMS scratch directories
FOR /D /R %%X IN (225*) DO RD /S /Q "%%X"
pause
exit
```

Annex 2. The GAMS program code for solution management and report generation

```
$Onmulti  $offOrder  $ONGLOBAL  $Oneolcom  $Oninline
*-------------------------------------------------------------------------------set directories to read/write the files
$if not set  SSADir                              $set   SSADir              SSA
$if not set  TempDir                             $set  TempDir          %SSADir%\Temporary_SSA
$if not set  PivotDir                            $set  PivotDir         %SSADir%\PivotTables_SSA
*-------------------------------------------------------------------------------set the default model settings  if they were not set in .cmd
$if not set  DynamicPolicyShocks                 $set  DynamicPolicyShocks     NO
$if not set  LastYear                            $set   LastYear                2010
$if not set  FlexibleWages                       $set   FlexibleWages          NO
$if not set  NEG                                 $set   NEG                     NO
*-------------------------------------------------------------------------------set the default counter for each combination of elasticities & shocks
$if not set  ActiveRun                           $set   ActiveRun               0
*------------------------------------------------------------------------------- set the default step of MSA
$if not set LoopChanging1ElasticityAtAtime       $set   LoopChanging1ElasticityAtAtime      NO
*-------------------------------------------------------------------------------set the default combinations of elasticities for the second step of MSA
$ifi %LoopChanging1ElasticityAtAtime%==NO    $if not set Run4Combinations   $set Run4Combinations Sig_ZS,Sig_XS,Sig_QS
$ifi %LoopChanging1ElasticityAtAtime%==NO    $include  %SSADir%\Combinations2Run.gms
*-------------------------------------------------------------------------------
$if not set  Vary_Sig_FacSupLab_H    $set  Vary_Sig_FacSupLab_H      NO
$if not set  Vary_Sig_ConHou         $set  Vary_Sig_ConHou            NO
$if not set  Vary_Sig_ZS             $set  Vary_Sig_ZS                NO
$if not set  Vary_Sig_XS             $set  Vary_Sig_XS                NO
$if not set  Vary_Sig_QS             $set  Vary_Sig_QS                NO
$if not set  Vary_Sig_KapS           $set  Vary_Sig_KapS              NO
$if not set  Vary_Sig_LabS           $set  Vary_Sig_LabS              NO
$if not set  Vary_Sig_Inv            $set  Vary_Sig_Inv               NO
$if not set  Vary_Sig_ConGov         $set  Vary_Sig_ConGov            NO
$if not set  Vary_Sig_ArmS           $set  Vary_Sig_ArmS              NO
$if not set  Vary_Sig_EuroInv        $set  Vary_Sig_EuroInv           NO
$if not set  Vary_Sig_EuroKap        $set  Vary_Sig_EuroKap           NO
$if not set  Vary_Sig_Arm_RnD        $set  Vary_Sig_Arm_RnD           NO
$if not set  Vary_KnowK_Ext          $set  Vary_KnowK_Ext             NO
$if not set  Vary_WgeCurveElast      $set  Vary_WgeCurveElast         NO
*------------------------------------------------------------------------------- coefficients to multiply the base values of elasticities
$if not set k1_elas               $set k1_elas              0.9
$if not set k2_elas               $set k2_elas              1.1
$if not set k1_TotFacProd         $set k1_TotFacProd      0.99
$if not set k2_TotFacProd         $set k2_TotFacProd      1.01
$if not set k1_LabProd            $set k1_LabProd          0.99
$if not set k2_LabProd            $set k2_LabProd          1.01
$if not set k1_IncTransf          $set k1_IncTransf        0.01
$if not set k2_IncTransf          $set k2_IncTransf       "-0.01"
*NB:  1 means absence of any shock - for the multiplicative shock ; 0 - absence of any shock for the additive shock
$if not set ShockTotFacProd      $set ShockTotFacProd      "1"
```

```
$if not set ShockLabProd         $set ShockLabProd         "1"
$if not set ShockIncTransf       $set ShockIncTransf       "0"
*---------------------------------------------------------------------------
$EvalGlobal   ShockTotFacProdk1   %ShockTotFacProd%*%k1_TotFacProd%
$EvalGlobal   ShockTotFacProdk2   %ShockTotFacProd%*%k2_TotFacProd%
$EvalGlobal   ShockLabProdk1      %ShockLabProd%*%k1_LabProd%
$EvalGlobal   ShockLabProdk2      %ShockLabProd%*%k2_LabProd%
$EvalGlobal   ShockIncTransfk1    %ShockIncTransf%+%k1_IncTransf%
$EvalGlobal   ShockIncTransfk2    %ShockIncTransf%%k2_IncTransf%
*---------------------------------------------------------------------------
