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How large and uncertain are costs of 2030 GHG emissions reduction target for the European countries? Sensitivity analysis in a global CGE model

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Abstract

In the paper we address the problem of parameters uncertainty of computable general equilibrium (CGE) simulation results concerning the economic effects of climate policy actions. Large scale CGE models utilize extensive, detailed databases on the structure of the economies (industry-specific technologies, international trade patterns etc.). At the same time, the behaviour of the economic system modelled in the CGE framework is largely driven by assumptions rooted in theory, with relatively little empirical content. It is therefore crucial to understand how assumptions affect outcomes of policy experiments.

We employ a static global CGE model PLACE, representing 35 regions and 20 industries, with a focus on representing links between economic activities, energy use and CO_2 emissions. We discuss difficulties with finding adequate and comparable sources of econometric estimates for CGE model parameters. By systematic sensitivity analysis based on Stroud's (1957) Gaussian quadratures approach we test how variation in elasticity parameters (values of which are subject to substantial uncertainty) affects economic assessment of emission reduction policies.

Our main simulation scenario is imposition of a 40% greenhouse gas (GHG) emission reduction target with respect to 1990 as approved by the European Council in October 2014. Our findings can be summarized as follows. First, the uncertainty of model simulation results driven by the uncertainty in assumed elasticities values is quite remarkable with double-digit variation coefficients in many cases. The uncertainty is larger with respect to non-energy elasticity parameters than with respect to energy parameters. Second, there is a clear pattern with mostly the New Member States experiencing relatively high cost of emissions reduction in terms of GDP and consumption loss. In the extreme case of strictly rigid energy mixes (no substitution at an industry level), these costs are remarkably higher (in some cases even doubled).

Keywords: computable general equilibrium model, systematic sensitivity analysis, emissions reduction
JEL Classification: C68, D58

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1. Introduction

CGE models are widely used for assessing the effects of economic (specifically climate and energy) policies, yet simulation results are sensitive to parameters assumed by the modeller. However, econometric evidence on those parameters available in the literature is often scarce or ambiguous and in addition, there is difficulty in finding results tailored to a specific CGE model (with its specific sectoral and regional disaggregation[3], nesting structure production functions etc). In practice, this makes a choice of parameter values more or less arbitrary and in fact in many cases modelers simply follow the perhaps equally arbitrary choices made by other authors. Although such an approach does not imply that simulation results are meaningless, it calls for at least a clear communication of uncertainties to the reader.

The problem of uncertainty with respect to CGE modelling results and the need for their validation is already well recognized, and has been addressed in a number of studies (see e.g. Abler et al., 1999; DeVuyst and Preckel, 1997; Arndt and Pearson, 1998; Hertel et al., 2007; Domingues et al., 2008). Although there may be many other sources of uncertainty for results of a CGE model (the choice of model functional forms, nesting structure, long-term forecasts uncertainty, data, etc.), we only focus here on uncertainty related to non-calibrated model parameters, namely elasticities of substitution. Peterson (2006) gives a survey of approaches and empirical results for more general uncertainty within the context of climate and energy policy evaluation.

One approach to identify parametric uncertainty of CGE modelling results is systematic sensitivity analysis which involves multiple solves of the model with disturbed parameter values. Due to the fact that global CGE models are often multi-dimensional and computationally demanding, it is of practical importance to apply the sensitivity analysis method that could be used for these models. Here we apply sensitivity analysis using Gaussian quadrature method based on Stroud (1957) that has been popularized for use in CGE models by Arndt and Pearson (1998). The experiment that we run in a global CGE model is the imposition of a 40% emission reduction target with respect to 1990 as proposed by the European Commission (see European Commission, 2014) and agreed by the European Council in October 2014. As a background for our analysis, we present a thorough discussion of sources of elasticity values in the literature and difficulties in their comparison.

The paper is organized as follows. Following the introduction to the paper in section 1, in section 2 we present our findings on empirical estimates of elasticities of substitution. The subject of section 3 is systematic sensitivity analysis in CGE models. In section 3.1 we introduce systematic sensitivity analysis method we use in this paper and in section 3.2 we discuss its application for a global CGE model and present our results. Finally, section 4 concludes.

2. Estimated elasticities of substitution – literature review

2.1. Introduction

In spite of their critical importance for simulation results, estimated elasticities of substitution are quite rarely found in papers published in the reviewed journals. This refers to interfuel elasticities of substitution, elasticities of substitution between labour and capital (K-L nest), between capital and energy composite (K-E nest), between capital-energy and labour-materials composites (KE-LM nest), or another combinations (KL-EM nest or KEL-M nest or KLE-M nest), as well as Armington

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[3] Here a “region” is either a single country or a group of (aggregated) countries.

elasticities.[4] In addition, existing empirical estimates are not directly comparable (see discussion in section 2.2). Concerning substitutability between capital and energy, there is a controversy in the literature whether these two inputs can actually be treated as substitutes in general (see Apostolakis, 1990; Thompson and Taylor, 1995).

Since our model PLACE[5] is a global CGE model designed to study energy and climate policies (for model overview see Appendix A and for a detailed description see Antoszewski et al., 2015), papers included in the review here are predominantly those with quite disaggregated energy-intensive sectors and with multiple countries included in the analysis. Moreover, we focus on relatively recent papers (1990s at the earliest, but more favorably published in 2000 or later). The estimated elasticities of substitution based on this review serve us as initial values to be then varied in sensitivity analysis.

2.2. Difficulties with comparison of alternative empirical studies

Choice of default values of elasticities of substitution for a global CGE model is not straightforward due to difficulties with comparison of estimated elasticities values stemming from alternative empirical studies. These difficulties arise due to several reasons which we discuss in what follows. Empirical analyses are based on different time span, different sector and country coverage, as well as different data sources. Concerning methodological issues, different methods of estimation are used or different functional forms of production or cost functions as well as different elasticity of substitution definitions are applied. Ideally, the estimation study should have the same countries and sectors coverage, the same elasticity of substitution definition as the CGE model and the time span of data sample should correspond to the CGE model base year (in other words estimation results should not be "too old"). It would also be worthwhile that functional forms be the same in the estimation study as in the CGE model or at least (in case of different functional forms for estimation and calibration) the calibration procedure should accord with exogenous estimation results.

Referring to the above issues, the World Input Output Database (WIOD) is a good step forward since it covers annual time series 1995-2011. Thus, it allows to use a multisector panel database with harmonized data for several countries for the estimation process and to derive elasticities from the same data which will be used to calibrate CGE model parameters. However, since this database has been released quite recently, peer-reviewed estimation results based on it are yet rare. The alternative database popular in the context of CGE modelling is the GTAP (Global Trade Analysis Project) database. GTAP data are available only for selected periods (1992, 1995, 1997, 2001, 2004, 2007, 2011) and in current prices, with differentiated sectors and regions coverage, making it difficult to use panel-data econometric techniques. Beside WIOD and GTAP, the sources of data used in the papers reviewed here are OECD, EU KLEMS as well as national primary data sources.

In terms of sectoral coverage, empirical studies differ in sectoral aggregations adopted. In addition, only few studies present estimation results for a wide group of countries (e.g. McKibbin and Wilcoxen, 1999, Van der Werf, 2008, Okagawa and Ban, 2008, Nemeth at al., 2011, Koesler and Schymura, 2012, Fragiadakis et al., 2012, Baccianti, 2013).

Empirical papers employ several functional forms of the estimated equations. Since there are usually more than two inputs in a production process, the most popular choice is the transcendental

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[4] In 1969 P. Armington proposed that goods from different sources be modelled as a CES aggregate (see Armington, 1969). Armington elasticity is the elasticity of substitution between groups of products identified by country of origin.

[5] "PLACE" stands for Polish Laboratory for the Analysis of Climate and Energy.

logarithmic (translog) production function, since it does not impose constraints on substitution patterns and is linear in parameters. Constant elasticity of substitution (CES) production function (nested or one-level) is found more rarely in empirical studies. In this case the so-called Kmenta approximation[6] (Kmenta, 1967) is commonly used as CES function is non-linear in parameters. However, the Kmenta approximation might result in unreliable[7] estimates of CES parameters (see Maddala and Kadane, 1967; Thursby and Lovell, 1978; Henningsen and Henningsen, 2011). This is one of the reasons why researchers often estimate cost (rather than production) functions, resting on derivation of a linear system of equations assuming that production cost is minimized, given a production function frontier.

Translog functional form is adopted i.a. in the following empirical studies: Bataille (1998), Koebel and Falk (1999), Christopoulos (2000), Jaccard and Bataille (2000), Yi (2000), Arnberg and Bjorner (2007), Dissou and Ghazal (2010), Serletis et al. (2010), Smyth et al. (2010), Mohler and Müller (2012), Krishnapillai and Thompson (2012), Azlina et al. (2013), Costantini and Paglialunga (2014), Kumar et al. (2014), Hyland and Heller (2015). CES functional form is used i.a. in the following papers: McKibbin and Wilcoxen (1999), Kemfert (1998), Claro (2002), Balistreri et al. (2003), Saito (2004); Van der Werf (2008), Okagawa and Ban (2008), Welsch (2008), Fragiadakis et al. (2012), Koesler and Schymura (2012), Mohler and Müller (2012), Tipper (2012), Turner et al. (2012), Baccianti (2013), Feenstra et al. (2014).

Most papers estimating elasticity of substitution between alternative fuels (so-called interfuel elasticity of substitution) adopt translog functional form. There are few exceptions where relevant elasticity parameters are estimated based on dynamic linear models (e.g. Jones, 1995; Ko and Dahl, 2001; Urga and Waters, 2003; U.S. Energy Information Administration, 2012), however to the best knowledge of the authors they only regard the U.S. energy sector.

Another issue important for comparability of estimation results for elasticities of substitution is the adopted definition of this measure. In the empirical studies several definitions of elasticities of substitution are applied, but a few of them use elasticity of substitution measure consistent with CES functional form adopted in an applied CGE work, namely the Hicksian elasticity of substitution. Under the translog production technology assumption the most often used definitions are Morishima elasticities, cross price elasticities or more rarely Allen-Uzawa elasticities. Hicksian elasticity of substitution or Allen-Uzawa elasticity of substitution or (more rarely) marginal rate of technical substitution between two factors[8] (sometimes referred to as "engineering elasticity of substitution") are in turn usually provided in the empirical papers in the case when nested CES production function form is estimated (for discussion of alternative definitions see Broadstock et al., 2007). However, Allen-Uzawa elasticity of substitution is in fact cross price elasticity of substitution scaled by a cost share, so it does not provide more information than cross price elasticity and it has been criticized in the literature for being very volatile as well as for its lack of meaning in the case of more than two

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[6] Due to difficulties with non-linear estimation, Kmenta (1967) proposed to logarithmise a two-input CES production function and then apply second-order Taylor series expansion. The resulting functional form can be estimated with ordinary least-squares techniques. The same formula as the original Kmenta's one can be obtained by applying the first-order Taylor series expansion to the entire logarithmised CES function around the same point.

[7] Kmenta (1967) notes that if in the CES production function the input ratio as well as the elasticity of substitution are either very high or very low, his approximation method may not perform well. Maddala and Kadane (1967) and Thursby and Lovell (1978) confirm this problem and show that the standard Kmenta procedure may not lead to reliable estimates of parameters in the CES framework. The paradox is that Kmenta approximation can provide more reliable estimation results for unitary elasticity of substitution while it was meant to facilitate the estimation of functions with non-unitary elasticity of substitution – see Henningsen and Henningsen (2011).

[8] Marginal rate of technical substitution between factors x_i and x_j assumes holding output and all input factors, except for x_i and x_j, constant – see e.g. Broadstock et al. (2007).

production factor inputs (see e.g. Thompson and Taylor, 1995). Morishima elasticity of substitution in turn, which generally should be positive, is uninformative in terms of whether inputs are substitutes or complements. A number of authors have argued that cross-price elasticity of substitution provides the best and most intuitive measure of factor substitutability, despite the fact that most empirical studies do not state this measure explicitly (Broadstock et al., 2007, p. 21). Since the CES functional form for production implies that all elasticities of substitution are greater than zero (which in turn implies that all inputs would be classified as substitutes based on the marginal rate of technical substitution), most empirical papers apply more flexible functional forms such as the translog (see e.g. Broadstock et al., 2007, Mohler and Müller, 2012 as well as Sorrell, 2014). As a consequence, the estimated elasticities of substitution in empirical papers (cross-price, Morishima or Allen-Uzawa elasticities) are not directly comparable to Hicks elasticities which are explicitly used in applied CGE models based on CES production functions. Although various elasticities measures are not directly comparable, mathematical relations between alternative definitions of elasticities of substitution can be derived (see e.g. Broadstock et al., 2007 and Sorrell, 2014). Out of the abovementioned elasticity of substitution concepts, the Morishima elasticity of substitution measure is closer to the original Hicks definition of elasticity of substitution as it measures the percentage change in a ratio of inputs and indicates the curvature of an isoquant (Sorrell, 2014).[9]

To sum up, based on the discussion here for systematic sensitivity analysis in this paper we only take into account empirical results based on the CES functional form for the production function.

Another issue closely related to the definition of the elasticity of substitution is an assumption about technological change which affects the substitutability between different production factors. It is of critical importance for the estimation procedure where factor substitution driven by changes in relative prices should be clearly separated from those induced by changes in technology. The majority of papers take into account Hicks-neutral technological change, i.e. they attribute technological progress to the overall factor productivity, with no distinction of alternative production inputs (see Christopoulos, 2000, Balistreri et al., 2003, Mohler and Müller, 2012, Koesler and Schymura, 2012). Examples of papers incorporating factor-augmenting technological change[10] concept are Kemfert (1998), Van der Werf (2008), Mohler and Müller (2012) and Baccianti (2013).

Apart from the above aspects regarding the difficulties with comparison of estimation results in various research studies, strict comparability of estimation results would only be possible for the same estimation method and algorithms. Depending on whether the production function adopted in the estimation procedure is linear or non-linear in parameters, the estimation method may also be linear or non-linear. Concerning data type, estimation can be done for data across sectors and countries. Henningsen and Henningsen (2011) stress that the results are highly vulnerable to the algorithm applied.

2.3. Range of estimated values for elasticities of substitution

Despite the fact that our review limits to the most recent empirical research, a range of results for estimated substitution elasticity parameters is quite large pointing at high uncertainty in this area. This uncertainty stems from differences in data sources, country and sectoral coverage, estimation method, estimated functional forms, definitions of elasticities of substitution applied, and other assumptions. Minimum and maximum values for elasticities of substitution parameters from

