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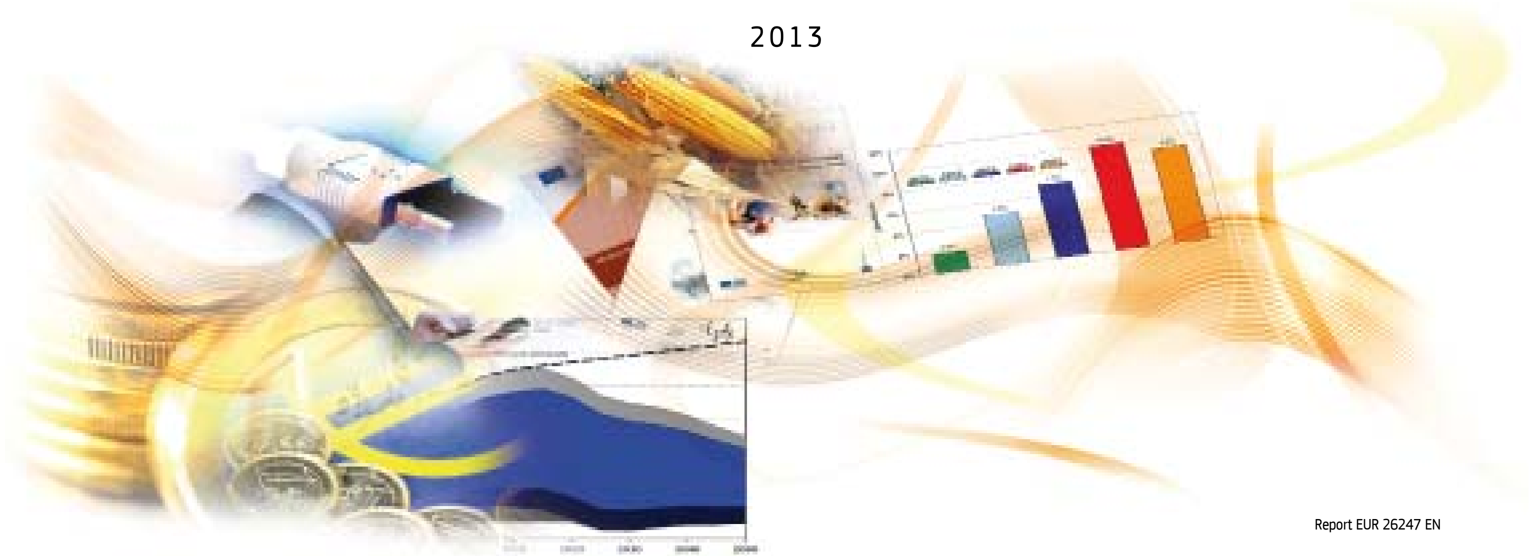

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TESTING THE SENSITIVITY OF CGE RESULTS: A MONTE CARLO FILTERING APPROACH TO AN APPLICATION TO RURAL DEVELOPMENT POLICIES IN ABERDEENSHIRE

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1. Introduction

Computable General Equilibrium (CGE) modeling is increasingly used for applied policy analysis, including the assessment of energy (e.g. Phimister and Roberts, 2012), agricultural (e.g. Psaltopoulos et al., 2011; Espinosa et al., 2013) or structural policies (e.g. Cardenete and Lima, 2007). While CGE models have several advantages, they suffer from a well-recognised issue of uncertainty in the choice of model elasticities – i.e. parameters may be known imprecisely – and the corollary issue that the choice of elasticities can be critical in determining model outcomes. The problem is worse for regional models because there is typically a lack of reliable data at regional level (Partridge and Rickman, 1998). This affects empirical studies on cohesion, agricultural or rural development policies, in which the modeling of regional or sub-regional features (e.g. differences between urban and rural areas) is often required. The existence of parametric uncertainty has thus fuelled criticisms on the robustness of CGE results and has led to the development of alternative approaches to sensitivity analyses.

Early studies used limited sensitivity analyses (LSA), with changes to a (single) few elasticities to evaluate how robust the simulation results are. However, there are several issues with LSA, especially in relation with the interpretation and the robustness of results (Wiggle, 1991). The increase in computing power over the last 20 years has meant that Monte Carlo analysis (MC) has increasingly been used as a basis for Systematic Sensitivity Analysis (SSA) of CGE models. Its flexibility and ease of implementation have made it an attractive approach for researchers. However, the "curse of dimensionality" issue remains when considering multiple integrals with the extent of approximation MC error increasing as the number of parameters under consideration increases. For example, DeVuyst and Preckel (2007) show that the MC approximation error can still be significant for simple functions with a small number of variables, even when a very large number of trials are undertaken.