SETS
ShockTotFacProd   alternative values of factor productivity shock    / "%ShockTotFacProd%","%ShockTotFacProdk1%","%ShockTotFacProdk2%"   /,
ShockLabProd      alternative values of labour productivity shock    / "%ShockLabProd%"   ,"%ShockLabProdk1%"   ,"%ShockLabProdk2%"          /,
ShockIncTransf    alternative values of income transfer shock        / "%ShockIncTransf%" ,"%ShockIncTransfk1%" ,"%ShockIncTransfk2%"       /,
BAUshocks(ShockTotFacProd,ShockLabProd,ShockIncTransf)  baseline values of model shocks
/ "%ShockTotFacProd%"."%ShockLabProd%"."%ShockIncTransf%" /;
*---------------------------------------------------------------------------
 $EvalGlobal   Sig_FacSupLab_H   1
$EvalGlobal   Sig_ConHou           1.2
$EvalGlobal   Sig_ZS                0.2
$EvalGlobal   Sig_XS                0.25
$EvalGlobal   Sig_QS               1
$EvalGlobal   Sig_KapS             2
$EvalGlobal   Sig_LabS             2
$EvalGlobal   Sig_Inv              1.3
$EvalGlobal   Sig_ConGov           0.3
$ifi %NEG%==NO                     $EvalGlobal   Sig_ArmS           2
$ifi %NEG%==YES                    $EvalGlobal   Sig_ArmS           6
$EvalGlobal   Sig_EuroInv          3
$EvalGlobal   Sig_EuroKap          3
$EvalGlobal   Sig_Arm_RnD          3
$EvalGlobal   KnowK_Ext            0.0053
$EvalGlobal   WgeCurveElast        0.1
*---------------------------------------------------------------------------
$EvalGlobal   Sig_FacSupLab_Hk1       %Sig_FacSupLab_H%*%k1_elas%
$EvalGlobal   Sig_ConHouk1            %Sig_ConHou%        *%k1_elas%
$EvalGlobal   Sig_ZSk1                %Sig_ZS%            *%k1_elas%
$EvalGlobal   Sig_XSk1                %Sig_XS%            *%k1_elas%
$EvalGlobal   Sig_QSk1                %Sig_QS%            *%k1_elas%
$EvalGlobal   Sig_KapSk1              %Sig_KapS%          *%k1_elas%
$EvalGlobal   Sig_LabSk1              %Sig_LabS%          *%k1_elas%
$EvalGlobal   Sig_Invk1               %Sig_Inv%           *%k1_elas%
$EvalGlobal   Sig_ConGovk1            %Sig_ConGov%        *%k1_elas%
$EvalGlobal   Sig_ArmSk1              %Sig_ArmS%          *%k1_elas%
$EvalGlobal   Sig_EuroInvk1           %Sig_EuroInv%       *%k1_elas%
$EvalGlobal   Sig_EuroKapk1           %Sig_EuroKap%       *%k1_elas%
```

```
$EvalGlobal   Sig_Arm_RnDk1           %Sig_Arm_RnD%     *%k1_elas%
$EvalGlobal   KnowK_Extk1             %KnowK_Ext%       *%k1_elas%
$EvalGlobal   WgeCurveElastk1         %WgeCurveElast%   *%k1_elas%
*---------------------------------------------------------------------------
$EvalGlobal   Sig_FacSupLab_Hk2       %Sig_FacSupLab_H%*%k2_elas%
$EvalGlobal   Sig_ConHouk2            %Sig_ConHou%      *%k2_elas%
$EvalGlobal   Sig_ZSk2                %Sig_ZS%          *%k2_elas%
$EvalGlobal   Sig_XSk2                %Sig_XS%          *%k2_elas%
$EvalGlobal   Sig_QSk2                %Sig_QS%          *%k2_elas%
$EvalGlobal   Sig_KapSk2              %Sig_KapS%        *%k2_elas%
$EvalGlobal   Sig_LabSk2              %Sig_LabS%        *%k2_elas%
$EvalGlobal   Sig_Invk2               %Sig_Inv%         *%k2_elas%
$EvalGlobal   Sig_ConGovk2            %Sig_ConGov%      *%k2_elas%
$EvalGlobal   Sig_ArmSk2              %Sig_ArmS%        *%k2_elas%
$EvalGlobal   Sig_EuroInvk2           %Sig_EuroInv%     *%k2_elas%
$EvalGlobal   Sig_EuroKapk2           %Sig_EuroKap%     *%k2_elas%
$EvalGlobal   Sig_Arm_RnDk2           %Sig_Arm_RnD%     *%k2_elas%
$EvalGlobal   KnowK_Extk2             %KnowK_Ext%       *%k2_elas%
$EvalGlobal   WgeCurveElastk2         %WgeCurveElast%   *%k2_elas%
**--------------------------------------------------------------------------add 0 to fractions and .0 to integers to avoid repetitive entries in a set
$ifthen %LoopChanging1ElasticityAtAtime%=="YES"
SETS  AllElasticities   /
"%Sig_FacSupLab_Hk1%"                     , "%Sig_FacSupLab_Hk2%"                  ,
"%Sig_ConHouk1%0"                         , "%Sig_ConHouk2%0"                      ,
"%Sig_ZSk1%00"                            , "%Sig_ZSk2%00"                         ,
"%Sig_XSk1%000"                           , "%Sig_XSk2%000"                        ,
"%Sig_QSk1%0000"                          , "%Sig_QSk2%0000"                       ,
"%Sig_KapSk1%00000"                       , "%Sig_KapSk2%00000"                    ,
"%Sig_LabSk1%000000"                      , "%Sig_LabSk2%000000"                   ,
"%Sig_Invk1%0000000"                      , "%Sig_Invk2%0000000"                   ,
"%Sig_ConGovk1%00000000"                  , "%Sig_ConGovk2%00000000"               ,