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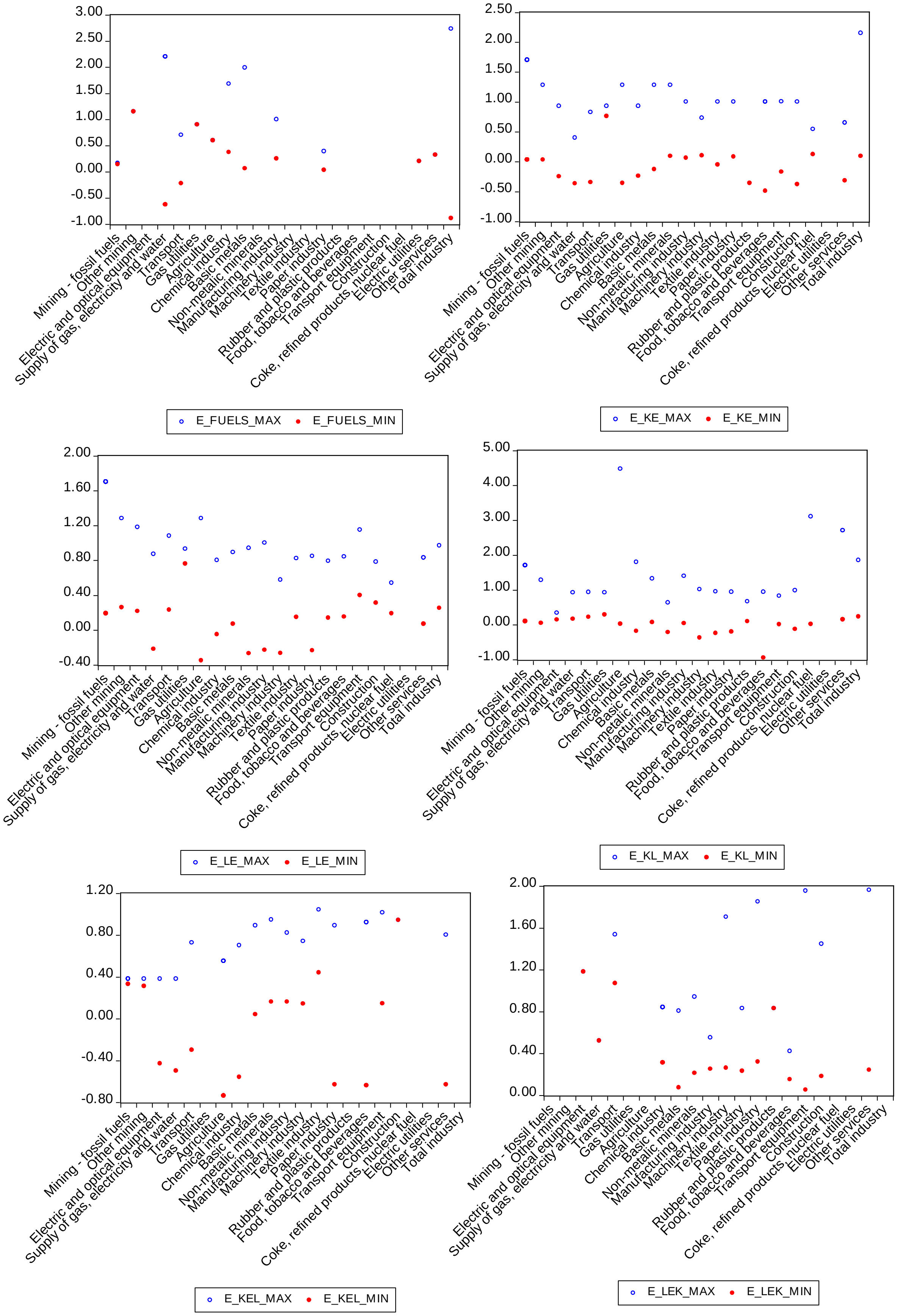
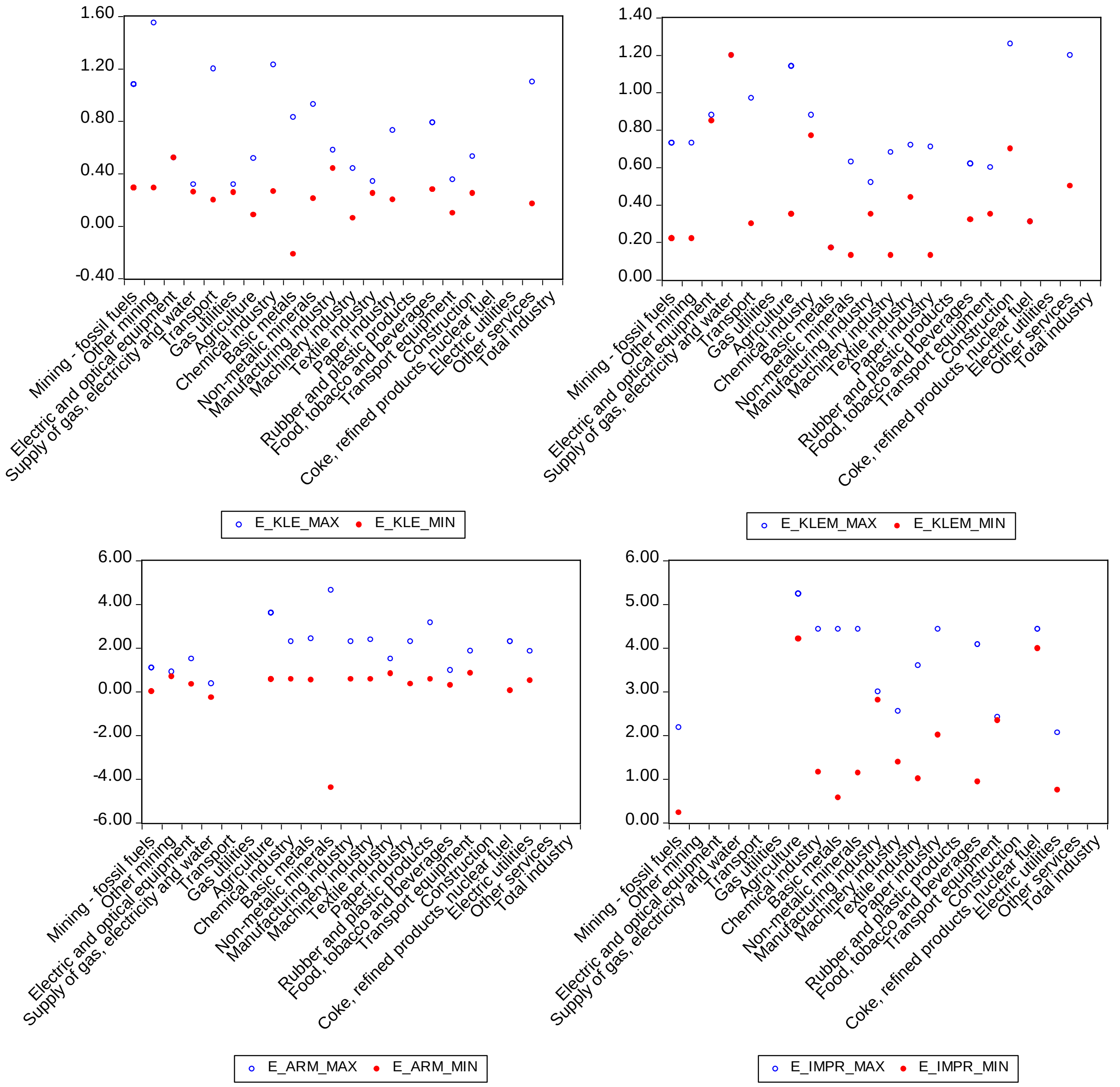
[9] Sorrell (2014) discusses conditions to be met to ensure comparability for different elasticity of substitution measures.

[10] Factor-augmenting technological change means that it can be ascribed to a specific production factor. Here we use "factor-augmenting technological change" term in cases when technological change has been attributed to every production factor in the estimation procedure.

Figure 1. Estimated values for elasticities of substitution from empirical studies (in %)





Notes: "E_KL" means elasticity of substitution between capital (K) and labour (L) in the KL nest, "E_KE_L" means elasticity of substitution between composite of capital and energy (KE) and labour (L) and "E_KLE_M" means elasticity of substitution between composite factor capital-labour-energy (KLE) and materials in the value added nest. "E_ARM" refers to elasticity of substitution for Armington good, i.e. elasticity of substitution between domestic and imported goods and "E_FUELS" means elasticity of substitution between coal, oil, gas and electricity. "Min" and "Max" refers to minimum and maximum value, respectively. On the horizontal axis are industries.

the review are presented in Figure 1. Each graph shows minimum and maximum values_of elasticities of substitution found in the literature, e.g. *KE_min* is a minimum value for elasticity of substitution between capital and energy, *KL_E_max* is a maximum value for elasticity of substitution between composite capital-labour factor and energy, and so on. If only one value is presented for a particular sector, it means that only one value for a given elasticity of substitution has been found in the literature. As it was mentioned above, due to differences in functional forms applied calculating mean values of elasticities for the purpose of sensitivity analysis we only take into account empirical estimates based on the CES functional form. Nonetheless, in order to better illustrate huge uncertainty regarding "true" values of elasticities of substitution, we present on graphs lower and upper bounds for parameter values based on all papers reviewed here (i.e. including those adopting other than CES functional form).

3. Systematic sensitivity analysis for elasticities of substitution of the PLACE model

3.1. Method

In this section we present systematic sensitivity analysis method chosen to study uncertainty of results in the context of European Union's 2030 climate and energy policy. By "systematic" we mean that alternative values of parameters are picked in a systematic way, i.e. they are determined by means of some specific method in order to explore the whole domain of plausible values. In general there are two classes of methods of conducting stochastic sensitivity analysis for the parameters of CGE models: Monte Carlo methods and methods based on quadratures (with Gaussian quadratures as a special case)[11]. Stochastic methods of sensitivity analysis view key exogenous variables (parameters) as random variables with associated probability distributions. Under the assumption that exogenous variables are random, the endogenous results of a model are also random. Abler et al. (1999) recommend Gaussian quadrature methods or Monte Carlo methods for sensitivity analysis of CGE model results since they ensure good quality of approximation of a true distribution of simulation results. However, both methods require large number of model solves what makes them difficult to apply in practice. Special cases of Gaussian quadratures can reduce significantly the number of model solves, which is why they are especially appealing in an applied work. One example of such an approach is the method based on Stroud's (1957) Fourier transform where, at the minimum, only *2n* number of model solves is needed (where *n* is a number of independent parameters taken into consideration for sensitivity analysis). This method is applied for systematic sensitivity analysis with the global CGE model in this paper.

Gaussian quadrature methods for sensitivity analysis produce estimates of mean $(\tilde{m})$ and variance $(\tilde{v})$ of the endogenous model results, which approximate the true moments of the distribution associated with the results:

$$m = \int_{\Omega} H(x,a) w(a) da \tag{1}$$

$$v = \int_{\Omega} \left(H(x,a) - m\right)^2 w(a) da, \tag{2}$$

where:
a – vector of parameters of a CGE model treated as random variables with multivariate density function $x(a)$,
x – vector of predetermined exogenous variables of a CGE model,
$H(x,a)$ – reduced form of a CGE model,
Ω – is a domain of parameters a (see Arndt, 1996).

Similar to Monte Carlo methods, Gaussian quadrature methods belong to the class of numerical integration methods, i.e. they aim at approximating true moments of a distribution (see formulas (1) and (2)) with a mean and variance of weighted sum of simulated model results:

$$\tilde{m} = \sum_{j=1}^{J} w_j H(x, a_j)$$

$$\tilde{v} = \sum_{j=1}^{J} w_j \left(H(x,a_j) - \tilde{m}\right)^2,$$

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[11] Gaussian quadrature method to evaluate sensitivity of key exogenous variables (parameters or shocks) in a CGE model was proposed by Arndt (1996) and DeVuyst and Preckel (1997).

where *J* is a total number of evaluations of *H*(.) and w_j is the weight associated with each evaluation and $\tilde{m} \approx m$ and $\tilde{v} \approx v$.

Quadratures are points determined in line with dedicated formulas at which the function that approximate integrand is evaluated and their associated weights. Perhaps the most popular are Gaussian quadratures. In the Gaussian quadrature method, points and their corresponding weights are determined in a way that approximation is exact for a specific form of an integrand polynomial. Accuracy of approximation is related to the ability of a polynomial to approximate the integrand. In case of order *d* Gaussian quadrature[12], the approximation will be exact if the integrand is a polynomial of order *d* or lower (Arndt, 1996).

Stroud-based Gaussian quadrature is an order three quadrature for symmetric distributions that can repeatedly reduce number of model solves needed for sensitivity analysis. Stroud's method permits systematic sensitivity analysis with respect to *n* exogenous variables using only 2*n* points or solves of the model. If a model takes five minutes to solve, then systematic sensitivity analysis using 1000 Monte Carlo draws, for 50 exogenous parameters for example, would take 3.5 days, while using Stroud's Gaussian quadrature method it would take 8 hours and 20 minutes. Moreover, if model results can be well approximated by an order three polynomial (which is usually the case in CGE models applications), the Gaussian quadrature sensitivity analysis will be more accurate than Monte Carlo analysis that is feasible to conduct for applied CGE models.

Points of Gaussian quadratures according to Stroud's method are determined as follows (see Arndt, 1996). If *n* is a number of random exogenous variables and $\Gamma_k(\gamma_{k1}, \gamma_{k2}, \ldots, \gamma_{kn})$ is a set of *k* quadrature points for *n* exogenous variables (*k*=1,2,…,2*n*), then formulas for order three quadratures for symmetric, independent distributions (with mean equal to zero and standard deviation equal to one) are the following:

$$\gamma_{2r-1} = \sqrt{2\cos\left(\frac{(2r-1)k\pi}{n}\right)}$$
$$\gamma_{2r} = \sqrt{2\sin\left(\frac{(2r-1)k\pi}{n}\right)} \qquad (3)$$

where *r*=1,2,…,$\lfloor n/2 \rfloor$ and $\lfloor n/2 \rfloor$ denotes the greatest integer not exceeding $\frac{n}{2}$. In case when *n* is an odd number the quadrature points for *n*-th variable are determined by formula $\gamma_{kn} = (-1)^k$ instead of formula for γ_{2r-1} as in (3). Weights w_j are equal and sum to one meaning that each weight is equal to $\frac{1}{2n}$.

In case when our aim is to conduct sensitivity analysis for symmetrically distributed random variable *x* (x_1 x_2,…, x_n), a column vector of size *n* with mean *μ* and variance covariance matrix *Σ*, assuming that exogenous variables are independent (i.e. *Σ* matrix is diagonal), the quadrature points, *Φ,* can be determined in the following way:

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[12] An order *d* Gaussian quadrature for an integration problem $\int_a^b f(x)g(x)dx$ solves the system of equations $\sum_{j-1}^{J} w_j (x^j)^s = \int_a^b (x)^s g(x)dx, \quad s = 0,1,2,\ldots,d$ (see Arndt 1996).

$$\Phi = \mu + \Gamma\sqrt{\Sigma}.$$

If correlation between exogenous variables is assumed (i.e. Σ matrix is not diagonal), the usual Cholesky factorization can be applied. More on systematic sensitivity analysis with respect to correlated variables can be found in Horridge and Pearson (2011).

3.2. Application for a climate policy simulation in the global CGE model

Below we present assumptions and results of systematic sensitivity analysis with Stroud-based Gaussian quadratures for the PLACE model. Other papers applying Stroud-based Gaussian quadrature method for sensitivity analysis are e.g. Domingues et al. (2008), Preckel et al. (2010), Horridge and Pearson (2011) as well as Boratyński (2011). It is worth noticing that the procedure based on Stroud's Gaussian quadratures has been implemented in GEMPACK software by Arndt and Pearson (1998). Here, we use GAMS software.

In our simulation experiment we analyze how the assessment of economic consequences of introducing 40% GHG emissions reduction target (with respect to 1990) for 2030 as proposed by the European Commission (2014) is affected by parameters uncertainty. Our baseline scenario is based on Reference Scenario 2013 from the PRIMES model (see European Commission, 2013). It assumes 32.4% GHG emissions reduction in 2030 (with respect to 1990) in the EU, based on the policies adopted up to April 2012 and implicitly assuming that all of the EU's legal measures necessary to fulfil the reference reduction target are in place. The baseline scenario is used as a reference against which alternative scenarios are compared.

To prepare baseline scenario for 2030 for the purpose of simulations with the PLACE model we use projections concerning the GDP growth rates, fuel prices, primary energy demand and energy-related CO_2 emissions, as well as process-related CO_2 emissions and non-CO_2 emissions (taken from Reference Scenario 2013). For non-EU regions we take the corresponding projections from OECD, IMF and IEA databases. Fossil fuel price projections are taken from "World Energy Outlook 2012" (IEA, 2012). The model is static and so the comparative static approach is used to assess the economic effects of particular policies. The model is initially calibrated to 2011 GTAP data. Next, the baseline scenario is generated through model solution, in which the above mentioned quantities (GDP, energy use etc.) are exogenized, while technologies and primary factor resources adapt to fit the desired levels of exogenous variables for 2030. Finally, the policy simulations represent the comparative-static, long-run effects of additional emission reduction, evaluated at projected 2030 conditions. The policy simulations assume that aggregate employment and capital stock is fixed in each region; labour and capital are mobile between sectors, but not between regions. This setting implies that GDP or welfare changes are due to changes in allocative efficiency of production factors. On the demand side, real investment and government consumption are fixed, as is the (nominal) current account balance; a change in government revenues are compensated with a change in a lump-sum transfer to households, such that the government balance is unaltered. Consequently, policy-induced shifts in private consumption are interpreted as long-run changes in welfare.

We conduct sensitivity analysis for the total of 15 non-calibrated parameters for 20 industries. Thus, we solve the model 30 times (i.e. 15*2, excluding the baseline solve). We assume that corresponding parameters in different sectors are moving together, i.e. relations between elasticities in line with the baseline solve are preserved. All CES nests for which we include elasticities of substitution in our sensitivity analysis are listed in Appendix B. The basecase values for elasticities of substitution are calculated as means of minimum and maximum values derived from the empirical papers adopting CES functional form for the production function (in line with the discussion in section 2.3). This rule however does not apply to elasticities between energy carriers (i.e. interfuel and between fuels and electricity) since empirical evidence is rather scarce and based on translog production function form which provides inadequate measure of elasticity of substitution for the purpose of applied CGE models. Instead, we assume central elasticity of substitution value of 0.75. In order to better account for uncertainty stemming from energy parameters we run sensitivity analysis separately for energy parameters and non-energy parameters. In line with the above, we first run sensitivity analysis for elasticities of substitution in the *crol*, *cofr*, *oibi*, *nsol*, *fuel*, *biof*, *ener*, *gele* and *kkee* nests.[13] Next we run sensitivity analysis for non-energy parameters. Thus, we include elasticities of substitution in the *labs*, *klab*, *klle*, *klem*, *armi* and *impr* nests. Lower and upper bounds of elasticities of substitution are defined, respectively, as a half of and double the mean value. As in the default model setup, we do not differentiate assumed elasticities values between countries. Since, as literature review showed, there are substantial discrepancies between empirical estimation results for elasticities of substitution and it is difficult to find "the most probable" (or representative) estimation value, we assume uniform distribution for parameters.

Tables 1 and 2 present assumed minimum and maximum values for energy and non-energy elasticity parameters, respectively, taken into account in sensitivity analysis (i.e. lower and upper bounds for values picked by the GQ procedure).[14] The ranges vary across different elasticity categories, according to empirical estimates found in literature. None of the parameters in the systematic sensitivity analysis simulations actually take the minimum or maximum values. This is how the GQ method works – it discards extreme values, since the aim of the procedure is only to determine the mean and standard deviation of endogenous responses to policy shocks. However, it is also interesting to determine policy effects in the case in which all parameters take zero values. We apply this approach to energy-related parameters. Assuming that all energy parameters are equal to zero is equivalent to imposing strictly rigid energy mixes in subsequent sectors (e.g. fixed proportions of fuels used in the electricity sector etc.) and it can indicate the maximum theoretical cost of additional emissions reduction for the economy – without the possibility of energy substitution emission constraint can only be met by output reduction.

Table 1. Range of energy elasticities values in sensitivity analysis

Elasticity	*e_biof, e_crol*	*e_cofr, e_ener, e_gele*	*e_oibi*	*e_fuel*	*e_nsol*	*e_kkee*
Sector	ele	col, cru, gas, oil, gdt, oth, atr, trn, chm, foo, isi, nem, nmm, ppp, oth, con, srv	atr, trn, oil, gdt	oil, gdt, oth, atr, trn, ele, chm, foo, isi, nem, nmm, ppp, oth, con, srv	agr, bio, frs atr, trn, oil, gdt chm, foo, isi, nem, nmm, ppp, oth, con, srv	ele
Min	0.375	0.375	0.375	0.375	0.375	0.15
Max	1.5	1.5	1.5	1.5	1.5	0.6

Source: own compilation

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[13] Nests acronyms are explained in Appendix B.

[14] Sectors' abbreviations used in all tables are explained in Table A1 in Appendix A.