The traditional approach used to address the dimensionality issue is to use Gaussian Quadrature methods, some of which are now included in standard GE software packages available (e.g. GEMPACK). This involves the moments of the joint distribution of the parameters being approximated using a discrete joint probability distribution evaluated over a finite number of points (Arndt, 1996; DeVuyst and Preckel, 1997, 2007). For example, if the parameters are assumed jointly independently and symmetrically distributed, then it is possible to apply the Stroud points (Stroud, 1957) and approximate the first and second moments of the joint distribution of the parameters using a significantly reduced number of model runs. However, if more general distributions are considered e.g. non-symmetric distributions, these methods are significantly more difficult to apply in practical modelling (DeVuyst and Preckel, 2007), while the restricted sampling in GQ may not be desirable in some applications (Preckel et al., 2011).

This report develops and applies an alternative approach to SSA, MC filtering (MCF). This both identifies the most influential parameters in the model in terms of their influence on model outcomes and provides robust policy impact estimates. The approach has the flexibility of the MC approach in that dealing with non-symmetric and general non-independent distributions is not difficult, while by limiting the dimensionality considered it reduces (but does not eliminate) the MC approximation error.

MCF is a two-step procedure, in which a non-parametric approach is first used to identify key elasticities in the CGE model and then MC sensitivity analysis is implemented focussing on only the most important model parameters. The approach breaks down parametric uncertainty in a systematic manner, which allows model parameters to be classified according to their relative importance in determining model results. In addition, by identifying which parameters are most important in determining model results, it provides useful information about the model properties which is helpful in understanding the model's behaviour. Parametric methods (e.g. regression-based approach) have been used in an analogous way to reveal the link between elasticities and model outputs in a CGE model (see e.g. Belgodère and Vellutini, 2011). However, although these may provide reasonable local approximations the assumption of linearity and monotonicity in the relationships is unlikely to hold generally except for a small number of parameters (Saltelli et al., 2008). Hence the non-parametric MCF technique is less restrictive than regression-based approaches while it also provides a method which identifies key parameters which is integrated with SSA.

The report illustrates the proposed MCF approach (and how its results compare to the alternative MC and GQ approaches to SSA) in relation to an analysis of the impact of

EU rural development policies on the Nomenclature d'Unités Territoriales Statistiques (NUTS) 3 region of Aberdeen City and Shire (ABS). The particular focus is on so called Pillar 2 Rural development measures which are aimed at supporting growth and diversification of rural areas and facilitating the provision of environmental public goods[1]. There is a vast literature on the evaluation of rural development policy impacts, using regional Input-Output (e.g. Mattas and Shrestha, 1991) and Social Accounting Matrix (SAM) models (e.g. Roberts, 2005). Such models are typically based on strong behavioural assumptions and often result in the generation of upper-bound estimates of the magnitude of impacts (Miller and Blair, 2009; Kilkenny, 2008). CGE models address these caveats and have been used to study EU agricultural policies at national level (e.g. Bascou et al., 2006; Gohin and Latruffe, 2006; Törmä and Lehtonen, 2009). Recent CGE studies have investigated the impacts of changing the structure of CAP Pillar 1 and 2 at a (much) more disaggregated level of analysis, allowing for a split between rural and urban areas at regional level (Psaltopoulos et al., 2011; Hyytiä, 2011; Espinosa et al., 2013). In line with these studies, this report examines the empirical impacts of a redistribution of CAP Pillar 2 funds between its axes, using a bi-regional CGE model, which allows for a split between the urban and the rural parts of the region, so as to explore the impact on the rural economy.

The remainder of the text is organised as follows. Section 2 presents the modelling framework. Section 3 details the construction of the Social Accounting Matrix and policy simulations. Section 4 identifies the key elasticities in the CGE model. Section 5 examines simulation results. Section 6 concludes.