"%Sig_ArmSk1%000000000"                   , "%Sig_ArmSk2%000000000"                ,
"%Sig_EuroInvk1%0000000000"               , "%Sig_EuroInvk2%0000000000"            ,
"%Sig_EuroKapk1%00000000000"              , "%Sig_EuroKapk2%00000000000"           ,
"%Sig_Arm_RnDk1%000000000000"             , "%Sig_Arm_RnDk2%000000000000"          ,
"%KnowK_Extk1%0000000000000"              , "%KnowK_Extk2%0000000000000"           ,
"%WgeCurveElastk1%00000000000000"  , "%WgeCurveElastk2%00000000000000"
/ ;  display AllElasticities;
*---------------------------------------------------------------------------
SETS
S_FacSupLab_H(AllElasticities)  / "%Sig_FacSupLab_Hk1%"         , "%Sig_FacSupLab_Hk2%"          /,
S_ConHou(AllElasticities)       / "%Sig_ConHouk1%0"             , "%Sig_ConHouk2%0"              /,
S_ZS(AllElasticities)           / "%Sig_ZSk1%00"                , "%Sig_ZSk2%00"                 /,
S_XS(AllElasticities)           / "%Sig_XSk1%000"               , "%Sig_XSk2%000"                /,
S_QS(AllElasticities)           / "%Sig_QSk1%0000"              , "%Sig_QSk2%0000"               /,
S_KapS(AllElasticities)         / "%Sig_KapSk1%00000"           , "%Sig_KapSk2%00000"            /,
```

```
S_LabS(AllElasticities)              / "%Sig_LabSk1%000000"                          , "%Sig_LabSk2%000000"                          /,
S_Inv(AllElasticities)               / "%Sig_Invk1%0000000"                          , "%Sig_Invk2%0000000"                          /,
S_ConGov(AllElasticities)            / "%Sig_ConGovk1%00000000"                      , "%Sig_ConGovk2%00000000"                      /,
S_ArmS(AllElasticities)              / "%Sig_ArmSk1%000000000"                       , "%Sig_ArmSk2%000000000"                       /,
S_EuroInv(AllElasticities)           / "%Sig_EuroInvk1%0000000000"                   , "%Sig_EuroInvk2%0000000000"                   /,
S_EuroKap(AllElasticities)           / "%Sig_EuroKapk1%00000000000"                  , "%Sig_EuroKapk2%00000000000"                  /,
S_Arm_RnD(AllElasticities)           / "%Sig_Arm_RnDk1%0000000000000"                , "%Sig_Arm_RnDk2%0000000000000"                /,
S_KnowK_Ext(AllElasticities)         / "%KnowK_Extk1%00000000000000"                 , "%KnowK_Extk2%00000000000000"                 /,
S_WgeCurveElast(AllElasticities) / "%WgeCurveElastk1%000000000000000"    , "%WgeCurveElastk2%000000000000000"    /;
*------------------------------------------------------------------------------define which elasticities we vary when we run for their combinations
$elseif %LoopChanging1ElasticityAtAtime%=="NO"
$ifi  %Vary_Sig_FacSupLab_H%==YES  $set  valuesSig_FacSupLab_H   ,"%Sig_FacSupLab_Hk1%","%Sig_FacSupLab_Hk2%"
$ifi  %Vary_Sig_ConHou%==YES         $set  valuesSig_ConHou         ,"%Sig_ConHouk1%","%Sig_ConHouk2%"
$ifi  %Vary_Sig_ZS%==YES              $set  valuesSig_ZS              ,"%Sig_ZSk1%","%Sig_ZSk2%"
$ifi  %Vary_Sig_XS%==YES              $set  valuesSig_XS              ,"%Sig_XSk1%","%Sig_XSk2%"
$ifi  %Vary_Sig_QS%==YES              $set  valuesSig_QS              ,"%Sig_QSk1%","%Sig_QSk2%"
$ifi  %Vary_Sig_KapS%==YES            $set  valuesSig_KapS            ,"%Sig_KapSk1%","%Sig_KapSk2%"
$ifi  %Vary_Sig_LabS%==YES            $set  valuesSig_LabS            ,"%Sig_LabSk1%","%Sig_LabSk2%"
$ifi  %Vary_Sig_Inv%==YES             $set  valuesSig_Inv             ,"%Sig_Invk1%","%Sig_Invk2%"
$ifi  %Vary_Sig_ConGov%==YES          $set  valuesSig_ConGov          ,"%Sig_ConGovk1%","%Sig_ConGovk2%"
$ifi  %Vary_Sig_ArmS%==YES            $set  valuesSig_ArmS            ,"%Sig_ArmSk1%","%Sig_ArmSk2%"
$ifi  %Vary_Sig_EuroInv%==YES         $set  valuesSig_EuroInv         ,"%Sig_EuroInvk1%","%Sig_EuroInvk2%"
$ifi  %Vary_Sig_EuroKap%==YES         $set  valuesSig_EuroKap         ,"%Sig_EuroKapk1%","%Sig_EuroKapk2%"
$ifi  %Vary_Sig_Arm_RnD%==YES         $set  valuesSig_Arm_RnD         ,"%Sig_Arm_RnDk1%","%Sig_Arm_RnDk2%"
$ifi  %Vary_KnowK_Ext%==YES           $set  valuesKnowK_Ext           ,"%KnowK_Extk1%","%KnowK_Extk2%"
$ifi  %Vary_WgeCurveElast%==YES       $set  valuesWgeCurveElast       ,"%WgeCurveElastk1%","%WgeCurveElastk2%"
SETS
 S_FacSupLab_H      / "%Sig_FacSupLab_H%" %valuesSig_FacSupLab_H%  /,
 S_ConHou           / "%Sig_ConHou%"       %valuesSig_ConHou%        /,
 S_ZS               / "%Sig_ZS%"           %valuesSig_ZS%            /,
 S_XS               / "%Sig_XS%"           %valuesSig_XS%            /,
 S_QS               / "%Sig_QS%"           %valuesSig_QS%            /,