Table 2. Range of non-energy elasticities values in sensitivity analysis

Elasticity	*e_klab*						*e_labs*
Sector	oil, nmm, con	isi, nem, atr, trn	agr, bio, frs, foo, chm, oth	gdt, ppp	col, cru, gas	srv	agr, bio, frs, col, cru, gas, gdt, oil, ele, isi, nem, nmm, chm, foo, ppp, oth, atr, trn, con, srv
Min	0.25	0.3	0.35	0.4	0.45	0.7	0.5
Max	1.0	1.2	1.4	1.6	1.8	2.8	2.0

Elasticity	*e_klle*					*e_klem*	
Sector	gdt, isi, nem	agr, bio, frs, foo, ppp, con	oil	nmm, srv	chm, oth, atr, trn	agr, bio, frs,	oth
Min	0.15	0.2	0.25	0.3	0.35	0.5	0.3
Max	0.6	0.8	1.0	1.2	1.4	2.0	1.2

Elasticity	*e_armi*					
Sector	oil	foo, ppp	agr, bio, frs, col, gas, gdt, isi, nem	ele	nmm	oth
Min	0.6	0.8	1.05	1.1	1.15	1.8
Max	2.4	3.2	4.2	4.4	4.6	7.2

Elasticity	*e_impr*								
Sector	ppp	foo	nmm	atr, trn, srv, con	chm, isi, nem	col, cru, gas, gdt, oil	agr, bio, frs	ele	oth
Min	1.6	1.7	1.75	1.9	1.95	2.1	2.35	2.8	3.7
Max	6.4	6.8	7.0	7.6	7.8	8.4	9.4	11.2	14.8

Source: own compilation

In Figures 2 to 9 we show results of our simulation experiment. We present mean variables reactions together with their standard deviations to illustrate the uncertainty of climate policy effects. As standard deviations usually grow with the means, we also calculate variation coefficients (i.e. standard deviations divided by their absolute means) for easier comparison of uncertainty between variables. Detailed simulation results for endogenous variables are presented in Appendix C. Although PLACE is a global model, we only present results for the EU and EFTA countries, since primarily the countries involved in EU ETS should be affected by the European emission reduction policy captured by our simulation experiment.

A general effect of the more stringent emission reduction target in the EU ETS is output reduction due to higher production costs. This reduction is deeper in energy-intensive sectors or in these sectors that have limited possibilities for fuels substitution (see Tables C2 and C7 in the Appendix). Gross output reductions differ between countries depending on the structures of their economies. Unequal responses between sectors are in turn mainly due to differences in their cost structures. Sectors for which output changes are large and differentiated between countries are especially “coal mining” (*col*) and “iron and steel” (*isi*) and these two sectors are presented on graphs (see Figures 4, 5, 8 and 9). Energy use decrease is differentiated between countries and energy carriers[15] and the exact magnitudes of reactions are hard to determine due to significant parameters uncertainty which is reflected in double-digit (in a single cases even triple-digit) variation coefficients values. In some

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[15] For sake of parsimony, in tables C3 and C8 we do not present results for 20 production sectors, instead we show results aggregated by sectors, but disaggregated according to alternative energy carriers.

cases we cannot be sure even of the sign of the outcome value, i.e. both positive and negative responses of energy use to the additional reduction of emissions are possible.[16] It is especially apparent for use of electricity (*ele*). In the cases where mean reaction is very small, e.g. 0.1% or lower, variation coefficient is practically meaningless – standard deviation then serves as a more informative uncertainty measure. Mean sectoral output reaction is uncertain to a relatively large extent for most industry branches (*col*, *chm*, *ele*, *frs*, *isi*, *nem*, *nmm*, *oth* and *ppp*) not only regarding its magnitude, but also regarding its sign which is embodied with double- or even triple-digit variation coefficients. This high uncertainty of mean output reaction stems both from uncertainty related to energy as well as non-energy parameters.

GHG emissions decline consistently with the reduction target, so uncertainty only relates to the relative efforts by countries, not to the overall EU (ETS) effort. Worth noticing is the lack of uncertainty with respect to GHG emissions in non-ETS sectors which stems from the fact that non-ETS targets are decided on individual country level (see Table C4 and C9).

We also calculate carbon leakage rates[17] implied by EU unilateral stringent climate policy (see Tables C5 and C10). Carbon leakage rate is an important measure of effectiveness of EU climate policy and at the same time it illustrates the threat of losing international competitiveness of EU energy-intensive and trade exposed (EITE) industries (see e.g. Böhringer et al., 2014). Mean leakage rate values shape between 14.5% for the food sector (*foo*) and 135.5% for chemical industry (*chm*) and uncertainty related to energy parameters values is low, only in three sectors (*foo*, *nem*, *ppp*) coefficients of variation are double-digit (see Table C5). When non-energy parameters are changing in sensitivity analysis the uncertainty related to elasticities parameters is moderate and calculated leakage rates are higher (see Table C10).

At the macroeconomic level, GDP loss is also differentiated between countries (see Table C1) being the highest for Croatia (3.2% with respect to the baseline level), Poland (2.1%), and Bulgaria (2.0%). Decline in consumption, which is a more adequate measure of welfare loss, is even more pronounced (see Table C1 and Figure 3). It ranges from 4.6% in Croatia and 3.0% in Poland to just 0.2% in Belgium. As can be seen both from graphs and Table C1 uncertainty related to assumed elasticities of substitution for energy parameters in case of macroeconomic variables is moderate (except for private consumption in Estonia for which variation coefficient exceeds 100% what implies that mean reaction of private consumption in Estonia can either be negative or positive). More generally, for most variables uncertainty related to non-energy parameters is higher than uncertainty related to energy parameters which suggests that at the macro level substitution opportunities (as represented in the CGE framework) towards less emission intensive or emission-free energy sources are in fact limited; a more important question might be how foreign trade would be affected by changes in the intra-EU production cost.

As energy parameters are crucial for calculation of emissions reduction costs, we also examine the implications of a “rigid” structure of energy sectors for calculation of 2030 EU climate and energy policy costs. To this end, we assume that all energy parameters are equal to zero. We find that the so defined “maximum theoretical” cost of EU climate and energy policy in terms of GDP loss could be as high as 4.4% (with respect to the baseline GDP level) for Croatia, 3.8% for Poland or 3.2% for Bulgaria (see Figure 10). Loss in consumption would be even higher: 6.3% with respect to the baseline consumption) for Croatia, 5.6% for Poland and 2.9% for Bulgaria (see Figure 11). As we can see in Figure 12, the declines in gross output in the coal sector under the assumption on no substitution possibilities for most countries are lower than the declines with substitution possibilities in place.

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[16] Chebychev’s inequality implies that in case of variation coefficient exceeding 33.3%, 89 percent confidence interval includes zero, implying that sign of a variable (i.e. direction of an endogenous variable reaction) cannot be specified.

[17] Carbon leakage rate, following the literature, is defined here as follows: $CL = -\frac{\Delta Emissions^{ROW}}{\Delta Emissions^{EU+EFTA}} \cdot 100\%$.

This can be interpreted as follows: if fuel substitution is not possible, energy demand, including demand for coal, declines. In case when there are big substitution possibilities, energy demand decline is less pronounced, but coal is substituted for less polluting fuels.

4. Conclusions

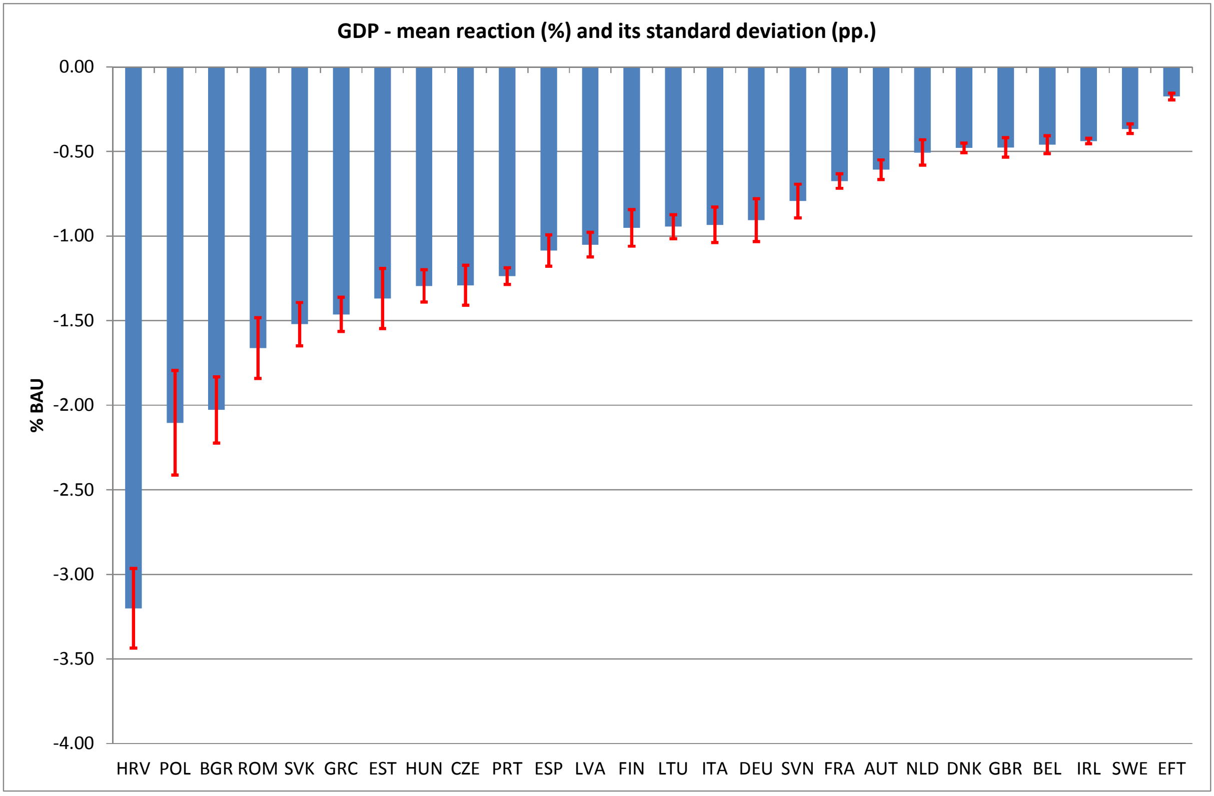
Our findings can be summarized as follows. First, there is a clear pattern with mostly EU New Member States experiencing relatively high costs of emissions reduction in terms of GDP and consumption loss. In the extreme case of strictly rigid energy mixes (no substitution at an industry level), these costs are remarkably higher. It is important to have in mind that the results represent mainly the domestic allocation efficiency trade-offs – with endowments of production factors being fixed at the country level (with only relatively small effects from changes in labour supply), as well as with fixed trade balances.

Another finding is that, in general, elasticity parameters uncertainty is moderate and, in most cases, it stems to the larger extent from non-energy parameters uncertainty. High uncertainty accompanies mean sectoral output and aggregate energy use reactions, while it is moderate in case of mean macroeconomic variables (GDP, private consumption) reactions, as well as carbon leakage rates; in addition, it is quite low in case of GHG emissions (in case of total non-ETS GHG emissions there is no uncertainty regarding elasticity parameter as emission limits are predetermined at the country level).

Modelling energy use and generation in the nested-CES framework makes it virtually impossible to include engineering information concerning technologies or other expert knowledge on the evolution of energy markets etc. Under this approach the modeller must rather rely on empirical studies based on historical data. Since such evidence is mixed, we believe that uncertainty issues should be communicated to decision makers, thus diminishing the influence of arbitrariness on the results of analyses.

Due to significant uncertainty regarding mean results from a CGE model, it should be a standard practice to present confidence bounds for the results rather than the point values. This paper only addresses parametric uncertainty (related to just a subset of parameters). The adoption of a more comprehensive approach is left for further work.

Figure 2. GDP change (%) with respect to baseline level – mean reaction (%) and its standard deviation (pp.) – energy parameters



Note (refers to Figures 2 to 9): The blue bars reflect mean reactions and the lower and upper bounds in red are respectively "minus" and "plus" one standard deviations of mean reactions.

Figure 3. Private consumption change (%) with respect to baseline level – mean reaction (%) and its standard deviation (pp.) – energy parameters

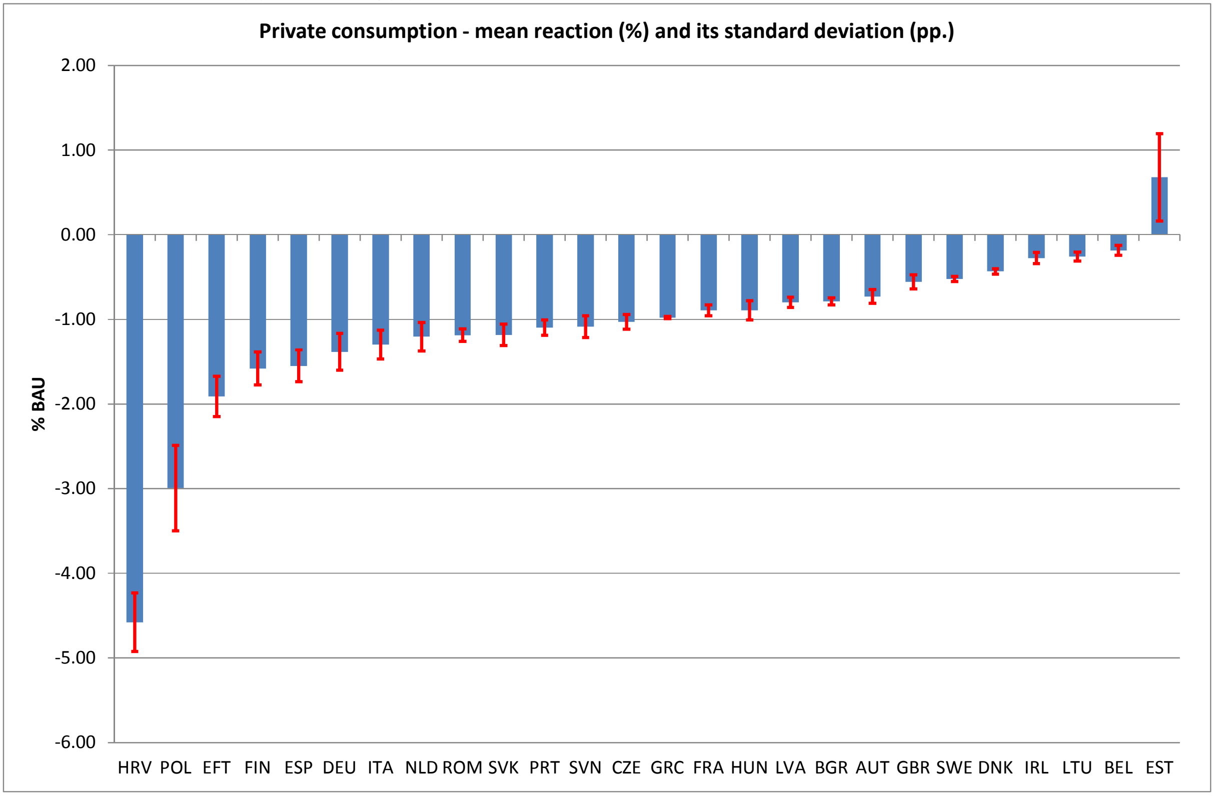


Figure 4. Coal mining gross output change (%) with respect to baseline level – mean reaction (%) and its standard deviation (pp.) – energy parameters

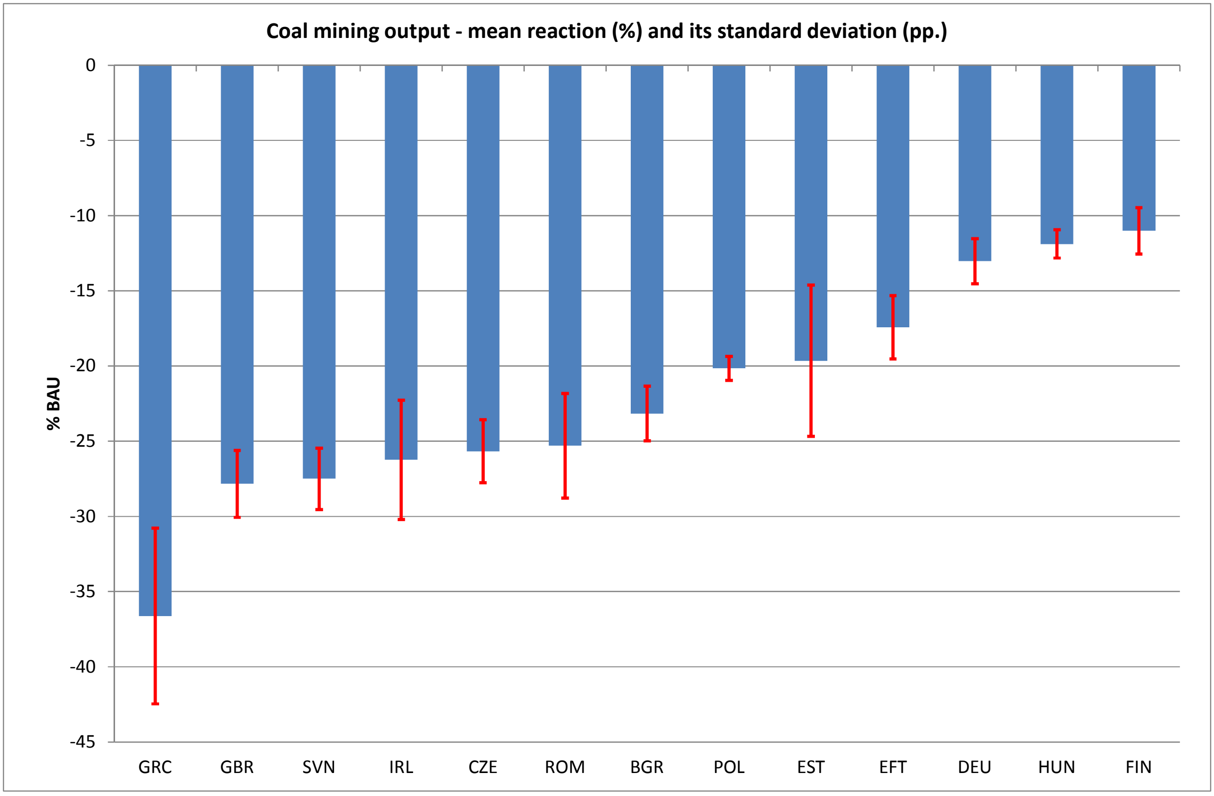


Figure 5. Iron and steel gross output change (%) with respect to baseline level – mean reaction (%) and its standard deviation (pp.) – energy parameters