2. Modelling framework

The model used for the analysis is a recursive dynamic CGE model,F[2]F which is solved one period at a time. Within each period the basic building block is a static CGE model drawing on the standard IFPRI framework (Lofgren et al., 2002). Following Thurlow (2008), the static model is extended by allowing period-to-period updating of key model parameters, either endogenously or exogenously, and then solving the model

[1] Pillar 1 is generally aimed at supporting producers through direct support and market measures.
[2] An abridged version of the model can be found in Table A6.

recursively in each period. In this way it is possible to generate a dynamic time path for model simulations. Furthermore, a number of modifications have been made so that the model is adapted to reflect the nature of the region and to capture the rural and urban areas within this region study. In particular, we develop a bi-regional (rural – urban) version of the standard model which captures the intra-regional linkages between the urban and rural part of the region. The use of regional CGE models (and particularly dynamic models) has been much less common than their application at the national level. Here, the application of methodology developed for the national scale to a single region can be criticized as it potentially misses important inter-regional feedback effects (Partridge and Rickman, 2010). However, while a full multi-regional CGE model capturing intra-regional rural-urban linkages may be theoretically appealing the extra data demands and the range of assumptions required to implement this make this relatively unappealing in practice. It therefore must be acknowledged that the pragmatic approach applied used here does ignore any potential inter-regional effects. However, arguably the remoteness of the study region (which limit inter-regional commuting) suggest that the most important potential inter-regional feedback effects may be limited and that missing these effects may not be too limiting in this case.

2.1 Production behaviour

Each production activity produces one or more commodities in fixed proportions per unit of activity. Production is modelled as a two-layered structure. At the top level, technology is specified by a constant elasticity of substitution (CES) function of the quantities of value-added and aggregate intermediate input. At the bottom level, each activity uses composite commodities as intermediate inputs, where intermediate demand is determined using fixed Input-Output (I-O) coefficients. Value added is a CES function defined over factors of production, labour, capital (and land where appropriate), which are spatially specific. Profit-maximising behaviour implies a derived demand for the factors of production up to the point where the marginal revenue product of the factor is equal to its price. A key element is that the production activities are spatially disaggregated, i.e. they are explicitly based in either the rural or urban part of the region.

2.2 Commodities

While activities are spatially differentiated, commodities are not, in order to reflect the fact that the market integration of the rural and urban areas in the study region is typically very high. However, each domestic commodity within the region is produced by one or more activities and where necessary aggregated via a CES function. The imperfect substitution embedded in the CES aggregation of outputs is exogenous and is assumed to capture "differences in timing, quality, and distance between the locations of activities." (Lofgren et al, 2002). This is then allocated to either domestic sales or exports via a constant elasticity of transformation (CET) function. Domestic sales of the aggregate commodity are then combined with imports via a CES function to create a composite commodity which is consumed domestically as private, public consumption, intermediate demand and investment demand. The non-linear (dis)-aggregation of output into exports and domestic sales, and domestic sales and imports to composite commodity, is a standard approach in the CGE literature known as the Armington approach (Armington, 1969). Effectively, it prevents complete specialisation so that the model outcomes can reflect the fact that regions may both import and export a broad commodity category. To justify this, we need to assume that there is some imperfect substitutability or that product differentiation exists across import, export and domestic commodity categories, which is not captured by the broad commodity definition (Lofgren et al., 2002).

2.3 Households, Government and the Rest of the World

Households in the model receive income from factors of production (in proportions determined initially at the base year level), transfers from Government and transfers from the rest of the national economy/world. They pay income tax, save a given proportion of their income and demand commodities. They use their income to pay direct taxes, save (using a fixed marginal propensity) and make transfers to other institutions. Their remaining income is spent on the consumption of marketed commodities. In common with most standard CGE models, this allocation is based on linear expenditure system (LES) demand functions. Like production activities, households are disaggregated according to their farm/rural/urban status.

The Government sector in the model represents the combined function of local and national government in the region. As is typical, government is treated as a passive actor, collecting taxes, consuming and making transfers, at exogenously given rates. Hence, the Government collects various types of taxes (direct taxes from households, activity taxes from production sectors, indirect tax on commodities and transfers from the Rest of the World (ROW) and receives transfers from other institutions. It then uses this income to purchase commodities for its consumption and for transfers to other institutions. Government savings are the residual given by the difference between government income and spending. The representation of the ROW is assumed to capture both economic relationships with the rest of the national economy and third countries. Certain previous regional CGE studies have considered separate accounts for imports and exports with the rest of the country and the rest of the world (e.g. Gillespie et al., 2001). However, this has not been universal and other regional CGE models have followed the approach taken here and aggregated transactions between the region and the rest of the country and the rest of world (Julia Wise et al., 2002), nor has the disaggregated approach been identified as essential part of a canonical regional CGE model (in contrast to modelling of inter-regional feedback effects) (Partridge and Rickman, 2010).