 S_KapS             / "%Sig_KapS%"         %valuesSig_KapS%          /,
 S_LabS             / "%Sig_LabS%"         %valuesSig_LabS%          /,
 S_Inv              / "%Sig_Inv%"          %valuesSig_Inv%           /,
 S_ConGov           / "%Sig_ConGov%"       %valuesSig_ConGov%        /,
 S_ArmS             / "%Sig_ArmS%"         %valuesSig_ArmS%          /,
 S_EuroInv          / "%Sig_EuroInv%"      %valuesSig_EuroInv%       /,
 S_EuroKap          / "%Sig_EuroKap%"      %valuesSig_EuroKap%       /,
 S_Arm_RnD          / "%Sig_Arm_RnD%"      %valuesSig_Arm_RnD%       /,
 S_KnowK_Ext        / "%KnowK_Ext%"        %valuesKnowK_Ext%         /,
 S_WgeCurveElast   / "%WgeCurveElast%"    %valuesWgeCurveElast%     /;
$endif
*------------------------------------------------------------------------------
parameter j counter of combinations;  j =0 ;
*------------------------------------------------------------------------------
```

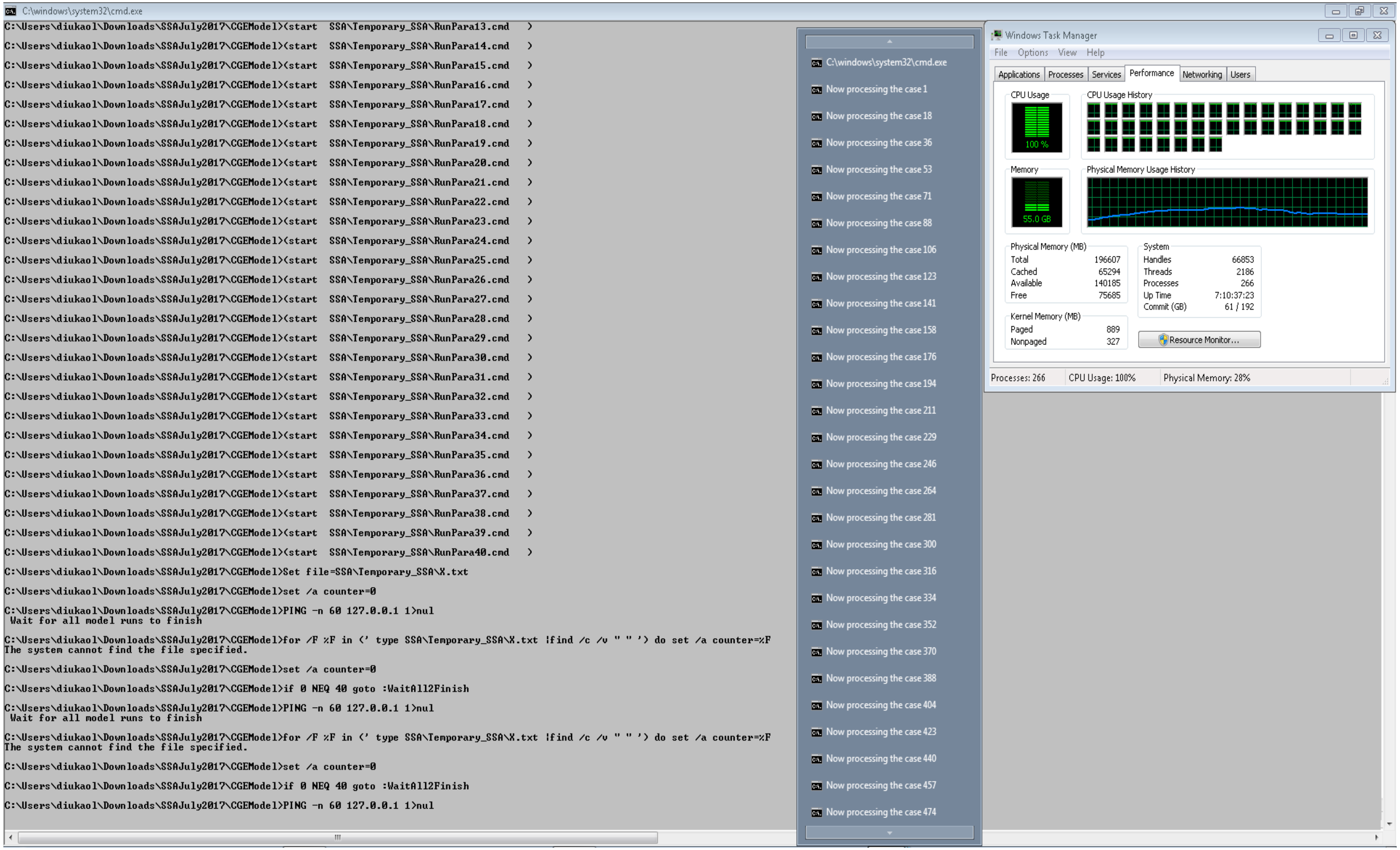
```
file ibat ;   ibat.nd=0; ibat.lw=0; ibat.nw=0;
put ibat;
$ifi %LoopChanging1ElasticityAtAtime%=="YES"
loop( (AllElasticities,ShockTotFacProd, ShockLabProd, ShockIncTransf)${ not BAUshocks(ShockTotFacProd,ShockLabProd,ShockIncTransf) },
$ifi %LoopChanging1ElasticityAtAtime%=="NO"
loop( (S_FacSupLab_H,S_ConHou,S_ZS,S_XS,S_QS,S_KapS,S_LabS,S_ConGov,S_Inv,S_EuroInv,S_EuroKap,S_ArmS,S_Arm_RnD,S_KnowK_Ext,
S_WgeCurveElast,ShockTotFacProd,ShockLabProd,ShockIncTransf )${ not BAUshocks(ShockTotFacProd,ShockLabProd,ShockIncTransf) },
  j=j+1;
put_utility  'ren' / '%TempDir%':0  '/':0  j:0 '.bat':0 ;
put   'title Now processing the case ',j, ''/;
put   'set DynamicPolicyShocks="%DynamicPolicyShocks%"'/;
put   'set LastYear="%LastYear%"'/;
put   'set NEG="%NEG%"'/;
put   'set FlexibleWages="%FlexibleWages%"'/;
put   '%GAMS%    %SSADir%\RunCGE.gms '
put   '--SSA=YES  --ActiveRun=',j,' --DynamicPolicyShocks=%DynamicPolicyShocks% --LastYear=%LastYear% ^'/
put   ' --FlexibleWages=%FlexibleWages% --NEG=%NEG% ^'/
$ifthen %LoopChanging1ElasticityAtAtime%=="YES"
**-----------------------------------------------changing one elasticity keeping the rest fixed for all shocks combinations
 if(S_ZS(AllElasticities)                  , put  ' --Sig_ZS='AllElasticities.tl,                  '^'/)
 if(S_QS(AllElasticities)                  , put  ' --Sig_QS='AllElasticities.tl,                  '^'/)
 if(S_XS(AllElasticities)                  , put  ' --Sig_XS='AllElasticities.tl,                  '^'/)
 if(S_FacSupLab_H(AllElasticities)    , put  ' --Sig_FacSupLab_H='AllElasticities.tl,  '^'/)
 if(S_ConHou(AllElasticities)            , put  ' --Sig_ConHou='AllElasticities.tl,          '^'/)
 if(S_KapS(AllElasticities)              , put  ' --Sig_KapS='AllElasticities.tl,              '^'/)
 if(S_LabS(AllElasticities)              , put  ' --Sig_LabS='AllElasticities.tl,              '^'/)
 if(S_Inv(AllElasticities)                , put  ' --Sig_Inv='AllElasticities.tl,                '^'/)
 if(S_ConGov(AllElasticities)            , put  ' --Sig_ConGov='AllElasticities.tl,          '^'/)
 if(S_EuroInv(AllElasticities)           , put  ' --Sig_EuroInv='AllElasticities.tl,         '^'/)
 if(S_EuroKap(AllElasticities)          , put  ' --Sig_EuroKap='AllElasticities.tl,         '^'/)
 if(S_KnowK_Ext(AllElasticities)       , put  ' --KnowK_Ext='AllElasticities.tl,          '^'/)
 if(S_WgeCurveElast(AllElasticities)  , put  ' --WgeCurveElast='AllElasticities.tl,     '^'/)
 if(S_ArmS(AllElasticities)              , put  ' --Sig_ArmS='AllElasticities.tl,            '^'/)
 if(S_Arm_RnD(AllElasticities)          , put  ' --Sig_Arm_RnD='AllElasticities.tl,       '^'/)
$elseif %LoopChanging1ElasticityAtAtime%=="NO"
* elasticity combinations
put  ' --Sig_ZS=',S_ZS.tl,' --Sig_XS=',S_XS.tl,' --Sig_QS=',S_QS.tl,' --Sig_LabS=',S_LabS.tl, '  --Sig_KapS=',S_KapS.tl,    '^'  /;
put  ' --Sig_FacSupLab_H=',S_FacSupLab_H.tl,'  --Sig_ConHou=',S_ConHou.tl,'  --Sig_ConGov=',S_ConGov.tl,              '^'  /;
put  ' --Sig_Inv=',S_Inv.tl,'  --Sig_EuroInv=',S_EuroInv.tl,'  --Sig_EuroKap=',S_EuroKap.tl,'  --Sig_ArmS=',S_ArmS.tl,    '^'   /;
put  ' --Sig_Arm_RnD=',S_Arm_RnD.tl,' --KnowK_Ext=',S_KnowK_Ext.tl,'  --WgeCurveElast=',S_WgeCurveElast.tl,         '^'  /;
$endif
*-----------------------------------------------------------------------------------------------model shocks combinations
put ' --ShockTotFacProd=',ShockTotFacProd.tl,' --ShockLabProd=',ShockLabProd.tl,' --ShockIncTransf=',ShockIncTransf.tl,   '^'  /;
    );
putclose  ibat
*--------------------------------------------------------------------------------