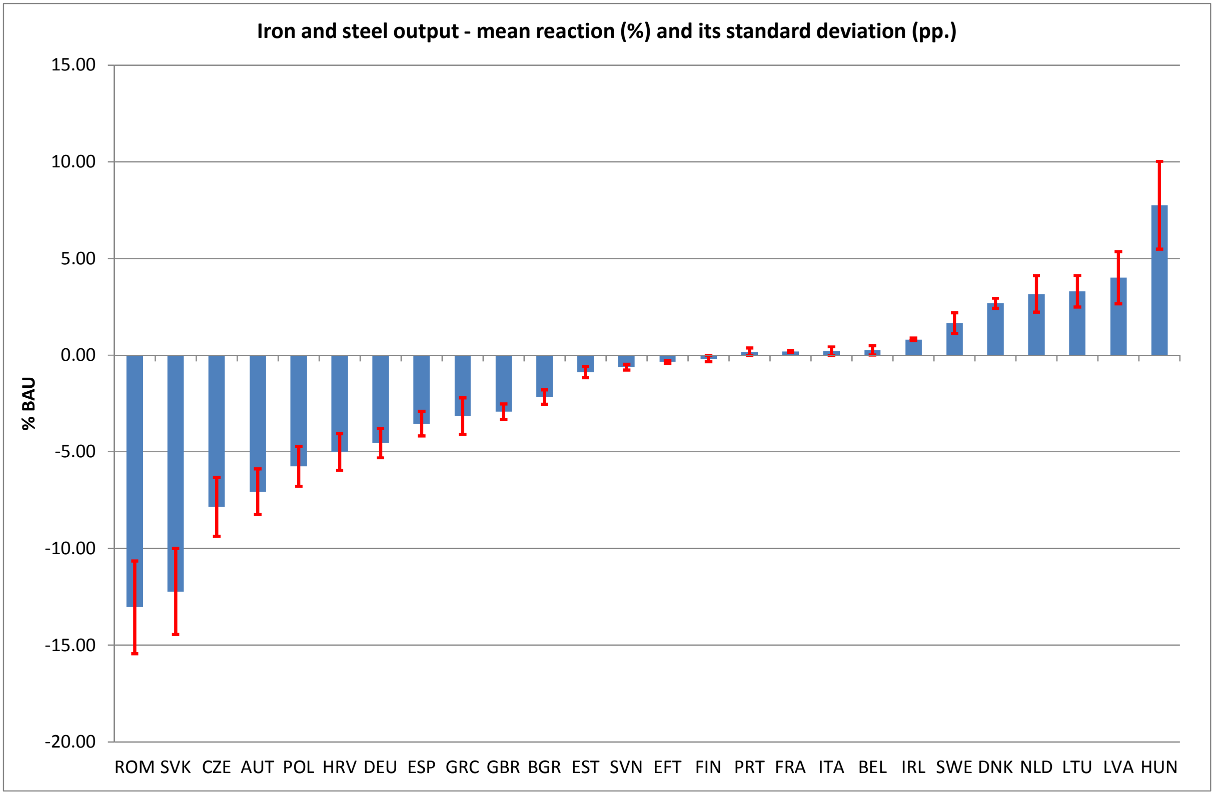


Figure 6. GDP change (%) with respect to baseline level – mean reaction (%) and its standard deviation (pp.) – non-energy parameters

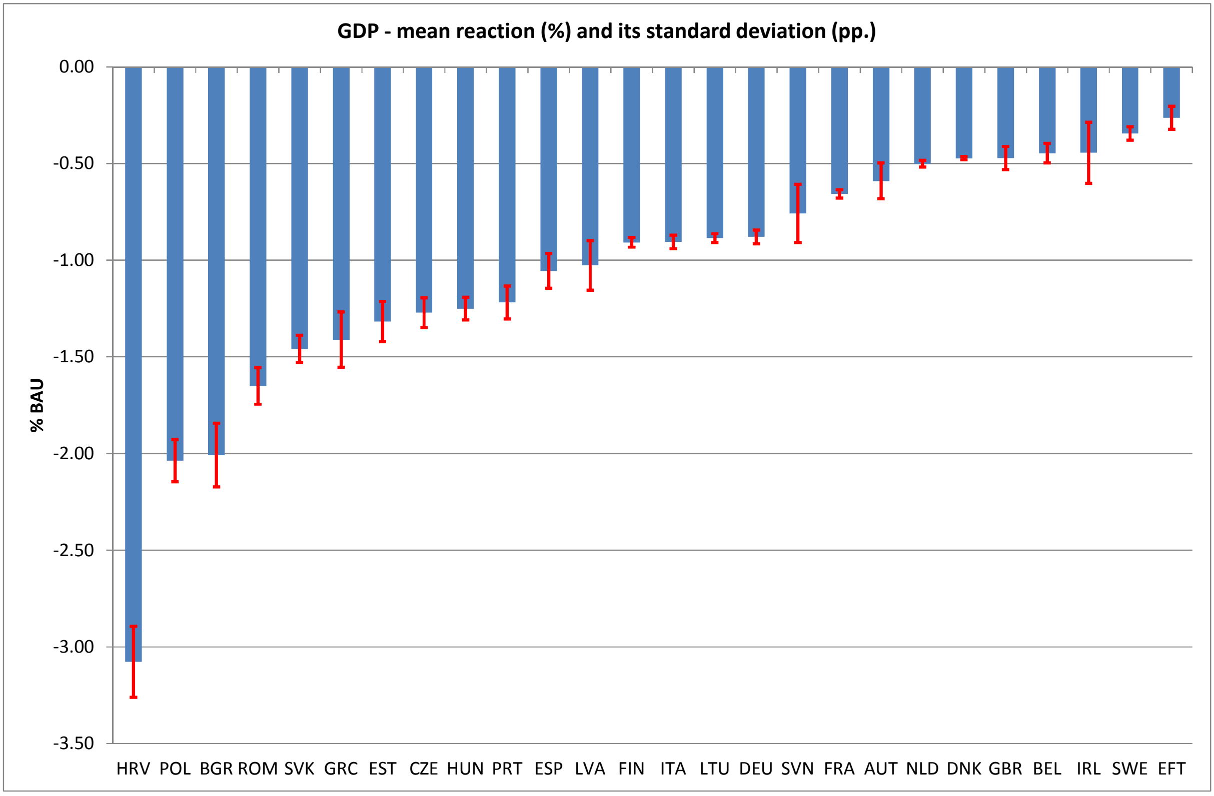


Figure 7. Private consumption change (%) with respect to baseline level – mean reaction (%) and its standard deviation (pp.) – non-energy parameters

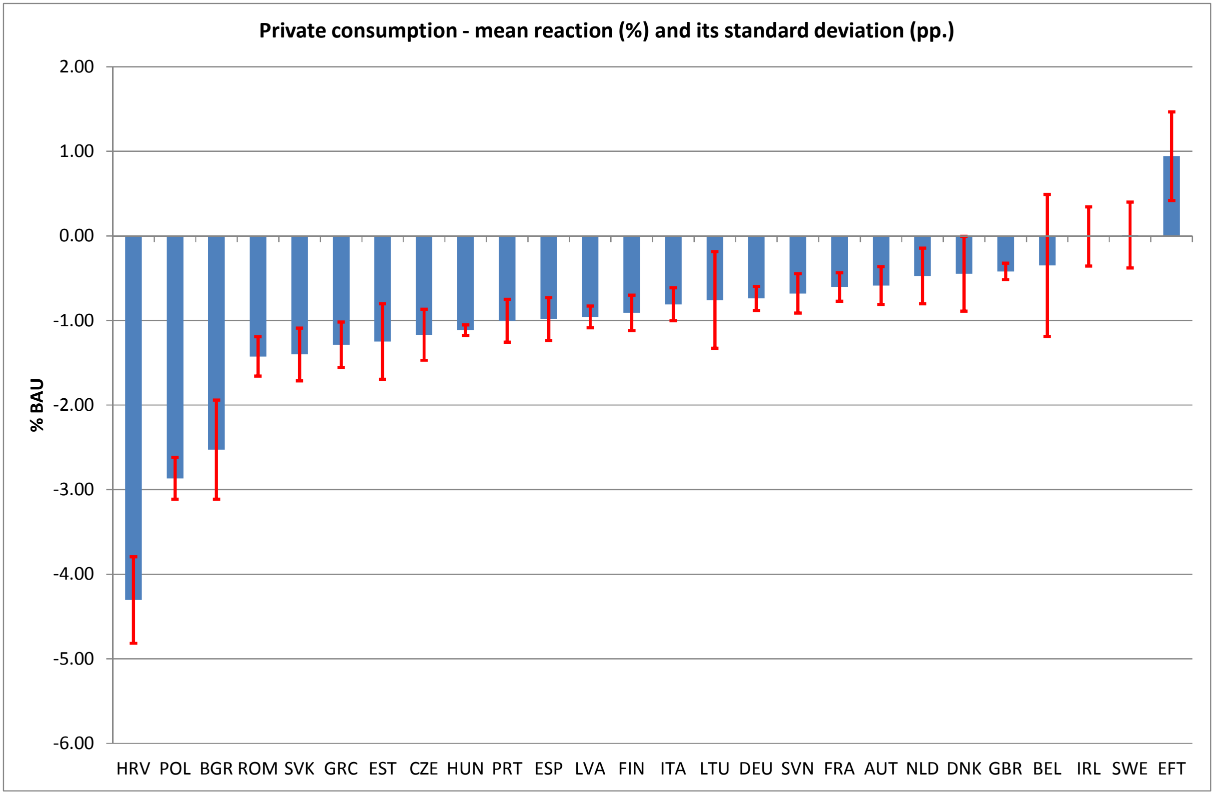


Figure 8. Coal mining gross output change (%) with respect to baseline level – mean reaction (%) and its standard deviation (pp.) – non-energy parameters

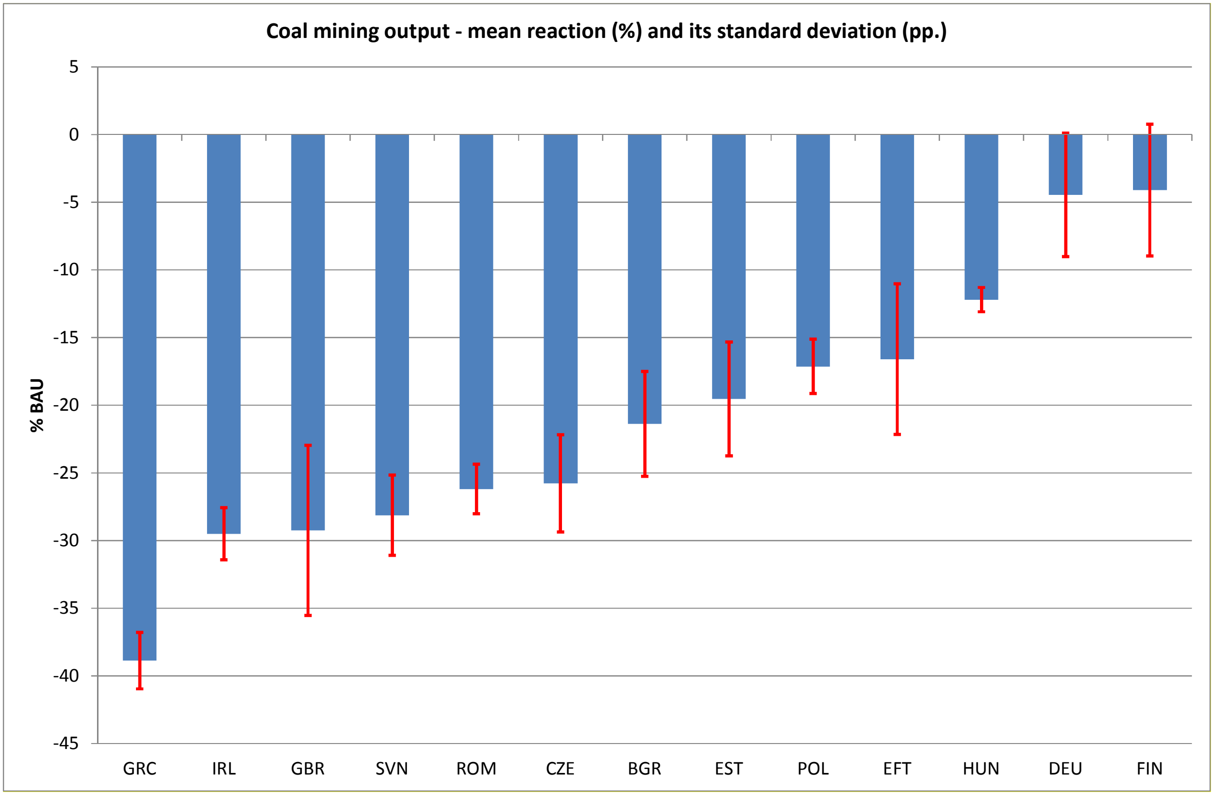


Figure 9. Iron and steel gross output change (%) with respect to baseline level – mean reaction (%) and its standard deviation (pp.) – non-energy parameters

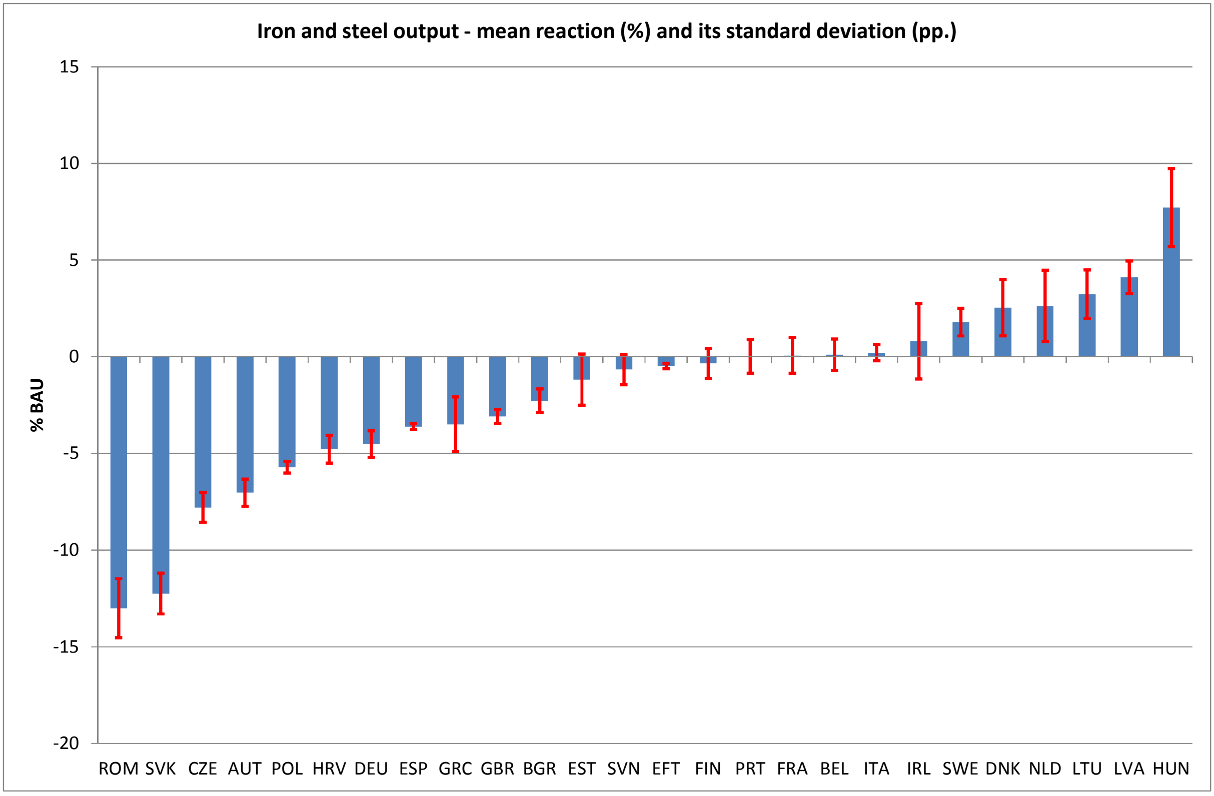


Figure 10. Maximum “theoretical” cost of 2030 emission reduction target – GDP

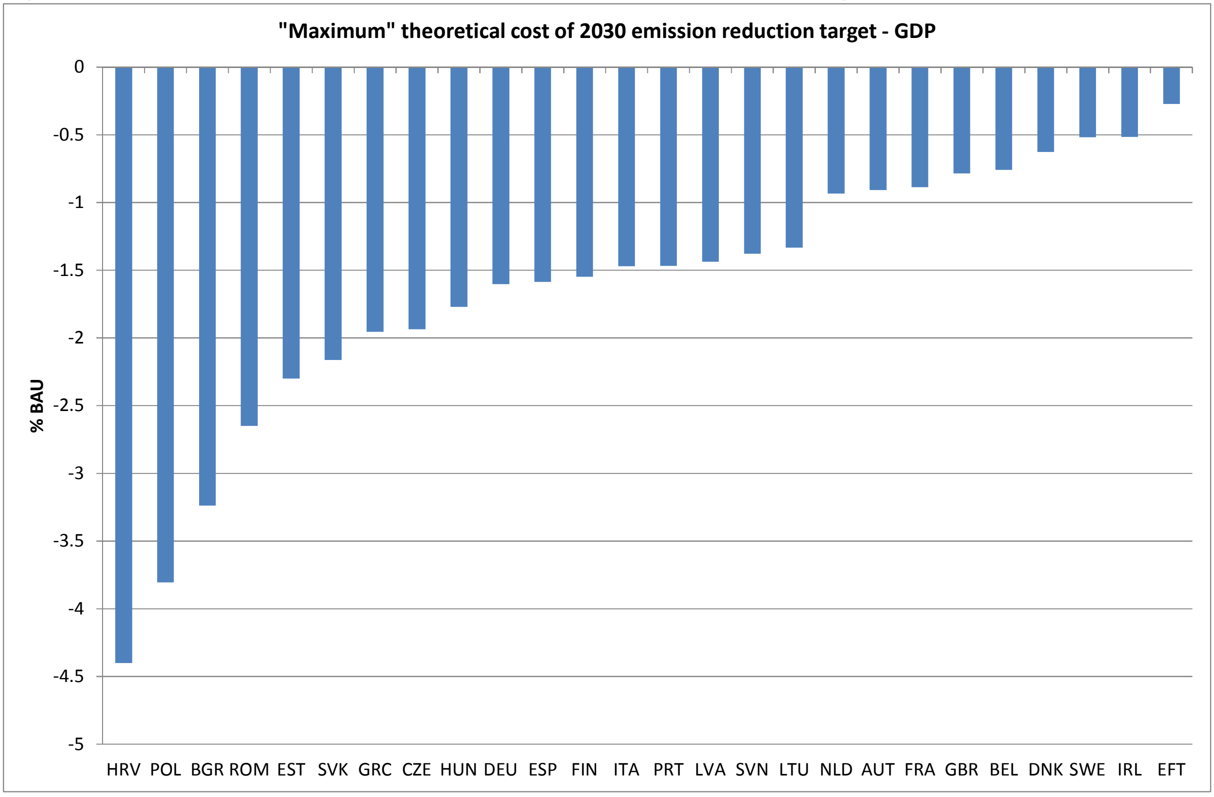


Figure 11. Maximum “theoretical” cost of 2030 emission reduction target – private consumption