2.4 Between-period updating

In the between-period component, a number of the parameters of the within period model are updated endogenously using outcomes of the model solution in the previous period as well as exogenously. As a result, the model is able to generate a path for the regional economy under an alternative policy scenario. The updating of the model parameters between periods draws on the extension of the static IFPRI model undertaken by Thurlow (2008). The systematic exogenous adjustments in parameters such as total or factor-specific productivity or government spending growth (cuts) means the projected base path of the model is able to produce “realistic” trends in key variables in the base path solution. Population and labour supply are exogenous between periods. The approach is simplistic, ignoring intra-regional migration and associated effects on the labour market, but, as with the treatment of the Rest of the World, a more comprehensive treatment was not considered necessary given the focus of the report. Instead, a more sophisticated treatment of population labour market dynamics is left as a possible future improvement to the model. It should be noted that population changes are assumed to change subsistence consumption levels by changing the demand system parameters (i.e. shift the intercept of demand).

In contrast to the other model parameters, while capital is fixed within each period, capital adjustment for each sector between periods is typically endogenous, with investment in the solution of the model in period *t-1* used to update capital stocks before the model solution in period *t.* Investment in any period is by commodity. As in the Thurlow model, to map this to capital stock in activities we employ the simple assumption that the commodity composition of capital stock is identical across activities. Effectively, the allocation of new capital across activities then uses a partial adjustment mechanism, with those activities where returns are higher than average obtaining a higher than average share of the available capital. This then determines, after accounting for (exogenous) depreciation, for the adjustment in capital stock in each activity. Alternatively, the growth rate of capital stock in a specific sector may be set exogenously. In this case, the amount of investment required for this sector is calculated and then the amount of investment available for endogenous allocation reduced accordingly. In order to run the model, a Social Accounting Matrix is required for the region of Aberdeen City and Shire along with elasticities for the behavioural functions. The next section describes the structure of the SAM built for this purpose, and details the model calibration.

3. Database and simulations

3.1 The Regional Social Accounting Matrix

The CGE model requires a SAM for the NUTS 3 region of Aberdeen City and Aberdeenshire. The SAM was constructed through a four-stage process. Stage 1 involved the regionalisation of existing national supply and use tables for year 2005

(Scottish Government, 2013). To avoid disclosure issues, a full supply matrix is not published at Scottish level. However an aggregate (11x11) supply matrix is released along with detailed percentage market share and percentage secondary production information at the 126 sector/commodity level. The latter was used to create a national supply matrix at the required level of sector and commodity disaggregation (see Appendix Table A1) while the national (126 x126) use matrix was aggregated up to this same level of aggregation. Using these two (national) tables, in conjunction with data on employment from the Annual Business Inquiry workplace analysis (NOMIS, 2009), a balanced regional set of accounts were produced for the Aberdeen City and Aberdeenshire region for calendar year 2005 maintaining a commodity by industry distinction throughout the process. Simple location quotients (Flegg and Tohmo, 2013) were used to generate import flows, while initial export levels were calculated residually.

This was followed by the rural-urban disaggregation of sectors, households and factors of production through the use of secondary data. The latter again included employment data from the Annual Business Inquiry workplace analysis but this time at sub-regional level (NOMIS, 2009), as well as information from the 2001 population Census (General Register Office for Scotland, 2013) and the Annual Survey of Hours and Earnings (ONS, 2006) to split the household accounts. The definitions of rural and urban sub-areas were, for convenience, based on administrative boundaries. In particular, firms and households within the Aberdeen City Local Authority area were classified as urban, while firms and households within the Aberdeenshire Local Authority were classified as rural.