```

```
* Distribute model runs among the parallel processes
*------------------------------------------------------------------------------
$Eval  NuRuns4Shocks  card(ShockTotFacProd)*card(ShockLabProd)*card(ShockIncTransf)-1
$Eval NuRuns4Elasticities card(S_ZS)*card(S_XS)*card(S_QS)*card(S_LabS)*card(S_KapS)*card(S_FacSupLab_H)*card(S_ConHou)*card(S_ConGov)*card(S_Inv)*
card(S_EuroInv)*card(S_EuroKap)*card(S_ArmS)*card(S_Arm_RnD)*card(S_KnowK_Ext)*card(S_WgeCurveElast)

$ifi   %LoopChanging1ElasticityAtAtime%=="YES"  $Eval  NuRuns  card(AllElasticities)*%NuRuns4Shocks%
$ifi   %LoopChanging1ElasticityAtAtime%=="NO"   $Eval  NuRuns  %NuRuns4Elasticities%*%NuRuns4Shocks%

set          cjob  parallel processes = the number of CPUs   / cjob1*cjob%CPUS% /,
               jj    number of model runs                        / 1*%NuRuns%        /,
assign(cjob,jj)  model runs assigned to the parallel processes ;

loop(   (cjob,jj),
assign(cjob,jj)$[  ( ord(jj) le {card(jj)/card(cjob)}* ord(cjob)     )  and
                ( ord(jj) gt {card(jj)/card(cjob)}*{ord(cjob) -1} )
             ]= YES  ;
      ); display  assign ;
abort$sum(jj, abs(sum(assign(cjob,jj),1)-1) ) "model runs are not correctly assigned";
*------------------------------------------------------------------------------make the parent batch file wait for the parallel child processes to finish
file f ;  f.nd=0; f.lw=0; f.nw=0;
loop{  cjob,
  put f, put_utility 'ren'/ '%TempDir%':0  '/':0  'RunPara',ord(cjob):0:0,'.cmd';
        loop( assign(cjob,jj),
put f, "call  %TempDir%\", ord(jj):0:0,'.bat'                                          /;
           );
put f, '@echo Have completed allocated to me model runs!'                         /;
put f, '@echo Now I will write my number to the file X.txt and close down !'    /;
put f, '>>%TempDir%\X.txt echo ',ord(cjob), ''                                     /;
putclose f,  "EXIT"                                                                  /;
     };
*------------------------------------------------------------------------------
*Merge the results of all model runs and produce pivot tables
*------------------------------------------------------------------------------
file  Pivoting /%PivotDir%\Pivot_SSA.gms/;
put  Pivoting ;
$onputS
*------------------------------------------------------------------------------
$if not set  SSADir                              $set SSADir                               SSA
$if not set  TempDir                             $set TempDir                              %SSADir%\Temporary_SSA
$if not set  PivotDir                            $set PivotDir                             %SSADir%\PivotTables_SSA
*------------------------------------------------------------------------------
$if not set  DynamicPolicyShocks                 $set DynamicPolicyShocks                   NO
$if not set  LastYear                             $set LastYear                               2010
$if not set  LoopChanging1ElasticityAtAtime    $set LoopChanging1ElasticityAtAtime       NO
*------------------------------------------------------------------------------extract the sets from any .gdx file
```

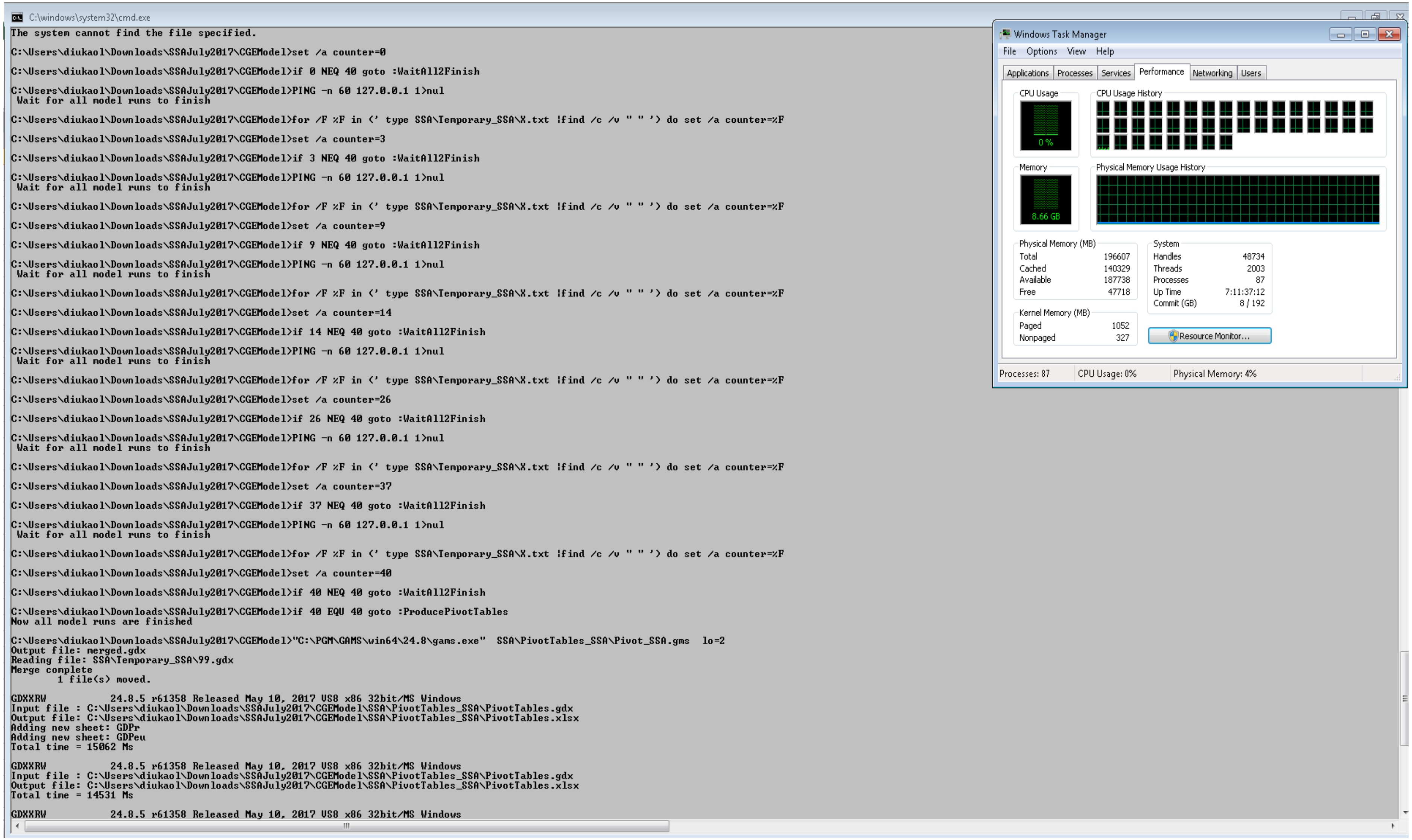
```
set T, Reg;
$gdxin %TempDir%\1.gdx
$load T
$load Reg
$gdxin
*----------------------------------------------------------------------------
$set  Elasticities Sig_FacSupLab_H, Sig_ConHou, Sig_ZS, Sig_QS, Sig_XS, Sig_KapS, Sig_LabS, Sig_Inv, Sig_ConGov, Sig_ArmS, Sig_EuroInv, Sig_EuroKap,
Sig_Arm_RnD, KnowK_Ext, WgeCurveElast
$set  Shocks  ShockTotFacProd, ShockLabProd, ShockIncTransf
alias (%Elasticities%,*); alias (*,%Shocks%);
*----------------------------------------------------------------------------merge .gdx files containing the results of individual model runs:
$call 'gdxmerge %TempDir%\*.gdx '
*----------------------------------------------------------------------------extract the results of MSSA runs:
$gdxin  merged.gdx
*----------------------------------------------------------------------------
set Merged_set_1                                    numbers of SA model runs;
$load Merged_set_1 = Merged_set_1
set Elasticities(Merged_set_1,%Elasticities%)      combinations of elasticity parameters;
$load Elasticities=Elasticities
set Shocks(Merged_set_1,%Shocks%)                combinations of model shocks;
$load Shocks=Shocks
parameter RealGDP(Merged_set_1,T,Reg)            real GDP: % deviation from the base year values ;
$load RealGDP