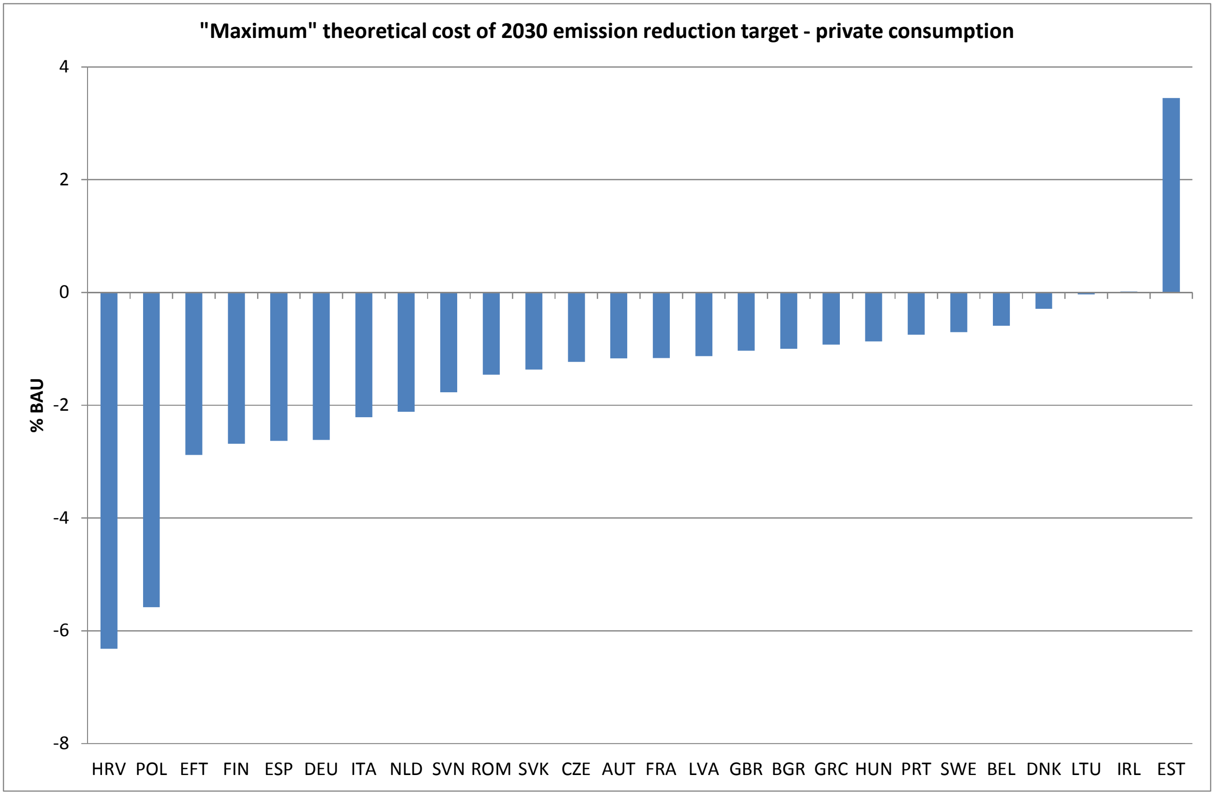


Figure 12. Maximum “theoretical” cost of 2030 emission reduction target – coal mining output

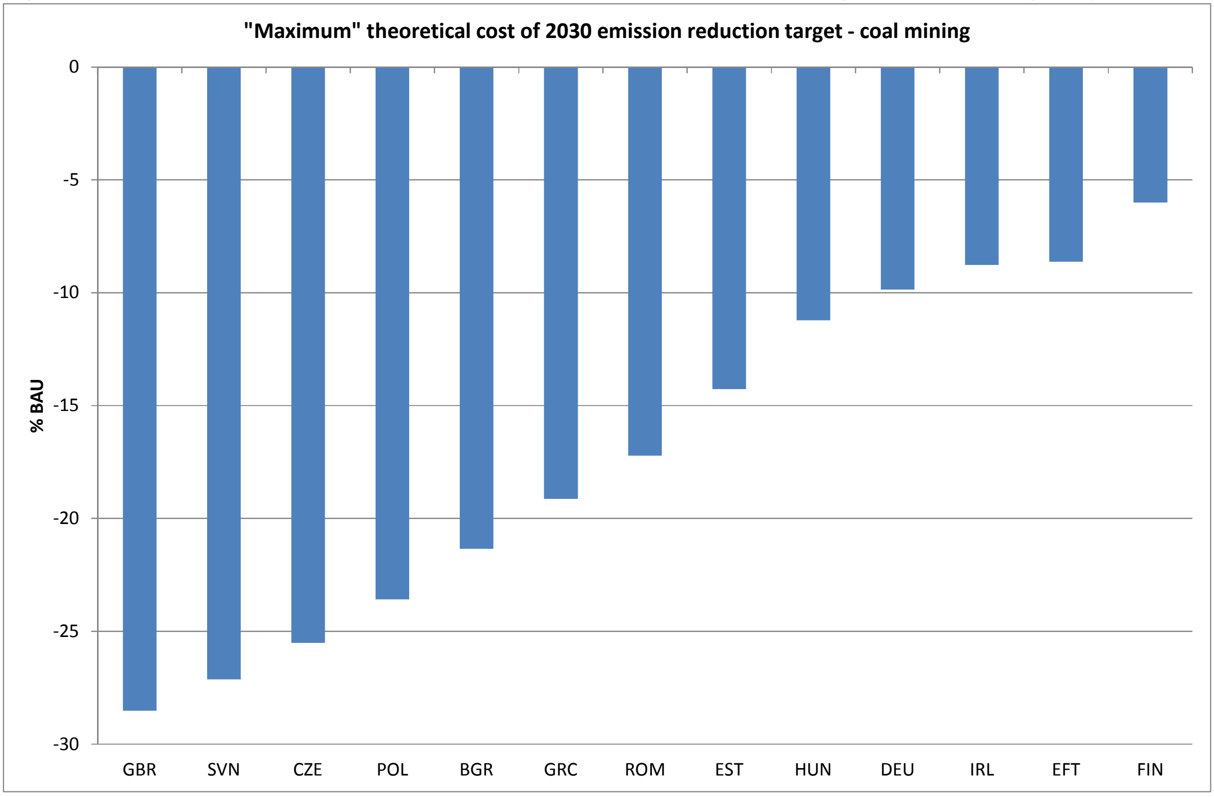
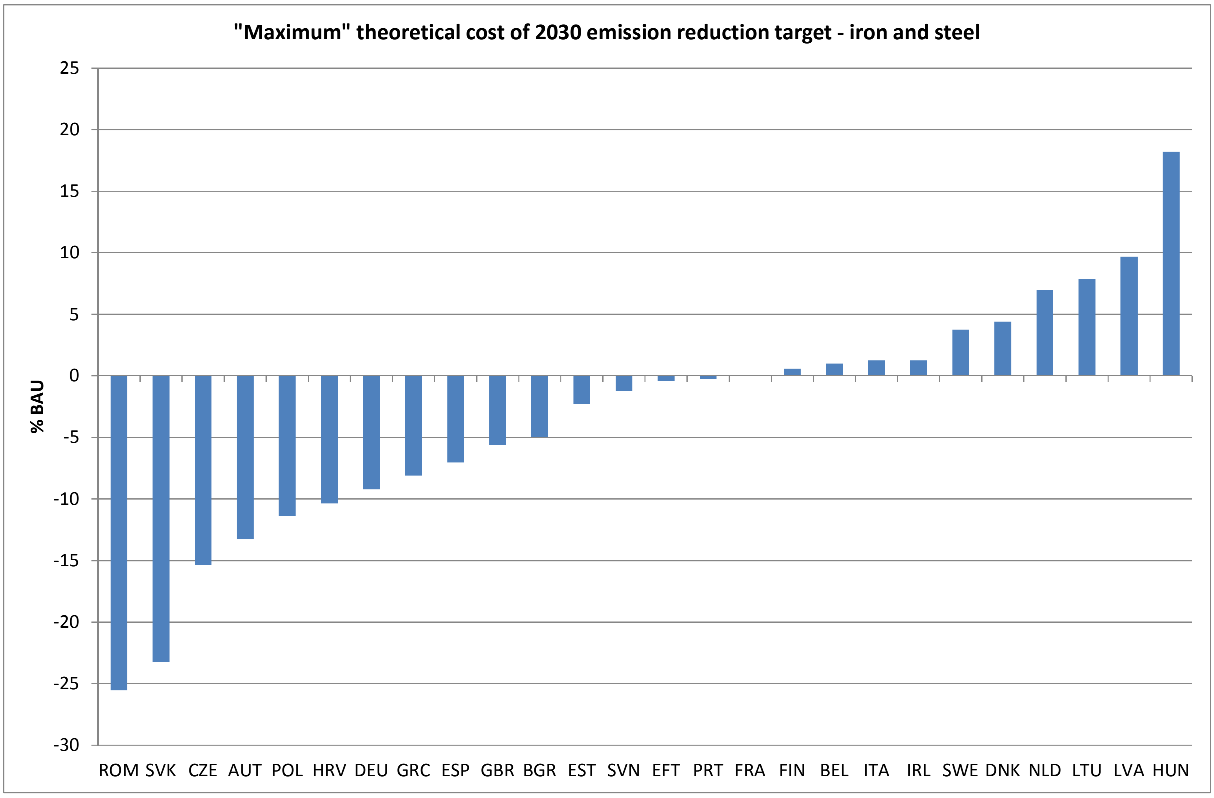


Figure 13. Maximum “theoretical” cost of 2030 emission reduction target – production of iron and steel



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Appendix A. PLACE model overview

PLACE is a global CGE model dedicated primarily to climate and energy policy simulations for Poland in the European and global context. It has been developed by the experts from the Polish government administration with the support of external experts under the World Bank project "Economic modeling for climate policy in Poland".

PLACE covers 20 sectors and 35 regions. Almost all EU Member States, as well as main global emitters are represented individually. Sectoral and regional disaggregation of the PLACE model are presented in Tables A1 and A2, respectively. The model is based on 2011 GTAP data.

In the current model version, each sector produces one specific good using three primary factors (skilled labour, unskilled labour, capital), with the additional natural resources factor used by the fossil fuel extraction sectors) and seven energy factors (coal, crude oil, refined petroleum, natural gas, electricity and heat, biofuels and biomass).

The production process for each sector is a combination of Leontief and nested constant elasticity of substitution (CES) functions. At the top level, a Leontief material composite (excluding energy use) is combined in fixed proportions (Leontief) with an aggregate of capital, labour and energy. At the second level, a CES function describes the substitution possibilities between the energy aggregate and the value-added composite of capital and labour (or between the labour aggregate and the composite of capital and energy in the case of electricity generation). At the third level, capital and labour or capital and energy substitution possibilities within the value-added composite are again captured by a CES function. Different energy inputs enter the energy composite subject to a sector-specific nested CES structure.

Capital and labour are mobile between sectors, but not between regions (except capital representing natural resources, which is sector-specific). The model distinguishes between skilled and unskilled labour, subject to substitution possibilities. The rate of involuntary unemployment is assumed to be fixed.

Household consumption is represented by a Cobb-Douglas function with respect to commodity (import-domestic) bundles – except for energy commodities, for which substitution possibilities are modelled within a nested CES structure.

The government collects taxes, makes and receives transfer payments and purchases goods and services. Commodity-structure of government consumption is fixed in real terms. Total government revenue in each region is a sum of revenues from taxes and emission allowances.

The product composition of investment outlays (gross fixed capital formation) is assumed to be fixed (but region-specific), i.e. investment demand is represented by the Leontief function. In each region, there is one representative investor who represents all producers, households and the government. Aggregate investment is exogenous in the policy simulation reported in this paper.

International trade is modelled under the Armington's assumption that domestic and foreign goods are distinguished by origin (Armington, 1969). All goods used on the domestic market in intermediate and final demand are CES composites that combine the domestically produced good and the bundle of goods imported from other regions. Each trade flow is accompanied by a transport margin. The production of 'margin services' is modelled using the Cobb-Douglas production function that demands as inputs transport services supplied by different regions.

CO_2 emissions from fuel combustion are proportional to the use of fossil fuels and the CO_2 coefficients are differentiated by fuels. Sources of GHG emissions also include industrial processes. Emission reduction can be reached either from the reduction of overall fossil fuel use (i.e. output reduction or energy intensity reduction) or from fuels substitution (i.e. substitution from high polluting to less polluting fuels). Substitution towards emission-free sources is modelled as the fuel-capital substitution.

PLACE includes a representation of the EU ETS cap-and-trade system with a common price of emission allowance; the model also determines country-specific CO_2 prices (taxes) necessary to satisfy national non-ETS emission targets.

Table A1. Sectors classification in PLACE

	Abbrev.	Sectors	ETS	EITE
ENERGY SECTORS				
1	COL	Coal (mining and agglomeration of hard coal, lignite and peat)	**X**	
2	CRU	Crude oil (extraction of crude petroleum, service activities excluding surveying)	**X**	
3	GAS	Primary gas production (extraction of natural gas, service activities excluding surveying)	**X**	
4	GDT	Gas manufacture and distribution (distribution of gaseous fuels through networks, production of town gas)	**X**	
5	OIL	Refined products (coke oven products, refined petroleum products, nuclear fuels)	**X**	**X**
6	ELE	Electricity and heating (production, collection and distribution)	**X**	
NON-ENERGY SECTORS				
7	FRS	Forestry (forestry, logging and related services)		
8	BIO	Biofuels agriculture (paddy rice, wheat, other grains, oilseeds, sugar cane and beat, vegetable oils)		
9	AGR	Rest of agriculture and fishing (vegetables and fruits, plant fibers, other crops, cattle, other animal products, raw milk, wool, fishing)		
10	FOO	Food industry (beverages, tobacco, cattle meat, other meat, milk, processed rice, sugar, other food)	**X**	**X**
11	CHM	Chemical industry (basic chemicals, rubber and plastics, other chemicals)	**X**	**X**
12	NMM	Non-metallic minerals (cement, lime, ceramic, glass, gypsum, plaster, gravel, concrete)	**X**	**X**
13	ISI	Iron and steel industry (basic production and casting)	**X**	**X**
14	NEM	Non-ferrous metals (production and casting of: copper, aluminum, zinc, lead, gold, silver)	**X**	**X**
15	PPP	Paper–pulp–print (including publishing, printing)	**X**	**X**
16	CON	Construction (building houses, factories, offices and roads)		
17	OTH	Other manufactures (textiles, clothing, leather, lumber, fabricated metal products, motor vehicles, other transport equipment, electronic equipment, other machinery, recycling, other mining: metal ores, uranium, gems)		
18	SRV	Services (water distribution, trade, hotels and restaurants, communications, financial intermediation, insurance, real estate, recreational, cultural and sporting activities, public administration and defense, social security, health and social work, sewage and refuse disposal, sanitation, dwellings)		
19	ATR	Air transport	**X**	
20	TRN	Other transport (water and land transport, travel agencies)		

Table A2. Regions in PLACE for the purpose of sensitivity analysis

Model region	Countries and regions included
AUT	Austria
BEL	Belgium, Luxembourg
BGR	Bulgaria
CZE	Czech Republic
DEU	Germany
DNK	Denmark
ESP	Spain
EST	Estonia
FIN	Finland
FRA	France
GBR	Great Britain
GRC	Greek, Cyprus
HRV	Croatia
HUN	Hungary
IRL	Ireland
ITA	Italy, Malta
LTU	Lithuania
LVA	Latvia
NLD	Netherlands
POL	Poland
PRT	Portugal
ROM	Romania
SVK	Slovakia
SVN	Slovenia
SWE	Sweden
AUS	Australia, New Zealand
BRA	Brazil
CHN	China
EFT	Norway, Liechtenstein, Island
IND	India
JPN	Japan
OPE	Saudi Arabia, Ecuador, Venezuela, Nigeria, United Arab Emirates, Iran, Kuwait, Qatar, Algeria, Libyan Arab Jamahiriya, Angola, Western Sahara, Congo
RUS	Russia
USA	United States of America, Canada
RWW	Switzerland, Mongolia, Lao People's Democratic Republic, Malaysia, Philippines, Tailand, Vietnam, Mexico, Argentina, Bolivia, Chile, Colombia, Paraguay, Peru, Uruguay, Costa Rica, Guatemala, Honduras, Nicaragua, Panama, Salvador, Kazakhstan, Egypt, Morocco, Tunisia, Cameroon, Côte d'Ivoire, Ghana, Senegal, Mauritius, Zimbabwe, Botswana, Namibia, Republic of South Africa, Rest of Southern-Eastern Asia, Rest of former USSR, Rest of Southern America, Rest of Central America, Rest of Western Asia, Rest of Oceania, Caribbean, Cambodia, Bangladesh, Nepal, Pakistan, Sri Lanka, Kyrgyzstan, Etiopia, Kenya, Madagascar, Malawi, Mozambique, Tanzania, Uganda, Zambia, Rest of Eastern Asia, Rest of Western Africa, Central Africa, Rest of South-African Customs Union, Rest of Southern Asia, Rest of Eastern Asia, Rest of the world