Stage 3 involved the disaggregation of agricultural activity through the use of FADN (Farm Accountancy Data Network) information on the farm-typology (European Commission, 2008). The regional accounts were then converted into a (square) SAM structure and by filling in the inter-institutional transactions. The latter draws on regional household income and expenditure data (Office for National Statistics, 2007), as well as information from regional agencies (Scottish Enterprise, 2009). Up to this point in the construction process, all of the information used was from publically available secondary sources. In Stage 4, some of the SAM entries relating to key sector in the region were "superiorised", in other words replaced with values considered more accurate, collected from interviews with local policy-makers and stakeholders. This information was considered to be more accurate than the values generated through mechanical regionalisation processes. As a result, some of the row and column totals of the SAM became unbalanced and the final stage of the construction process (Stage 5) involved the application of the cross entropy optimisation procedure (Robinson *et al.*, 2001) in order to estimate a balanced SAM.

The activity accounts included in the SAM are shown in Appendix Table A1. Each production sector is represented in the rural and urban part of the SAM (even though their significance in each area may be very different), resulting in 48 sectors in totalF. Twelve different farm accounts are distinguished in the SAM according to farm type and farm size. Only the two major farm types in the region (specialist cereals and specialist livestock) are shown separately, with the remaining FADN farm types aggregated into an "Other" category. In terms of downstream food processing sectors, despite original intentions, meat processing was aggregated with "other foods" due to the need to preserve confidentiality while the fish processing and fruit and vegetable processing are combined reflecting the level of aggregation in the national 126 sector input-output tables. The twenty commodity accounts in the Aberdeen and Aberdeenshire SAM reflect closely the production sectors. The main difference relates to agricultural output where two commodity types are distinguished – crops and livestock. Four factors of production are distinguished in the Aberdeen and Aberdeenshire SAM – two types of labour (skilled and unskilled), capital and land, the latter defined such that it only includes agricultural and forestry land. The capital account in the matrix includes, in addition to returns to capital, gross profit and payments for self-employment (the latter form of labour dominates agricultural labour input in the region). Four different household groups are distinguished in the Aberdeen and Aberdeenshire SAM:

- Urban households – Households resident in Aberdeen City local authority area
- Rural households – Households resident in Aberdeenshire local authority area
- Small farm households – Households managing farms of less than 40 European Size Units (ESU)
- Large farm households – Households managing farms of 40 or more ESUs

The small farm household category receives factor income from the small farm types, the large from the large farm types. An explicit tourist household account is also included. For accounting purposes, an account reflecting non-profit institutions serving households is included to capture the expenditure of such institutions. Finally a combined (local and central) government account, single ROW account and investment-savings account are distinguished in the matrix.

3.2 Modelling policy simulations

The simulated policy scenario is compared with a baseline that represents a situation in which the CAP Health Check and the 2007-13 rural development programmes are implemented unmodified until 2020. To assess the impact on the rural economy of a CAP Pillar 2 reform, we model the removal of Axis 3 expenditure (diversification and quality of life in rural areas). All Axis 3 funds are redistributed to Axes 1 and 2 (respectively, aiming at improving competitiveness of agriculture and forestry and at improving the environment and the countryside) measures in proportion to their shares in the baseline. Simulation results are over the time-span 2006-2020. Such a scenario can be regarded partly reflecting the "refocus" scenario of the Impact assessment of Commission's proposals for CAP towards 2020 (European Commission, 2011), where a refocus of CAP on the agricultural sector has been contemplated, in so far it includes deleting axis 3 of Pillar 2.

For Aberdeen City and Aberdeenshire, information on Rural Development Programme expenditure in the region was gathered from the Scottish Government website and interviews with the local Scottish Government Rural Inspections and Payments Directorate (SGRIPD) representative and the Rural Development Officer in Aberdeenshire Council. Total Pillar 2 payments are calculated (Table 1) using a combination of actual and total planned annual expenditure for the period 2005-2013, with the Aberdeen and Aberdeenshire share calculated on the proportion of total RDP funds which has been spent in the area. It is assumed that the average expenditure in the 2007-2013 period is maintained to 2020. The share of spending undertaken by measure is calculated using the proportions in each measure in actual spending provided by the Scottish Government. LEADER expenditure is directly incorporated in the calculations.