parameter RealGDPe(Merged_set_1,T,Reg)           real GDP:  mln euro;
$load RealGDPe
parameter RealGDPeuE(Merged_set_1,T)             real GDP in the EU:mln euro;
$load RealGDPeuE
$gdxin
*----------------------------------------------------------------------------
$call 'if exist merged.gdx   move  merged.gdx  %PivotDir%\'
*----------------------------------------------------------------------------
set  ElasticitiesShocks(Merged_set_1,%Elasticities%,%Shocks%) combinations of elasticity parameters and model shocks ;
ElasticitiesShocks(Merged_set_1,%Elasticities%,%Shocks%) =Elasticities(Merged_set_1,%Elasticities%)*Shocks(Merged_set_1,%Shocks%);
*----------------------------------------------------------------------------redefine parameters over the set of elasticity and shocks combinations
Parameters  RealGDP1(%Elasticities%,%Shocks%,T,Reg), GDPrE(%Elasticities%,%Shocks%,T,Reg), GDPeuE(%Elasticities%,%Shocks%,T)    ;
*----------------------------------------------------------------------------Attn: not to exceed 20 dimensions
RealGDP1      (%Elasticities%,%Shocks%,T,Reg)=
sum(ElasticitiesShocks(Merged_set_1,%Elasticities%,%Shocks%)${RealGDP(Merged_set_1,T,Reg) ne 0}, RealGDP(Merged_set_1,T,Reg)      ) ;
GDPrE          (%Elasticities%,%Shocks%,T,Reg)=
sum(ElasticitiesShocks(Merged_set_1,%Elasticities%,%Shocks%), RealGDPe(Merged_set_1,T,Reg)   ) ;
GDPeuE          (%Elasticities%,%Shocks%,T)    =
sum(ElasticitiesShocks(Merged_set_1,%Elasticities%,%Shocks%), RealGDPeuE(Merged_set_1,T)     ) ;
*----------------------------------------------------------------------------
$set title  gdxxrw i=%PivotDir%\PivotTables.gdx   o=%PivotDir%\PivotTables.xlsx  text=
*----------------------------------------------------------------------------
set  Header /%Elasticities%,%Shocks%,"YEAR"/;
```

```
*------------------------------------------------------------------------------
execute_unload  '%PivotDir%\PivotTables.gdx',Header, RealGDP1,GDPrE,GDPeuE
$onecho >gdxxrw.rsp
set=Header          rng="GDP!a2"        values=nodata   rdim=0     cdim=1
par=RealGDP1        rng="GDP!a3"                        rdim=19    cdim=1
set=Header          rng="GDPr!a2"       values=nodata   rdim=0     cdim=1
par=GDPrE           rng="GDPr!a3"                       rdim=19    cdim=1
set=Header          rng="GDPeu!a2"      values=nodata   rdim=0     cdim=1
par=GDPeuE          rng="GDPeu!a3"                      rdim=18    cdim=1
$offecho
execute 'gdxxrw i=%PivotDir%\PivotTables.gdx   o=%PivotDir%\PivotTables.xlsx  @gdxxrw.rsp';
execute '%title%"Elasticity Parameters:"                                    rng=GDP!a1'
execute '%title%"Model Shocks:"                                             rng=GDP!p1'
execute '%title%"real GDP: % deviation from the base year values"   rng=GDP!t1'
execute '%title%"Elasticity Parameters:"                                    rng=GDPr!a1'
execute '%title%"Model Shocks:"                                             rng=GDPr!p1'
execute '%title%"real GDP: NUTS2,mln euro"                                  rng=GDPr!t1'
execute '%title%"Elasticity Parameters:"                                    rng=GDPeu!a1'
execute '%title%"Model Shocks:"                                             rng=GDPeu!p1'
execute '%title%"real GDP, EU: mln euro"                                    rng=GDPeu!t1'
execute '=shellexecute %PivotDir%\PivotTables.xlsx';
$offput
putclose Pivoting
```

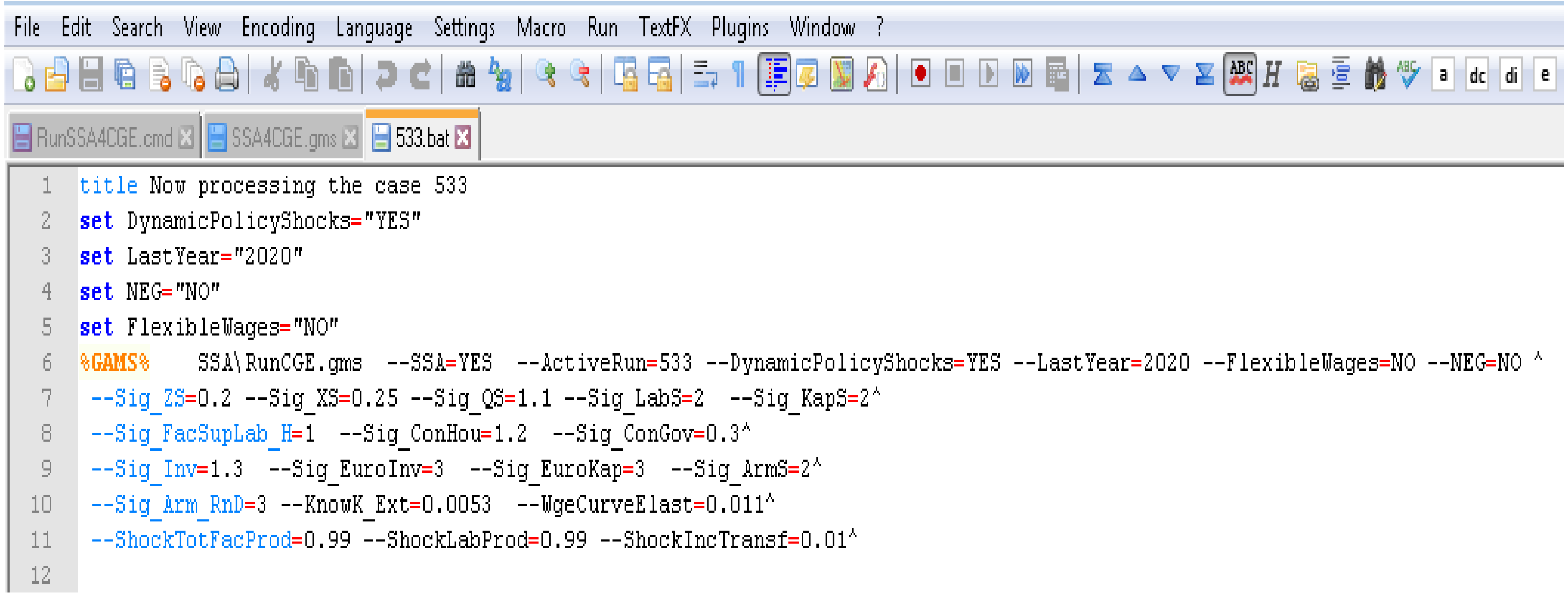
Annex 3. Illustration of the parallel execution of multiple model instances



Annex 4. Illustration of the delayed execution procedure

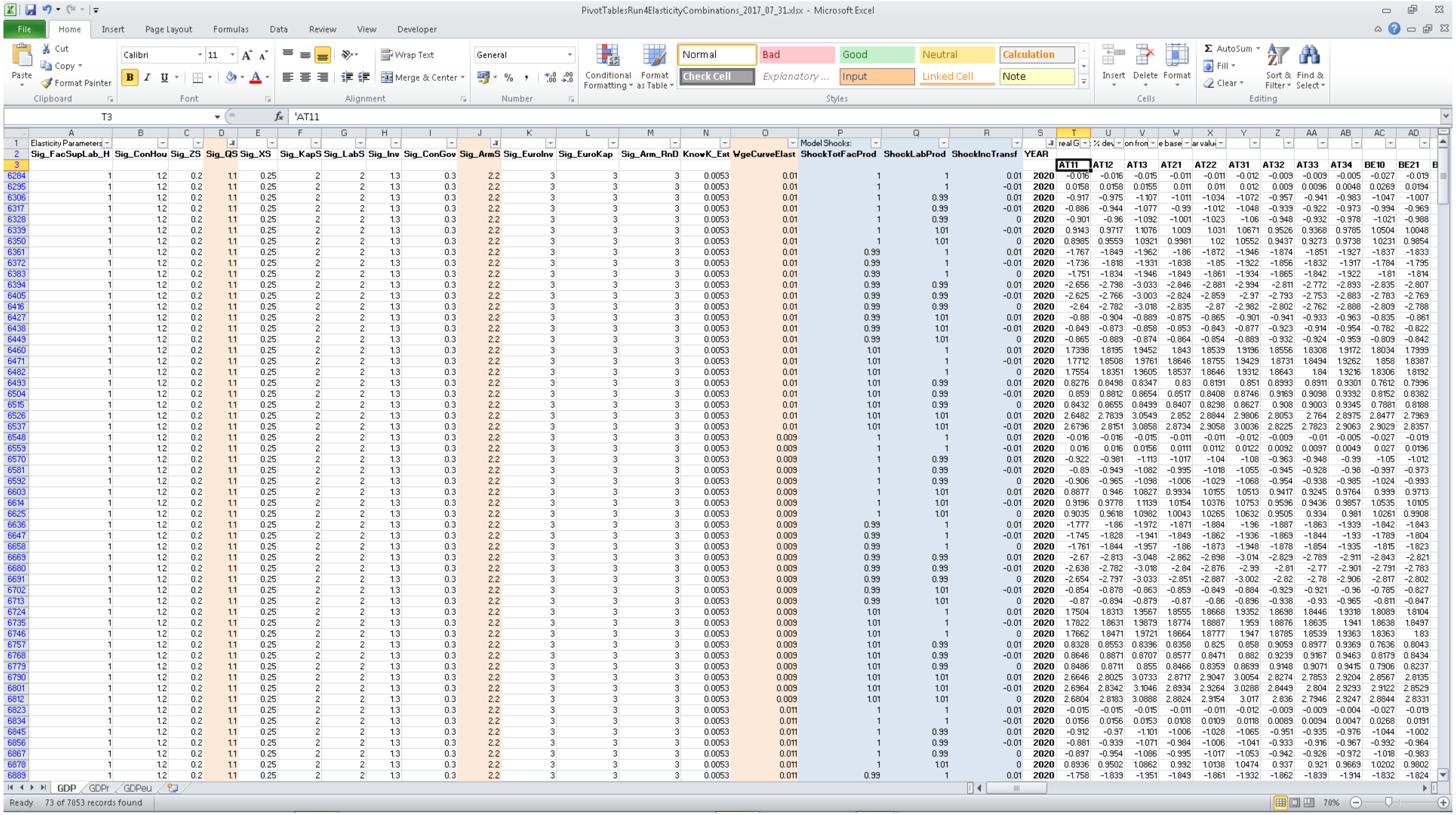


Annex 5. An example of a batch file which runs a single instance of RHOMOLO for a given combinations of elasticity parameters and scenario shocks




```
title Now processing the case 533
set DynamicPolicyShocks="YES"
set LastYear="2020"
set NEG="NO"
set FlexibleWages="NO"
%GAMS%    SSA\RunCGE.gms  --SSA=YES  --ActiveRun=533 --DynamicPolicyShocks=YES --LastYear=2020 --FlexibleWages=NO --NEG=NO ^
 --Sig_ZS=0.2 --Sig_XS=0.25 --Sig_QS=1.1 --Sig_LabS=2  --Sig_KapS=2^
 --Sig_FacSupLab_H=1  --Sig_ConHou=1.2  --Sig_ConGov=0.3^
 --Sig_Inv=1.3  --Sig_EuroInv=3  --Sig_EuroKap=3  --Sig_ArmS=2^
 --Sig_Arm_RnD=3 --KnowK_Ext=0.0053  --WgeCurveElast=0.011^
 --ShockTotFacProd=0.99 --ShockLabProd=0.99 --ShockIncTransf=0.01^

```

Annex 6. Excel pivot table that combines the results of all model runs for the second step of MSA



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
1	Elasticity Parameters															Model Shocks:				real G	% dev	on fron	e base	ar valu						