Appendix B. List of elasticity parameters subject to sensitivity analysis

e_crol – elasticity of substitution between crude oil and refined oil
e_cofr – elasticity of substitution between coal and biomass
e_oibi – elasticity of substitution between refined oil and biofuels
e_biof – elasticity of substitution between biofuels and other fuels
e_nsol – elasticity of substitution between natural gas and oil
e_fuel – elasticity of substitution between natural gas, oil and coal-biomass composite
e_ener – elasticity of substitution between fuels and electricity
e_gele – elasticity of substitution between natural gas and electricity
e_labs – elasticity of substitution between skilled and unskilled labour
e_klab – elasticity of substitution between capital and labour
e_klle – elasticity of substitution between energy and capital-labour composite
e_kkee – elasticity of substitution between capital and fuels
e_klem – elasticity of substitution between materials and capital-labour-energy composite
e_armi – elasticity of substitution domestic and imported goods (Armington nest)
e_impr – elasticity of substitution imported goods from different regions

Appendix C. Detailed systematic sensitivity analysis results

Table C1. Simulation results of macroeconomic variables for alternative values of energy elasticities

region	GDP			Private consumption		
	M (%)	S (pp.)	V (%)	M (%)	S (pp.)	V (%)
AUT	-0.61	0.06	9.42	-0.73	0.08	11.03
BEL	-0.46	0.05	11.69	-0.19	0.06	31.22
BGR	-2.03	0.20	9.65	-0.79	0.04	5.19
CZE	-1.29	0.12	9.16	-1.03	0.09	8.48
DEU	-0.91	0.13	13.88	-1.38	0.22	15.70
DNK	-0.48	0.03	5.80	-0.43	0.03	7.56
EFT	-0.18	0.02	11.39	-1.91	0.24	12.53
ESP	-1.09	0.09	8.57	-1.55	0.19	12.19
EST	-1.37	0.18	12.96	0.68	0.52	76.12
FIN	-0.95	0.11	11.44	-1.58	0.20	12.39
FRA	-0.68	0.04	6.32	-0.89	0.07	7.35
GBR	-0.48	0.06	12.02	-0.56	0.08	14.99
GRC	-1.46	0.10	6.89	-0.98	0.01	1.34
HRV	-3.20	0.24	7.36	-4.58	0.35	7.55
HUN	-1.30	0.10	7.39	-0.89	0.11	12.53
IRL	-0.44	0.02	3.68	-0.28	0.07	24.05
ITA	-0.93	0.10	11.24	-1.30	0.17	13.10
LTU	-0.94	0.07	7.45	-0.26	0.05	20.15
LVA	-1.05	0.07	6.87	-0.80	0.06	7.59
NLD	-0.51	0.08	14.87	-1.20	0.17	13.98
POL	-2.10	0.31	14.73	-2.99	0.50	16.85
PRT	-1.24	0.05	3.93	-1.10	0.09	8.35
ROM	-1.66	0.18	10.80	-1.19	0.07	6.16
SVK	-1.52	0.13	8.43	-1.18	0.13	10.62
SVN	-0.79	0.10	12.61	-1.09	0.13	11.79
SWE	-0.37	0.03	7.89	-0.52	0.03	5.77

Notes: “M” stands for mean value of endogenous variable in sensitivity analysis. “S” is standard deviation result of variables and “V” is variation coefficient.

Table C2. Simulation results of gross output for alternative values of energy elasticities

region	agr			atr			bio			chm			col			con			cru		
	M	S	V	M	S	V	M	S	V	M	S	V	M	S	V	M	S	V	M	S	V
	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)
AUT	-7.56	0.36	4.74	-4.85	0.99	20.38	-9.21	0.51	5.54	-0.64	0.06	9.85				-0.11	0.01	8.94			
BEL	-4.17	0.13	3.15	-2.44	0.58	23.59	-9.76	0.12	1.22	-1.86	0.33	17.83				-0.12	0.01	10.84			
BGR	-7.83	0.21	2.66	-3.31	0.28	8.59	-13.15	0.37	2.80	-5.30	1.03	19.50	-23.17	1.81	7.82	-0.46	0.03	5.82			
CZE	-9.83	0.79	8.01	-7.26	1.46	20.08	-7.60	0.75	9.90	-1.85	0.29	15.67	-25.68	2.09	8.15	-0.29	0.02	8.12			
DEU	-9.49	0.49	5.20	-5.20	1.03	19.74	-19.25	0.88	4.55	-2.98	0.68	22.79	-13.04	1.51	11.56	-0.16	0.02	11.69			
DNK	-6.41	0.10	1.53	-2.40	0.42	17.48	-18.75	0.37	1.95	0.94	0.10	10.69				-0.06	0.01	17.64	-0.27	0.10	36.62
EFT	3.23	0.17	5.22	-3.61	0.88	24.38	6.14	0.25	4.09	1.18	0.30	25.47	-17.43	2.11	12.11	-0.04	0.00	11.41	-0.27	0.05	19.95
ESP	-5.43	0.33	6.05	-8.39	1.54	18.34	-12.35	0.71	5.78	-1.14	0.12	10.39				-0.22	0.02	11.24			
EST	-9.36	0.51	5.46	-30.04	5.11	17.02	-17.95	0.83	4.61	-1.00	0.06	6.44	-19.65	5.03	25.62	-0.20	0.04	20.15	-0.51	0.07	14.19
FIN	-7.59	0.24	3.17	-5.01	1.11	22.17	-32.23	0.24	0.74	-2.43	0.45	18.46	-11.01	1.54	14.02	-0.15	0.01	8.63			
FRA	-8.97	0.45	5.06	-5.12	1.16	22.66	-19.96	0.97	4.86	-0.94	0.01	1.12				-0.07	0.01	15.28			
GBR	-5.81	0.46	7.90	-5.56	1.22	21.94	-6.65	0.58	8.74	-1.91	0.19	10.17	-27.84	2.23	8.00	-0.13	0.01	11.31	-0.77	0.14	18.38
GRC	-5.93	0.06	1.06	-22.43	4.62	20.59	-8.61	0.23	2.71	-2.88	0.59	20.34	-36.63	5.85	15.96	0.00	0.00	301.16			
HRV	-7.55	0.42	5.51	-6.79	1.17	17.23	-10.38	0.54	5.21	-3.00	0.56	18.82				-1.16	0.10	8.48	-1.42	0.29	20.43
HUN	-8.40	0.57	6.74	-6.75	1.28	18.92	-6.71	0.55	8.24	-2.31	0.45	19.64	-11.88	0.94	7.94	-0.32	0.03	7.85			
IRL	-10.02	0.09	0.88	-0.68	0.26	38.88	-20.24	0.14	0.71	1.13	0.11	9.38	-26.23	3.97	15.13	-0.15	0.01	6.20			
ITA	-5.93	0.63	10.63	-5.96	1.07	18.00	-6.77	0.78	11.54	-2.02	0.30	14.61				-0.17	0.02	10.28			
LTU	-5.78	0.12	2.10	-5.03	0.80	15.99	-24.14	0.57	2.37	-5.49	1.04	18.98				0.01	0.01	164.34			
LVA	-17.40	0.37	2.10	-14.78	3.16	21.39	-20.18	0.43	2.12	-0.53	0.03	5.80				-0.18	0.02	9.90			
NLD	-6.28	0.83	13.21	-5.36	1.14	21.24	-14.74	1.53	10.38	0.95	0.09	9.49				-0.07	0.01	10.86			
POL	-8.58	0.82	9.54	-8.45	1.71	20.25	-10.28	0.88	8.55	-4.06	0.68	16.74	-20.16	0.80	3.96	-0.96	0.17	17.46			
PRT	-11.55	0.37	3.21	-11.73	2.16	18.37	-18.52	0.66	3.59	-0.87	0.08	9.68				-0.24	0.02	7.53			
ROM	-3.86	0.23	5.91	-8.98	2.14	23.83	-4.55	0.27	5.88	-8.85	1.61	18.22	-25.31	3.48	13.74	-0.25	0.03	10.88	-0.98	0.20	20.72
SVK	-6.40	0.52	8.19	-7.09	1.19	16.84	-15.22	1.18	7.78	-0.91	0.07	7.73				-0.33	0.04	10.54			
SVN	-7.98	1.01	12.65	-9.14	1.96	21.48	1.87	0.45	24.26	-0.08	0.21	276.11	-27.50	2.04	7.42	-0.14	0.01	6.76			
SWE	-3.92	0.26	6.55	-2.76	0.59	21.32	-16.43	0.77	4.68	0.22	0.12	55.75				-0.12	0.01	10.56			

Table C2. Simulation results of gross output for alternative values of energy elasticities – cont.

region	ele			foo			frs			gas			gdt			isi			nem		
	M	S	V	M	S	V	M	S	V	M	S	V	M	S	V	M	S	V	M	S	V
	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)
AUT	3.56	0.91	25.45	-2.87	0.19	6.64	-0.59	0.06	10.81				-24.41	2.56	10.48	-7.07	1.19	16.78	-0.65	0.13	19.97
BEL	-2.18	0.91	41.59	-1.38	0.12	8.50	0.20	0.07	37.32							0.25	0.24	93.92	-1.41	0.18	12.72
BGR	-9.91	2.29	23.11	-0.04	0.23	570.81	-2.36	0.25	10.77				-18.04	1.85	10.23	-2.17	0.37	17.23	-3.14	0.58	18.54
CZE	-5.19	1.81	34.85	-2.17	0.17	7.67	-1.92	0.12	6.38				-14.14	0.98	6.93	-7.84	1.53	19.44	-1.43	0.14	9.59
DEU	-5.53	1.82	32.85	-3.28	0.28	8.50	0.00	0.06	11957.93				-18.94	0.29	1.52	-4.55	0.76	16.65	-0.87	0.06	7.40
DNK	1.03	0.32	31.12	-3.75	0.11	3.03	-1.78	0.08	4.72	-5.05	0.78	15.55	-11.38	0.21	1.85	2.68	0.26	9.74	1.79	0.08	4.60
EFT	-0.54	0.18	33.33	-0.10	0.02	15.58	0.50	0.20	39.11	-3.51	0.52	14.73	-9.07	0.46	5.09	-0.35	0.08	24.45	-2.21	0.34	15.60
ESP	-3.28	1.40	42.69	-2.86	0.20	7.06	-1.04	0.05	5.21							-3.54	0.63	17.86	-4.09	0.70	17.01
EST	-3.59	0.78	21.73	-1.20	0.52	43.58	-3.38	0.72	21.34	-3.81	0.84	22.07	-1.65	1.89	114.83	-0.88	0.29	32.76	-1.31	0.31	24.06
FIN	-5.22	1.34	25.63	-2.89	0.24	8.34	-1.26	0.05	4.17							-0.19	0.16	85.32	-1.16	0.28	24.10
FRA	3.09	1.03	33.41	-2.25	0.13	5.62	-0.45	0.06	13.33							0.19	0.05	25.62	0.25	0.11	42.47
GBR	-1.81	0.85	46.80	-1.52	0.15	9.53	-0.49	0.04	8.36	-3.47	0.14	4.11	-21.39	2.00	9.35	-2.93	0.41	13.86	-3.35	0.68	20.30
GRC	-8.70	1.85	21.30	-2.31	0.08	3.29	-0.62	0.07	11.94							-3.15	0.95	30.11	-36.09	5.93	16.44
HRV	-10.19	2.85	27.93	-4.70	0.34	7.22	-1.90	0.18	9.25	-6.45	1.03	15.90	-43.82	0.11	0.25	-5.01	0.95	18.91	-2.51	0.37	14.85
HUN	1.63	0.77	47.36	-3.44	0.25	7.24	-1.96	0.14	7.22				-18.44	1.02	5.52	7.75	2.27	29.32	-1.05	0.11	10.77
IRL	-0.69	0.45	65.42	-5.91	0.12	2.10	0.02	0.06	304.43							0.81	0.07	8.29	-2.69	0.82	30.68
ITA	-3.36	1.29	38.32	-2.17	0.23	10.61	-1.54	0.11	7.26				-12.17	1.03	8.46	0.20	0.23	113.10	-2.53	0.45	17.78
LTU	-5.77	1.61	27.85	0.02	0.13	786.20	-0.39	0.20	50.50							3.30	0.82	24.79	2.97	0.78	26.30
LVA	-2.87	1.23	42.84	0.16	0.07	40.16	-3.02	0.21	7.08							4.00	1.34	33.49	1.04	0.40	38.89
NLD	-9.00	2.36	26.22	-1.49	0.23	15.07	-4.26	0.70	16.49	-3.01	0.19	6.30	-12.37	1.34	10.82	3.16	0.94	29.82	-13.93	3.05	21.87
POL	-9.56	2.37	24.82	-4.50	0.56	12.48	-1.93	0.25	12.88				-46.25	2.79	6.04	-5.75	1.04	18.02	-2.60	0.49	18.73
PRT	1.23	0.70	56.78	-3.65	0.13	3.53	0.41	0.09	21.96							0.17	0.20	117.52	-0.14	0.33	234.58
ROM	-5.25	2.00	38.04	0.03	0.07	205.27	-1.57	0.12	7.66	-22.65	1.60	7.08	-18.76	1.64	8.73	-13.04	2.40	18.40	-2.78	0.22	7.91
SVK	2.08	0.99	47.43	-1.76	0.14	7.95	-1.94	0.19	9.58				-15.21	1.08	7.12	-12.23	2.22	18.19	-2.96	0.28	9.52
SVN	-13.76	3.56	25.90	-0.81	0.10	12.08	-0.15	0.02	11.04							-0.63	0.15	23.41	-12.55	2.60	20.70
SWE	0.81	0.34	42.18	-1.09	0.07	6.24	-0.44	0.01	1.68							1.66	0.54	32.38	-0.46	0.05	10.15

Table C2. Simulation results of gross output for alternative values of energy elasticities – cont.

region	nmm			oil			oth			ppp			srv			trn		
	M	S	V	M	S	V	M	S	V	M	S	V	M	S	V	M	S	V
	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)
AUT	3.56	0.91	25.45	-2.87	0.19	6.64	-0.59	0.06	10.81				-24.41	2.56	10.48	-7.07	1.19	16.78
BEL	-2.18	0.91	41.59	-1.38	0.12	8.50	0.20	0.07	37.32							0.25	0.24	93.92
BGR	-9.91	2.29	23.11	-0.04	0.23	570.81	-2.36	0.25	10.77				-18.04	1.85	10.23	-2.17	0.37	17.23
CZE	-5.19	1.81	34.85	-2.17	0.17	7.67	-1.92	0.12	6.38				-14.14	0.98	6.93	-7.84	1.53	19.44
DEU	-5.53	1.82	32.85	-3.28	0.28	8.50	0.00	0.06	11957.93				-18.94	0.29	1.52	-4.55	0.76	16.65
DNK	1.03	0.32	31.12	-3.75	0.11	3.03	-1.78	0.08	4.72	-5.05	0.78	15.55	-11.38	0.21	1.85	2.68	0.26	9.74
EFT	-0.54	0.18	33.33	-0.10	0.02	15.58	0.50	0.20	39.11	-3.51	0.52	14.73	-9.07	0.46	5.09	-0.35	0.08	24.45
ESP	-3.28	1.40	42.69	-2.86	0.20	7.06	-1.04	0.05	5.21							-3.54	0.63	17.86
EST	-3.59	0.78	21.73	-1.20	0.52	43.58	-3.38	0.72	21.34	-3.81	0.84	22.07	-1.65	1.89	114.83	-0.88	0.29	32.76
FIN	-5.22	1.34	25.63	-2.89	0.24	8.34	-1.26	0.05	4.17							-0.19	0.16	85.32
FRA	3.09	1.03	33.41	-2.25	0.13	5.62	-0.45	0.06	13.33							0.19	0.05	25.62
GBR	-1.81	0.85	46.80	-1.52	0.15	9.53	-0.49	0.04	8.36	-3.47	0.14	4.11	-21.39	2.00	9.35	-2.93	0.41	13.86
GRC	-8.70	1.85	21.30	-2.31	0.08	3.29	-0.62	0.07	11.94							-3.15	0.95	30.11
HRV	-10.19	2.85	27.93	-4.70	0.34	7.22	-1.90	0.18	9.25	-6.45	1.03	15.90	-43.82	0.11	0.25	-5.01	0.95	18.91
HUN	1.63	0.77	47.36	-3.44	0.25	7.24	-1.96	0.14	7.22				-18.44	1.02	5.52	7.75	2.27	29.32
IRL	-0.69	0.45	65.42	-5.91	0.12	2.10	0.02	0.06	304.43							0.81	0.07	8.29
ITA	-3.36	1.29	38.32	-2.17	0.23	10.61	-1.54	0.11	7.26				-12.17	1.03	8.46	0.20	0.23	113.10
LTU	-5.77	1.61	27.85	0.02	0.13	786.20	-0.39	0.20	50.50							3.30	0.82	24.79
LVA	-2.87	1.23	42.84	0.16	0.07	40.16	-3.02	0.21	7.08							4.00	1.34	33.49
NLD	-9.00	2.36	26.22	-1.49	0.23	15.07	-4.26	0.70	16.49	-3.01	0.19	6.30	-12.37	1.34	10.82	3.16	0.94	29.82
POL	-9.56	2.37	24.82	-4.50	0.56	12.48	-1.93	0.25	12.88				-46.25	2.79	6.04	-5.75	1.04	18.02
PRT	1.23	0.70	56.78	-3.65	0.13	3.53	0.41	0.09	21.96							0.17	0.20	117.52
ROM	-5.25	2.00	38.04	0.03	0.07	205.27	-1.57	0.12	7.66	-22.65	1.60	7.08	-18.76	1.64	8.73	-13.04	2.40	18.40
SVK	2.08	0.99	47.43	-1.76	0.14	7.95	-1.94	0.19	9.58				-15.21	1.08	7.12	-12.23	2.22	18.19
SVN	-13.76	3.56	25.90	-0.81	0.10	12.08	-0.15	0.02	11.04							-0.63	0.15	23.41
SWE	0.81	0.34	42.18	-1.09	0.07	6.24	-0.44	0.01	1.68							1.66	0.54	32.38

Table C3. Simulation results of aggregate energy use according to energy carriers for alternative values of energy elasticities

region	col			gas			gdt			oil			ele		
	M	S	V	M	S	V	M	S	V	M	S	V	M	S	V
	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)
AUT	-11.47	0.77	6.67	-8.31	1.22	14.74	-15.86	0.81	5.09	-6.26	0.44	6.99	0.40	0.88	220.17
BEL	-11.80	1.62	13.77	-8.31	0.31	3.73	-3.40	1.22	35.96	-1.99	0.59	29.83	-1.75	0.75	42.73
BGR	-25.50	2.39	9.35	-8.19	3.36	40.98	-18.04	1.85	10.23	-7.95	0.63	7.89	-5.43	1.30	23.96
CZE	-23.85	3.21	13.47	-11.30	2.63	23.32	-14.14	0.98	6.93	-5.68	0.69	12.16	-3.17	1.33	41.94
DEU	-17.62	1.88	10.67	-9.93	2.31	23.30	-14.59	0.18	1.26	-5.35	0.61	11.38	-3.56	1.37	38.57
DNK	-15.46	2.89	18.72	-8.14	0.30	3.68	-11.52	0.13	1.09	-6.54	0.84	12.84	-0.55	0.28	51.20
EFT	-17.94	3.62	20.20	0.23	0.81	357.34	-7.79	1.46	18.74	-1.30	0.35	26.68	-1.40	0.28	20.20
ESP	-24.87	4.86	19.53	-9.89	1.96	19.78	-17.52	0.98	5.58	-8.09	0.51	6.28	-2.53	1.24	49.00
EST	-19.65	5.03	25.62	-3.83	1.03	27.06	-1.57	1.89	119.78	-14.26	3.11	21.78	-2.72	0.58	21.46
FIN	-17.24	2.12	12.31	-4.26	2.08	48.80	-19.12	0.39	2.04	-4.19	0.31	7.50	-3.72	0.98	26.31
FRA	-12.87	0.74	5.78	-13.55	2.10	15.51	-20.45	1.06	5.20	-6.75	0.33	4.85	1.46	1.14	78.10
GBR	-14.77	2.19	14.81	-12.74	0.37	2.90	-17.35	1.50	8.63	-4.21	1.26	30.02	-1.71	0.83	48.41
GRC	-36.63	5.85	15.96	-9.03	1.42	15.75				-7.44	0.33	4.44	-7.44	1.50	20.16
HRV	-34.20	4.65	13.59	-14.65	1.57	10.70	-39.95	0.18	0.46	-7.47	0.53	7.12	-2.57	1.26	48.84
HUN	-12.86	1.33	10.34	-11.35	1.90	16.71	-17.83	1.02	5.69	-4.54	0.40	8.73	0.59	0.93	156.86
IRL	-25.33	4.10	16.18	-7.38	0.55	7.49	2.73	2.37	86.52	-6.04	1.72	28.50	-0.74	0.46	61.41
ITA	-19.53	3.56	18.23	-11.51	1.22	10.62	-11.06	0.97	8.79	-6.00	0.56	9.38	-2.60	1.13	43.34
LTU	-12.47	7.21	57.81	-7.16	1.07	14.95				-5.45	0.31	5.61	-2.38	0.78	32.71
LVA	-26.58	3.59	13.50	-6.71	0.47	7.02	-9.44	0.47	5.00	-8.42	0.50	5.90	-1.49	0.95	63.95
NLD	-18.88	2.04	10.83	-4.49	1.08	24.14	-11.27	1.08	9.59	-2.60	0.68	26.17	-5.35	1.62	30.21
POL	-20.87	0.99	4.73	-14.41	4.33	30.04	-17.96	2.97	16.52	-5.03	0.90	17.92	-8.14	2.09	25.64
PRT	-26.32	6.65	25.27	-10.27	1.41	13.75	-31.42	0.81	2.57	-10.05	0.46	4.54	0.23	0.77	333.71
ROM	-26.60	3.74	14.05	-11.96	1.83	15.31	-18.76	1.64	8.73	-6.76	1.00	14.72	-3.91	1.74	44.45
SVK	-14.66	2.00	13.61	-11.49	1.53	13.28	-15.21	1.08	7.12	-4.67	0.60	12.95	-0.85	1.23	145.45
SVN	-30.56	2.11	6.92	-1.18	1.34	114.06				-6.76	0.83	12.23	-3.97	1.17	29.47
SWE	-13.84	2.96	21.39	-3.57	1.43	39.99	-11.15	1.15	10.35	-2.82	0.29	10.26	-0.11	0.35	320.68

Table C4. Simulation results of carbon prices and GHG emissions for alternative values of energy elasticities

region	carbon price						GHG emissions					
	EU ETS			non-ETS			EU ETS			non-ETS		
	M	S	V	M	S	V	M	S	V	M	S	V
	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)
AUT	104.57	16.21	15.50	66.21	4.05	6.12	-9.11	1.32	14.46	-9.40	0.00	0.00
BEL	104.57	16.21	15.50	43.22	1.14	2.63	-8.20	0.97	11.82	-8.72	0.00	0.00
BGR	104.57	16.21	15.50	59.06	2.47	4.18	-18.94	1.06	5.60	-12.40	0.00	0.00
CZE	104.57	16.21	15.50	61.62	5.18	8.41	-18.58	1.51	8.10	-13.89	0.00	0.00
DEU	104.57	16.21	15.50	79.82	4.60	5.77	-13.26	0.11	0.80	-11.67	0.00	0.00
DNK	104.57	16.21	15.50	86.43	2.50	2.89	-5.53	0.31	5.53	-13.36	0.00	0.00
EFT	104.57	16.21	15.50	8.84	0.38	4.28	-4.79	0.35	7.36	0.00	0.00	0.00
ESP	104.57	16.21	15.50	88.48	5.72	6.46	-13.09	0.91	6.95	-10.37	0.00	0.00
EST	104.57	16.21	15.50	49.84	2.95	5.93	-14.47	1.70	11.75	-15.19	0.00	0.00
FIN	104.57	16.21	15.50	67.14	0.70	1.05	-10.10	0.20	1.99	-9.41	0.00	0.00
FRA	104.57	16.21	15.50	85.23	5.21	6.11	-7.65	0.84	11.02	-12.73	0.00	0.00
GBR	104.57	16.21	15.50	45.19	3.50	7.73	-9.85	0.47	4.75	-12.78	0.00	0.00
GRC	104.57	16.21	15.50	104.03	1.20	1.15	-14.50	1.11	7.66	-7.83	0.00	0.00
HRV	104.57	16.21	15.50	133.75	7.71	5.77	-11.84	0.56	4.69	-14.53	0.00	0.00
HUN	104.57	16.21	15.50	65.33	4.78	7.31	-6.50	0.54	8.32	-11.48	0.00	0.00
IRL	104.57	16.21	15.50	55.47	1.06	1.90	-5.48	0.92	16.73	-14.03	0.00	0.00
ITA	104.57	16.21	15.50	91.01	9.08	9.98	-10.78	0.62	5.76	-9.45	0.00	0.00
LTU	104.57	16.21	15.50	73.74	2.41	3.27	-4.30	0.21	4.89	-14.95	0.00	0.00
LVA	104.57	16.21	15.50	68.71	2.12	3.09	-7.90	0.77	9.72	-13.55	0.00	0.00
NLD	104.57	16.21	15.50	66.43	6.31	9.50	-11.76	0.56	4.78	-9.43	0.00	0.00
POL	104.57	16.21	15.50	55.27	3.36	6.08	-17.55	0.32	1.84	-16.85	0.00	0.00
PRT	104.57	16.21	15.50	110.63	4.80	4.34	-7.48	0.74	9.92	-12.31	0.00	0.00
ROM	104.57	16.21	15.50	65.54	4.25	6.48	-17.55	0.25	1.40	-11.05	0.00	0.00
SVK	104.57	16.21	15.50	80.28	6.59	8.21	-18.35	0.78	4.25	-10.52	0.00	0.00
SVN	104.57	16.21	15.50	60.07	7.16	11.92	-18.42	0.82	4.43	-8.85	0.00	0.00
SWE	104.57	16.21	15.50	56.40	2.92	5.18	-8.15	1.05	12.85	-6.99	0.00	0.00

Table C5. Simulation results of carbon leakage rate for alternative values of energy elasticities – EITE sectors

sector	regions in EU ETS		
	M (%)	S (pp.)	V (%)
chm	135.52	11.23	8.29
foo	14.50	2.10	14.49
isi	14.81	0.79	5.31
nem	63.48	8.97	14.13
nmm	50.28	4.77	9.48
oil	86.90	2.99	3.44
ppp	17.65	4.16	23.58

Table C6. Simulation results of macroeconomic variables for alternative values of non-energy elasticities

region	GDP			Private consumption		
	M (%)	S (pp.)	V (%)	M (%)	S (pp.)	V (%)
AUT	-0.59	0.09	15.65	-0.68	0.23	34.13
BEL	-0.45	0.05	11.17	0.01	0.39	3563.59
BGR	-2.01	0.16	8.21	-0.59	0.22	37.67
CZE	-1.27	0.08	6.10	-0.91	0.21	23.16
DEU	-0.88	0.04	4.02	-1.25	0.45	35.74
DNK	-0.47	0.01	1.84	-0.45	0.44	99.44
EFT	-0.26	0.06	22.57	-2.53	0.59	23.18
ESP	-1.06	0.09	8.56	-1.42	0.23	16.26
EST	-1.32	0.10	7.90	0.94	0.52	55.55
FIN	-0.91	0.02	2.73	-1.40	0.31	22.22
FRA	-0.66	0.02	3.32	-0.81	0.19	23.92
GBR	-0.47	0.06	12.77	-0.47	0.33	69.75
GRC	-1.41	0.14	10.13	-0.76	0.57	75.19
HRV	-3.08	0.18	5.97	-4.31	0.51	11.87
HUN	-1.25	0.06	4.66	-0.74	0.14	19.34
IRL	-0.44	0.16	35.67	-0.35	0.84	240.89
ITA	-0.91	0.04	3.88	-1.17	0.30	25.76
LTU	-0.89	0.02	2.52	-0.01	0.35	5474.88
LVA	-1.03	0.13	12.46	-0.60	0.17	28.05
NLD	-0.50	0.02	3.32	-1.28	0.27	20.91
POL	-2.04	0.11	5.34	-2.87	0.25	8.65
PRT	-1.22	0.09	7.05	-1.00	0.25	25.24
ROM	-1.65	0.09	5.73	-1.11	0.06	5.54
SVK	-1.46	0.07	4.82	-0.98	0.25	25.80
SVN	-0.76	0.15	19.77	-0.96	0.13	13.52
SWE	-0.34	0.03	10.07	-0.42	0.10	23.06

Table C7. Simulation results of gross output for alternative values of non-energy elasticities

region	agr			atr			bio			chm			col			con		
	M	S	V	M	S	V	M	S	V	M	S	V	M	S	V	M	S	V
	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)
AUT	-7.88	1.03	13.03	-4.66	0.89	19.12	-9.73	1.63	16.73	-0.55	0.22	40.74				-0.10	0.06	59.97
BEL	-5.35	1.29	24.14	-1.92	1.23	64.17	-12.05	4.16	34.51	-1.82	1.09	60.04				-0.10	0.09	86.99
BGR	-8.08	0.89	11.04	-3.59	1.35	37.65	-13.63	1.72	12.62	-4.82	0.60	12.46	-21.38	3.88	18.14	-0.45	0.15	33.17
CZE	-10.09	1.57	15.59	-7.18	1.55	21.63	-7.84	0.95	12.08	-1.69	0.28	16.74	-25.77	3.60	13.97	-0.26	0.05	21.25
DEU	-9.53	1.39	14.54	-5.04	1.54	30.62	-19.72	1.99	10.09	-3.07	1.54	50.33	-4.45	4.57	102.62	-0.13	0.23	175.30
DNK	-6.82	1.68	24.62	-2.39	0.43	17.89	-19.43	3.01	15.49	0.52	2.22	423.43				-0.03	0.18	541.31
EFT	2.83	0.49	17.42	-3.66	1.41	38.66	5.45	1.99	36.49	1.20	0.71	59.54	-16.60	5.56	33.48	-0.08	0.00	4.89
ESP	-5.62	1.10	19.62	-8.43	1.15	13.66	-12.60	1.87	14.85	-1.21	0.38	31.38				-0.19	0.07	36.48
EST	-9.26	1.16	12.49	-29.13	7.54	25.89	-19.11	7.22	37.78	-1.16	1.83	157.73	-19.54	4.21	21.53	-0.17	0.03	18.20
FIN	-7.87	0.84	10.64	-4.82	1.41	29.27	-32.68	2.72	8.33	-2.50	1.14	45.54	-4.11	4.87	118.61	-0.13	0.05	41.14
FRA	-9.05	0.63	6.93	-5.03	1.11	22.05	-20.43	2.17	10.64	-1.12	0.97	86.28				-0.06	0.04	63.32
GBR	-6.31	1.56	24.74	-5.38	1.58	29.33	-7.40	1.76	23.77	-2.18	1.15	52.43	-29.25	6.28	21.48	-0.11	0.05	49.93
GRC	-6.17	1.28	20.80	-22.02	4.58	20.80	-8.70	0.32	3.64	-2.81	0.42	14.87	-38.87	2.09	5.37	0.01	0.02	306.98
HRV	-7.42	0.51	6.92	-6.66	0.58	8.67	-10.22	1.26	12.29	-2.31	0.25	10.82				-1.10	0.13	11.73
HUN	-8.47	0.50	5.91	-6.73	0.70	10.41	-6.65	0.27	4.11	-2.12	0.08	3.95	-12.20	0.90	7.36	-0.30	0.14	46.68
IRL	-10.83	1.53	14.09	0.59	0.36	60.44	-21.14	1.16	5.48	0.97	0.20	20.72	-29.50	1.92	6.51	-0.13	0.01	8.17
ITA	-5.98	0.87	14.61	-6.00	1.05	17.48	-6.76	1.38	20.42	-2.17	0.81	37.16				-0.16	0.03	18.74
LTU	-5.83	0.90	15.49	-4.93	1.23	24.95	-24.59	2.31	9.39	-5.08	0.42	8.29				0.02	0.02	124.10
LVA	-17.66	1.42	8.04	-14.53	3.03	20.84	-21.00	4.05	19.30	-0.86	1.64	192.04				-0.16	0.05	28.69
NLD	-6.57	1.76	26.83	-5.32	1.06	19.91	-15.20	2.37	15.59	2.07	0.76	36.92				-0.08	0.07	80.96
POL	-8.66	0.55	6.38	-8.29	1.05	12.65	-10.36	1.20	11.61	-3.99	0.41	10.34	-17.13	2.00	11.69	-0.88	0.10	10.87
PRT	-11.62	1.26	10.85	-11.71	1.53	13.08	-18.64	2.15	11.53	-0.82	0.34	41.07				-0.24	0.01	3.46
ROM	-4.01	0.32	8.05	-8.90	1.37	15.36	-4.65	0.51	11.06	-8.78	1.20	13.62	-26.19	1.84	7.01	-0.24	0.05	20.28
SVK	-6.58	0.97	14.76	-6.99	1.01	14.46	-15.66	1.49	9.51	-0.53	0.75	141.17				-0.31	0.06	17.82
SVN	-7.94	0.21	2.69	-8.98	1.28	14.28	1.90	1.36	71.54	-0.32	0.38	118.60	-28.13	2.97	10.54	-0.12	0.04	34.12
SWE	-4.26	0.65	15.14	-2.69	0.60	22.22	-17.59	2.15	12.22	0.36	0.82	231.33				-0.11	0.05	43.98

Table C7. Simulation results of gross output for alternative values of non-energy elasticities – cont.