2	Sig_FacSupLab_H	Sig_ConHou	Sig_ZS	Sig_QS	Sig_XS	Sig_KapS	Sig_LabS	Sig_Inv	Sig_ConGov	Sig_ArmS	Sig_EuroInv	Sig_EuroKap	Sig_Arm_RnD	KnowK_Ext	WgeCurveElast	ShockTotFacProd	ShockLabProd	ShockIncTransf	YEAR											
3																				AT11	AT12	AT13	AT21	AT22	AT31	AT32	AT33	AT34	BE10	BE21
6284	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.01	1	1	0.01	2020	-0.016	-0.016	-0.015	-0.011	-0.011	-0.012	-0.009	-0.009	-0.005	-0.027	-0.019
6295	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.01	1	1	-0.01	2020	0.0158	0.0158	0.0155	0.011	0.011	0.012	0.009	0.0096	0.0048	0.0269	0.0194
6306	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.01	1	0.99	0.01	2020	-0.917	-0.975	-1.107	-1.011	-1.034	-1.072	-0.957	-0.941	-0.983	-1.047	-1.007
6317	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.01	1	0.99	-0.01	2020	-0.886	-0.944	-1.077	-0.99	-1.012	-1.048	-0.939	-0.922	-0.973	-0.994	-0.969
6328	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.01	1	0.99	0	2020	-0.901	-0.96	-1.092	-1.001	-1.023	-1.06	-0.948	-0.932	-0.978	-1.021	-0.988
6339	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.01	1	1.01	-0.01	2020	0.9143	0.9717	1.1076	1.009	1.031	1.0671	0.9526	0.9368	0.9785	1.0504	1.0048
6350	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.01	1	1.01	0	2020	0.8985	0.9559	1.0921	0.9981	1.02	1.0552	0.9437	0.9273	0.9738	1.0231	0.9854
6361	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.01	0.99	1	0.01	2020	-1.767	-1.849	-1.962	-1.86	-1.872	-1.946	-1.874	-1.851	-1.927	-1.837	-1.833
6372	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.01	0.99	1	-0.01	2020	-1.736	-1.818	-1.931	-1.838	-1.85	-1.922	-1.856	-1.832	-1.917	-1.784	-1.795
6383	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.01	0.99	1	0	2020	-1.751	-1.834	-1.946	-1.849	-1.861	-1.934	-1.865	-1.842	-1.922	-1.81	-1.814
6394	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.01	0.99	0.99	0.01	2020	-2.656	-2.798	-3.033	-2.846	-2.881	-2.994	-2.811	-2.772	-2.893	-2.835	-2.807
6405	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.01	0.99	0.99	-0.01	2020	-2.625	-2.766	-3.003	-2.824	-2.859	-2.97	-2.793	-2.753	-2.883	-2.783	-2.769
6416	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.01	0.99	0.99	0	2020	-2.64	-2.782	-3.018	-2.835	-2.87	-2.982	-2.802	-2.762	-2.888	-2.809	-2.788
6427	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.01	0.99	1.01	0.01	2020	-0.88	-0.904	-0.889	-0.875	-0.865	-0.901	-0.941	-0.933	-0.963	-0.835	-0.861
6438	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.01	0.99	1.01	-0.01	2020	-0.849	-0.873	-0.858	-0.853	-0.843	-0.877	-0.923	-0.914	-0.954	-0.782	-0.822
6449	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.01	0.99	1.01	0	2020	-0.865	-0.889	-0.874	-0.864	-0.854	-0.889	-0.932	-0.924	-0.959	-0.809	-0.842
6460	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.01	1.01	1	0.01	2020	1.7398	1.8195	1.9452	1.843	1.8539	1.9196	1.8556	1.8308	1.9172	1.8034	1.7999
6471	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.01	1.01	1	-0.01	2020	1.7712	1.8508	1.9761	1.8646	1.8755	1.9429	1.8731	1.8494	1.9262	1.858	1.8387
6482	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.01	1.01	1	0	2020	1.7554	1.8351	1.9605	1.8537	1.8646	1.9312	1.8643	1.84	1.9216	1.8306	1.8192
6493	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.01	1.01	0.99	0.01	2020	0.8276	0.8498	0.8347	0.83	0.8191	0.851	0.8993	0.8911	0.9301	0.7612	0.7996
6504	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.01	1.01	0.99	-0.01	2020	0.859	0.8812	0.8654	0.8517	0.8408	0.8746	0.9169	0.9098	0.9392	0.8152	0.8382
6515	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.01	1.01	0.99	0	2020	0.8432	0.8655	0.8499	0.8407	0.8298	0.8627	0.908	0.9003	0.9345	0.7881	0.8188
6526	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.01	1.01	1.01	0.01	2020	2.6482	2.7839	3.0549	2.852	2.8844	2.9806	2.8053	2.764	2.8975	2.8477	2.7969
6537	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.01	1.01	1.01	-0.01	2020	2.6796	2.8151	3.0858	2.8734	2.9058	3.0036	2.8225	2.7823	2.9063	2.9029	2.8357
6548	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.009	1	1	0.01	2020	-0.016	-0.016	-0.015	-0.011	-0.011	-0.012	-0.009	-0.01	-0.005	-0.027	-0.019
6559	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.009	1	1	-0.01	2020	0.016	0.016	0.0156	0.0111	0.0112	0.0122	0.0092	0.0097	0.0049	0.027	0.0196
6570	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.009	1	0.99	0.01	2020	-0.922	-0.981	-1.113	-1.017	-1.04	-1.08	-0.963	-0.948	-0.99	-1.05	-1.012