region	ele			foo			frs			gas			gdt			isi			nem		
	M	S	V	M	S	V	M	S	V	M	S	V	M	S	V	M	S	V	M	S	V
	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)
AUT	3.73	3.18	85.13	-2.93	0.34	11.56	-0.56	0.28	50.65				-23.30	8.09	34.71	-7.03	0.70	9.95	-0.61	1.44	236.47
BEL	-1.66	0.85	51.44	-1.40	0.25	18.03	0.16	0.34	208.71							0.11	0.81	745.71	-1.56	2.12	135.37
BGR	-9.45	0.76	8.06	0.14	0.53	387.56	-2.32	0.44	19.08				-18.31	0.94	5.16	-2.27	0.61	26.84	-3.27	1.37	41.93
CZE	-4.70	1.44	30.72	-2.08	0.12	5.84	-1.85	0.13	6.91				-14.23	1.71	12.01	-7.79	0.77	9.86	-1.46	0.57	39.19
DEU	-4.85	1.34	27.69	-3.31	0.31	9.49	0.01	0.35	3682.06				-18.95	3.00	15.84	-4.51	0.68	15.16	-0.92	2.73	297.04
DNK	1.29	0.64	49.41	-3.98	0.92	22.98	-1.93	0.75	38.72	0.00	0.00	0.00	-10.97	1.30	11.84	2.54	1.46	57.38	1.60	2.66	166.72
EFT	-1.08	0.66	61.30	-0.52	0.16	30.17	0.18	0.49	279.93	0.00	0.00	0.00	-10.32	2.56	24.82	-0.47	0.14	29.91	-2.58	0.36	13.91
ESP	-2.85	1.16	40.92	-2.82	0.32	11.40	-1.03	0.38	37.38							-3.61	0.16	4.37	-4.06	0.48	11.78
EST	-3.32	3.35	100.79	-1.09	0.29	26.95	-3.43	1.11	32.49	0.00	0.00	0.00	-0.83	3.44	414.11	-1.18	1.33	112.45	-1.29	1.40	108.87
FIN	-4.84	0.67	13.81	-2.88	0.21	7.26	-1.22	0.25	20.51							-0.34	0.77	223.54	-1.33	2.26	170.21
FRA	3.26	1.76	53.95	-2.24	0.25	11.13	-0.34	0.55	161.70							0.07	0.93	1371.98	0.18	1.31	744.94
GBR	-1.42	0.92	64.95	-1.57	0.26	16.57	-0.45	0.36	79.75	0.00	0.00	0.00	-21.65	1.68	7.77	-3.09	0.37	11.88	-3.71	2.80	75.38
GRC	-8.54	3.02	35.32	-2.28	0.18	7.75	-0.42	0.79	186.87							-3.49	1.41	40.51	-35.23	3.68	10.45
HRV	-9.32	8.59	92.13	-4.48	0.46	10.22	-1.81	0.26	14.56	0.00	0.00	0.00	-44.55	2.03	4.56	-4.78	0.72	14.99	-2.35	0.74	31.32
HUN	1.94	1.79	91.97	-3.35	0.30	8.91	-1.91	0.24	12.75				-19.01	1.76	9.28	7.71	2.02	26.18	-1.05	0.92	87.65
IRL	-0.61	0.34	56.00	-6.40	1.14	17.87	0.06	0.92	1653.90							0.81	1.96	241.90	-1.82	8.92	490.74
ITA	-2.95	1.65	55.86	-2.12	0.15	7.02	-1.45	0.79	54.71				-12.24	1.53	12.51	0.21	0.42	200.14	-2.62	1.05	40.19
LTU	-5.14	1.73	33.67	0.17	0.30	175.89	-0.34	0.68	202.90							3.23	1.26	38.92	3.10	1.85	59.74
LVA	-2.34	3.16	135.18	0.26	0.28	105.40	-3.13	0.80	25.50							4.11	0.84	20.39	0.90	1.59	177.15
NLD	-8.74	1.22	13.95	-1.72	0.60	35.08	-4.54	0.65	14.38	0.00	0.00	0.00	-12.46	0.81	6.54	2.63	1.84	70.04	-14.34	2.77	19.31
POL	-8.90	1.31	14.68	-4.44	0.30	6.65	-1.80	0.25	14.06				-45.56	10.78	23.67	-5.71	0.30	5.25	-2.41	0.44	18.18
PRT	1.47	1.12	75.76	-3.66	0.34	9.19	0.47	0.29	61.99							0.02	0.87	5472.69	-0.38	2.54	661.71
ROM	-4.63	1.23	26.56	0.15	0.19	126.44	-1.50	0.41	27.61	-5.04	5.29	104.97	-19.19	0.75	3.89	-13.00	1.52	11.72	-2.95	0.64	21.80
SVK	2.31	2.26	97.97	-1.61	0.39	24.44	-1.76	0.28	16.11				-15.31	1.72	11.21	-12.24	1.06	8.66	-2.92	0.14	4.91
SVN	-13.40	0.48	3.56	-0.73	0.27	36.79	-0.04	0.30	727.05							-0.66	0.78	117.76	-12.40	1.37	11.04
SWE	0.96	0.76	79.67	-1.07	0.15	13.59	-0.44	0.17	38.65							1.79	0.72	39.98	-0.59	1.87	318.56

Table C7. Simulation results of gross output for alternative values of non-energy elasticities – cont.

region	nmm			oil			oth			ppp			srv			trn		
	M	S	V	M	S	V	M	S	V	M	S	V	M	S	V	M	S	V
	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)
AUT	0.91	0.51	56.41	-6.24	0.55	8.80	-0.51	0.57	112.56	-0.20	0.31	150.60	-0.29	0.11	36.36	-2.26	0.49	21.47
BEL	-3.10	0.25	8.03	-1.67	0.63	37.98	-0.47	0.62	130.89	-0.73	0.14	18.87	-0.12	0.30	242.01	-1.52	0.76	49.60
BGR	-6.21	0.84	13.53	-8.16	0.53	6.51	-2.12	1.03	48.75	-2.15	0.87	40.52	-0.85	0.24	28.14	-4.45	0.77	17.40
CZE	0.20	0.33	163.95	-5.50	1.11	20.18	-1.51	0.27	17.64	-1.51	0.57	37.81	-0.69	0.07	10.56	-2.07	0.42	20.16
DEU	-1.19	0.12	9.83	-4.81	0.88	18.20	-0.20	0.59	292.95	-1.19	0.04	3.14	-0.56	0.27	47.51	-2.66	0.82	30.68
DNK	1.92	0.45	23.73	-6.76	0.27	4.02	1.10	0.61	55.88	-0.05	0.12	259.81	-0.06	0.33	529.23	-4.19	1.25	29.84
EFT	0.28	0.09	33.64	1.61	0.23	14.17	0.87	0.22	25.27	-0.40	0.06	15.21	-0.57	0.08	14.25	0.91	0.38	41.55
ESP	-1.89	0.23	12.13	-7.83	0.53	6.83	-1.43	0.23	16.39	-1.06	0.14	13.12	-0.55	0.11	19.42	-4.84	0.72	14.84
EST	6.19	1.11	17.95	-26.94	15.23	56.55	-3.25	1.04	31.94	-1.64	0.22	13.46	-0.50	0.16	31.10	-1.26	1.30	103.17
FIN	0.15	0.48	319.16	-3.88	0.68	17.54	-0.32	0.48	150.39	-1.65	0.54	32.84	-0.63	0.27	42.60	-1.77	0.18	10.41
FRA	-0.84	0.14	16.58	-6.36	0.58	9.16	-0.11	0.18	167.75	-0.47	0.10	21.55	-0.35	0.11	30.94	-3.37	0.39	11.66
GBR	-1.86	0.60	32.31	-3.87	0.58	15.03	-0.42	0.31	74.52	-0.65	0.04	6.31	-0.22	0.10	45.92	-2.19	0.80	36.42
GRC	-1.63	2.71	166.91	-6.61	0.83	12.58	0.17	0.63	375.74	-0.79	0.27	34.13	-0.08	0.10	123.99	-10.36	0.21	2.01
HRV	-5.01	0.82	16.36	-7.20	0.80	11.16	-1.56	0.69	44.37	-3.06	0.34	10.94	-2.47	0.11	4.59	-5.02	0.28	5.63
HUN	-2.38	0.17	7.07	-4.28	0.68	15.83	-0.75	0.63	83.73	-1.36	0.45	33.13	-0.88	0.27	30.95	-4.20	0.73	17.42
IRL	-0.05	0.21	426.61	-5.51	0.56	10.13	0.27	0.80	295.09	-0.39	0.45	116.11	-0.12	0.08	70.33	-5.51	0.70	12.79
ITA	-1.44	0.26	17.84	-5.98	0.41	6.83	-0.89	0.24	27.25	-1.39	0.05	3.40	-0.63	0.16	24.90	-4.48	0.58	12.90
LTU	21.56	3.38	15.65	-4.69	0.91	19.44	-0.59	1.20	203.65	-0.50	0.24	48.67	-0.20	0.20	102.72	-2.58	0.60	23.40
LVA	-0.11	0.55	517.13				-1.42	0.67	46.89	-0.45	0.30	65.51	-0.62	0.23	36.59	-3.25	0.67	20.59
NLD	0.59	0.70	118.86	-2.30	0.53	23.05	0.42	0.81	191.59	-0.27	0.30	110.72	-0.29	0.21	71.41	-2.47	0.94	38.05
POL	-5.11	0.37	7.22	-4.97	1.30	26.21	-1.09	0.69	63.36	-1.68	0.20	11.79	-1.53	0.05	3.34	-4.08	0.48	11.65
PRT	-1.09	0.44	40.12	-9.11	0.26	2.83	-1.10	0.64	57.66	5.04	0.89	17.72	-0.60	0.14	23.51	-8.05	0.87	10.76
ROM	-1.91	0.15	7.93	-6.47	1.01	15.54	-1.95	0.39	19.99	-0.82	0.16	18.94	-0.71	0.17	24.42	-4.99	0.55	11.10
SVK	0.71	0.48	67.85	-4.69	0.90	19.12	-2.35	0.10	4.14	-1.49	0.63	42.15	-0.97	0.06	6.09	-2.82	0.47	16.69
SVN	-0.02	0.24	1412.60				-0.60	0.36	59.40	-1.68	0.54	32.37	-0.33	0.04	11.96	0.73	0.37	51.20
SWE	1.99	0.53	26.65	-2.52	0.55	21.78	-0.79	0.40	51.12	0.13	0.05	41.25	-0.29	0.14	49.32	-0.40	0.43	107.40

Table C8. Simulation results of aggregate energy use according to energy carriers for alternative values of non-energy elasticities

region	col			gas			gdt			oil			ele		
	M	S	V	M	S	V	M	S	V	M	S	V	M	S	V
	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)	(%)	(pp.)	(%)
AUT	-11.00	0.70	6.32	-7.58	1.28	16.90	-16.25	2.03	12.50	-6.03	0.61	10.10	0.77	1.11	144.19
BEL	-11.76	0.53	4.49	-7.74	0.32	4.15	-2.32	0.78	33.74	-1.62	0.56	34.60	-1.34	0.77	57.63
BGR	-26.06	1.51	5.79	-7.17	1.06	14.85	-18.31	0.94	5.16	-7.69	1.10	14.35	-4.91	0.98	20.07
CZE	-24.33	1.48	6.07	-10.71	1.04	9.68	-14.23	1.71	12.01	-5.31	1.19	22.43	-2.63	1.50	56.80
DEU	-16.42	0.36	2.22	-9.22	0.60	6.49	-14.88	2.04	13.68	-5.04	0.98	19.36	-2.92	1.20	40.91
DNK	-17.25	1.09	6.30	-6.56	0.49	7.47	-11.21	1.17	10.45	-6.37	0.52	8.13	-0.44	0.46	104.43
EFT	-19.27	2.36	12.25	3.06	0.23	7.41	-8.70	1.09	12.52	-1.20	0.19	15.86	-1.76	0.31	17.56
ESP	-26.32	0.85	3.24	-9.33	0.46	4.93	-17.53	2.51	14.32	-7.92	0.61	7.71	-2.08	1.26	60.56
EST	-19.54	4.21	21.53	-3.22	2.50	77.72	-0.64	2.31	359.38	-14.24	0.39	2.72	-2.22	1.29	58.12
FIN	-17.35	0.71	4.11	-3.48	0.70	20.17	-20.47	3.86	18.87	-4.02	0.73	18.13	-3.34	0.80	23.92
FRA	-12.58	0.44	3.52	-13.30	1.63	12.22	-20.44	2.86	14.01	-6.63	0.72	10.86	1.74	1.25	71.68
GBR	-15.19	0.87	5.73	-12.45	0.57	4.58	-17.71	1.26	7.10	-3.73	1.01	26.99	-1.32	0.93	70.26
GRC	-38.87	2.09	5.37	-8.53	2.16	25.34				-7.32	0.50	6.89	-7.13	0.52	7.26
HRV	-35.82	3.43	9.57	-13.33	1.75	13.14	-40.57	1.78	4.38	-7.15	0.84	11.73	-1.89	1.27	66.85
HUN	-12.65	0.29	2.33	-11.03	0.76	6.86	-18.37	1.59	8.65	-4.23	0.66	15.73	0.99	1.26	126.88
IRL	-27.37	2.01	7.35	-6.01	0.74	12.37	5.73	0.36	6.33	-5.50	0.55	9.93	-0.65	0.38	58.21
ITA	-20.51	0.42	2.06	-11.29	0.40	3.58	-11.09	1.49	13.47	-5.85	0.65	11.20	-2.17	1.42	65.55
LTU	-13.65	2.50	18.35	-6.36	0.73	11.47				-5.20	1.12	21.63	-1.84	0.80	43.49
LVA	-27.67	1.95	7.04	-6.25	2.65	42.34	-9.28	1.75	18.86	-8.23	0.77	9.40	-0.99	0.97	98.03
NLD	-19.31	0.25	1.31	-2.86	0.42	14.52	-11.29	0.38	3.36	-1.89	0.83	43.66	-4.97	1.47	29.56
POL	-20.23	0.68	3.39	-13.98	1.41	10.10	-18.35	1.45	7.92	-4.59	1.49	32.52	-7.43	1.44	19.41
PRT	-28.76	1.66	5.78	-10.19	0.64	6.33	-31.91	3.73	11.70	-9.97	0.39	3.87	0.53	1.04	197.09
ROM	-27.91	1.19	4.26	-11.19	0.83	7.42	-19.19	0.75	3.89	-6.49	1.35	20.73	-3.29	1.43	43.45
SVK	-14.51	0.88	6.04	-11.23	0.82	7.34	-15.31	1.72	11.21	-4.33	0.91	20.96	-0.44	1.35	304.31
SVN	-31.72	1.92	6.06	0.21	0.85	406.75				-6.83	0.86	12.62	-3.60	0.78	21.77
SWE	-14.80	1.01	6.82	2.83	0.30	10.70	-9.48	1.51	15.94	-2.66	0.55	20.68	0.07	0.38	549.68

Table C9. Simulation results of carbon prices and GHG emissions for alternative values of non-energy elasticities

region	carbon price						GHG emissions					
	EU ETS			non-ETS			EU ETS			non-ETS		
	M (%)	S (pp.)	V (%)	M (%)	S (pp.)	V (%)	M (%)	S (pp.)	V (%)	M (%)	S (pp.)	V (%)
AUT	105.09	8.68	8.26	70.71	12.76	18.05	-8.84	0.65	7.33	-9.40	0.00	0.00
BEL	105.09	8.68	8.26	51.26	11.95	23.32	-8.04	0.55	6.85	-8.72	0.00	0.00
BGR	105.09	8.68	8.26	61.97	9.83	15.87	-19.23	0.81	4.19	-12.40	0.00	0.00
CZE	105.09	8.68	8.26	64.61	9.26	14.32	-19.10	0.80	4.19	-13.89	0.00	0.00
DEU	105.09	8.68	8.26	85.69	18.23	21.28	-13.10	0.14	1.05	-11.67	0.00	0.00
DNK	105.09	8.68	8.26	93.24	22.04	23.64	-5.00	0.13	2.53	-13.36	0.00	0.00
EFT	105.09	8.68	8.26	12.06	2.84	23.53	-3.48	0.07	2.15	0.00	0.00	318.91
ESP	105.09	8.68	8.26	93.11	16.61	17.84	-13.46	0.14	1.07	-10.37	0.00	0.00
EST	105.09	8.68	8.26	54.85	16.11	29.37	-14.34	3.25	22.65	-15.19	0.00	0.00
FIN	105.09	8.68	8.26	75.73	22.68	29.95	-10.14	0.15	1.52	-9.41	0.00	0.00
FRA	105.09	8.68	8.26	89.94	17.01	18.92	-7.56	0.34	4.51	-12.73	0.00	0.00
GBR	105.09	8.68	8.26	50.84	11.91	23.42	-9.80	0.15	1.49	-12.78	0.00	0.00
GRC	105.09	8.68	8.26	114.79	31.16	27.15	-14.48	2.62	18.08	-7.83	0.00	0.00
HRV	105.09	8.68	8.26	139.46	19.52	13.99	-11.33	2.13	18.83	-14.53	0.00	0.00
HUN	105.09	8.68	8.26	68.05	8.45	12.41	-6.58	0.45	6.79	-11.48	0.00	0.00
IRL	105.09	8.68	8.26	61.79	11.43	18.50	-5.15	0.50	9.73	-14.03	0.00	0.00
ITA	105.09	8.68	8.26	95.79	17.04	17.79	-10.98	0.30	2.69	-9.45	0.00	0.00
LTU	105.09	8.68	8.26	78.03	14.92	19.12	-3.97	0.70	17.52	-14.95	0.00	0.00
LVA	105.09	8.68	8.26	72.88	14.44	19.81	-7.64	1.26	16.56	-13.55	0.00	0.00
NLD	105.09	8.68	8.26	68.86	12.48	18.13	-11.68	0.37	3.17	-9.43	0.00	0.00
POL	105.09	8.68	8.26	58.52	9.13	15.60	-17.59	0.42	2.37	-16.85	0.00	0.00
PRT	105.09	8.68	8.26	116.79	23.64	20.24	-7.39	0.16	2.21	-12.31	0.00	0.00
ROM	105.09	8.68	8.26	69.80	9.36	13.41	-17.84	0.23	1.28	-11.05	0.00	0.00
SVK	105.09	8.68	8.26	84.67	10.98	12.96	-18.69	0.56	2.99	-10.52	0.00	0.00
SVN	105.09	8.68	8.26	63.03	11.85	18.80	-18.65	0.86	4.61	-8.85	0.00	0.00
SWE	105.09	8.68	8.26	62.86	13.36	21.26	-8.06	0.61	7.52	-6.99	0.00	0.00

Table C10. Simulation results of carbon leakage rate for alternative values of non-energy elasticities – EITE sectors

sector	regions in EU ETS		
	M (%)	S (pp.)	V (%)
chm	279.13	56.16	20.12
foo	36.38	11.79	32.40
isi	33.92	7.51	22.14
nem	129.83	21.02	16.19
nmm	120.69	32.90	27.26
oil	153.84	6.13	3.98
ppp	58.46	10.41	17.81