6581	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.009	1	0.99	-0.01	2020	-0.89	-0.949	-1.082	-0.995	-1.018	-1.055	-0.945	-0.928	-0.98	-0.997	-0.973
6592	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.009	1	0.99	0	2020	-0.906	-0.965	-1.098	-1.006	-1.029	-1.068	-0.954	-0.938	-0.985	-1.024	-0.993
6603	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.009	1	1.01	0.01	2020	0.8877	0.946	1.0827	0.9934	1.0155	1.0513	0.9417	0.9245	0.9764	0.999	0.9713
6614	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.009	1	1.01	-0.01	2020	0.9196	0.9778	1.1139	1.0154	1.0376	1.0753	0.9596	0.9436	0.9857	1.0535	1.0105
6625	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.009	1	1.01	0	2020	0.9035	0.9618	1.0982	1.0043	1.0265	1.0632	0.9505	0.934	0.981	1.0261	0.9908
6636	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.009	0.99	1	0.01	2020	-1.777	-1.86	-1.972	-1.871	-1.884	-1.96	-1.887	-1.863	-1.939	-1.842	-1.843
6647	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.009	0.99	1	-0.01	2020	-1.745	-1.828	-1.941	-1.849	-1.862	-1.936	-1.869	-1.844	-1.93	-1.789	-1.804
6658	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.009	0.99	1	0	2020	-1.761	-1.844	-1.957	-1.86	-1.873	-1.948	-1.878	-1.854	-1.935	-1.815	-1.823
6669	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.009	0.99	0.99	0.01	2020	-2.67	-2.813	-3.048	-2.862	-2.898	-3.014	-2.829	-2.789	-2.911	-2.843	-2.821
6680	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.009	0.99	0.99	-0.01	2020	-2.638	-2.782	-3.018	-2.84	-2.876	-2.99	-2.81	-2.77	-2.901	-2.791	-2.783
6691	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.009	0.99	0.99	0	2020	-2.654	-2.797	-3.033	-2.851	-2.887	-3.002	-2.82	-2.78	-2.906	-2.817	-2.802
6702	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.009	0.99	1.01	-0.01	2020	-0.854	-0.878	-0.863	-0.859	-0.849	-0.884	-0.929	-0.921	-0.96	-0.785	-0.827
6713	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.009	0.99	1.01	0	2020	-0.87	-0.894	-0.879	-0.87	-0.86	-0.896	-0.938	-0.93	-0.965	-0.811	-0.847
6724	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.009	1.01	1	0.01	2020	1.7504	1.8313	1.9567	1.8555	1.8668	1.9352	1.8698	1.8446	1.9318	1.8089	1.8104
6735	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.009	1.01	1	-0.01	2020	1.7822	1.8631	1.9879	1.8774	1.8887	1.959	1.8876	1.8635	1.941	1.8638	1.8497
6746	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.009	1.01	1	0	2020	1.7662	1.8471	1.9721	1.8664	1.8777	1.947	1.8785	1.8539	1.9363	1.8363	1.83
6757	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.009	1.01	0.99	0.01	2020	0.8328	0.8553	0.8396	0.8358	0.825	0.858	0.9059	0.8977	0.9369	0.7636	0.8043
6768	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.009	1.01	0.99	-0.01	2020	0.8646	0.8871	0.8707	0.8577	0.8471	0.882	0.9239	0.9167	0.9463	0.8179	0.8434
6779	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.009	1.01	0.99	0	2020	0.8486	0.8711	0.855	0.8466	0.8359	0.8699	0.9148	0.9071	0.9415	0.7906	0.8237
6790	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.009	1.01	1.01	0.01	2020	2.6646	2.8025	3.0733	2.8717	2.9047	3.0054	2.8274	2.7853	2.9204	2.8567	2.8135
6801	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.009	1.01	1.01	-0.01	2020	2.6964	2.8342	3.1046	2.8934	2.9264	3.0288	2.8449	2.804	2.9293	2.9122	2.8529
6812	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.009	1.01	1.01	0	2020	2.6804	2.8183	3.0888	2.8824	2.9154	3.017	2.836	2.7946	2.9247	2.8844	2.8331
6823	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.011	1	1	0.01	2020	-0.015	-0.015	-0.015	-0.011	-0.011	-0.012	-0.009	-0.009	-0.004	-0.027	-0.019
6834	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.011	1	1	-0.01	2020	0.0156	0.0156	0.0153	0.0108	0.0109	0.0118	0.0089	0.0094	0.0047	0.0268	0.0191
6845	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.011	1	0.99	0.01	2020	-0.912	-0.97	-1.101	-1.006	-1.028	-1.065	-0.951	-0.935	-0.976	-1.044	-1.002
6856	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.011	1	0.99	-0.01	2020	-0.881	-0.939	-1.071	-0.984	-1.006	-1.041	-0.933	-0.916	-0.967	-0.992	-0.964
6867	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.011	1	0.99	0	2020	-0.897	-0.954	-1.086	-0.995	-1.017	-1.053	-0.942	-0.926	-0.972	-1.018	-0.983
6878	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.011	1	1.01	0	2020	0.8936	0.9502	1.0862	0.992	1.0138	1.0474	0.937	0.921	0.9669	1.0202	0.9802
6889	1	1.2	0.2	1.1	0.25	2	2	1.3	0.3	2.2	3	3	3	0.0053	0.011	0.99	1	0.01	2020	-1.758	-1.839	-1.951	-1.849	-1.861	-1.932	-1.862	-1.839	-1.914	-1.832	-1.824

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