Table 1. Pillar 2 expenditure in Aberdeen City and Aberdeenshire, 2007-2013 programming period (total cost, ml. GBP)

Measures, Pillar 2		Axis 4	Total cost	% share in Pillar 2
111	Vocational training	-	0.04	0.0
112	Setting up young farmers	-	0.58	0.3
114	Use of advisory services	-	0.00	0.0
121	Modernization of agricultural holdings	-	54.35	27.0
122	Improvement of the economic value of forests	-	0.59	0.3
123	Adding value to agricultural and forestry products	-	0.96	0.5
125	Infrastructure related to the development and adaptation of agriculture and forestry	-	0.11	0.1
Total Axis 1		**-**	**56.64**	**28.1**
214	Agri-environment payments	-	81.29	40.3
223	First afforestation of non-agricultural land	-	16.37	8.1
225	Forest-environment payments	-	2.42	1.2
227	Non-productive investments	-	0.75	0.4
Total Axis 2		**-**	**100.83**	**50.0**
311	Diversification into non-agricultural activities	-	14.14	7.0
312	Support for business creation and development	1.16	6.88	3.4
313	Encouragement of tourism activities	1.34	4.10	2.0
321	Basic services for the economy and rural population	2.05	10.05	5.0
323	Conservation and upgrading of the rural heritage	1.87	5.36	2.7
331	Training and information	1.26	3.53	1.7
341	Skills-acquisition and animation measure with a view to preparing and implementing a local development strategy	0.06	0.15	0.1
Total Axis 3		**7.73**	**44.21**	**21.9**
Total Pillar 2		**7.73**	**201.68**	**100**

Source: Scottish Government; DEFRA; Authors' calculations.

Detailed information regarding all financed projects (especially total costs and private costs) has been provided by the Local Action Group (LAG) Rural Aberdeenshire. Similarly, the private contributions in Axis 1 and 3 are taken into account. Further, modulation in Scotland includes a voluntary component and these flows between Pillar 1 and 2 are incorporated in the Baseline. Following the Health Check agreement, the total modulation rates (compulsory and voluntary) in Scotland are calculated as shown below. If the compulsory modulation rate is 10% and the additional voluntary rate is 4% in 2012, the total modulation rate is equal to 14% for the same year. The proportion of modulation funds attributed to each Axis is calculated using the base-period proportion of Pillar 2 funds going to the concerned Axis. Table 1 shows that Axis 1 represents approximately 28% of total Pillar 2 expenditure, Axis 2 50% and Axis 3 22%. The most important measures in terms of expenditure are 214 (40.3% of total Pillar 2), 121 (27%), 223 (8.1%), and among Axis 3 measures, 311 (7%), 321 (5%) and 312 (3.4%). Axis 1 expenditure is assumed to either add to capital investment either in agriculture or forestry (Measure 122). These flows are allocated to various agricultural and forestry sectors on the basis of their shares in the model base-year capital.

There is very little information related to allocating Axis 3 expenditure to the SAM sectors as the Scottish Government does not collect information identifying the destination of RDP spending by sector. Therefore in order to do this, a number of ultimately arbitrary assumptions are required and are summarised in Table 2. For each Axis 3 measure, we assume which sectors might benefit based on the informal information we have, e.g. discussion with the local RDP co-ordinator. Hence, for example, Measure Axis 311 expenditure is assumed to benefit rural forestry, energy and hotels, 312 rural energy and hotels, 313 rural hotels only. It is assumed that spending in Measures 321-341 is allocated to the rural public sector and other services.

Table 2. Sectors benefitting from Axis 3 investment, Aberdeen City and Shire

	311	312	313	321	323	331	341
R-Forestry	10%						
R-Energy	40%	20%					
R-Hotels	50%	80%	100%				
R-Public				100%	100%		
R-Other Services						100%	100%

Source: Authors' calculations.

The main mechanism used to implement the policy change in the model has been to focus on the assumed induced changes in investment, as in Psaltopoulos et al. (2011), but also on capital stock within key industries. This methodology is motivated by the fact it accommodates the fact that RDP investment projects (and their economic effects) are generally specific to a time-path and in parallel, generates a dynamic capital stock adjustment amongst different activities. For exogenous sectors (i.e. those targeted by policy measures), the growth rate of capital stock is set and the amount of investment required for this sector is calculated. These values are then taken from the total amount of investment available for allocation to endogenous sectors. In endogenous sectors (i.e. those not targeted by policy measures), allocation of new capital uses a partial adjustment mechanism, with those activities where returns are higher than average obtaining a higher than average share of the available new capital; new capital is determined by the total investment in commodities (minus the amount required for exogenous sectors).

This approach requires assumptions on the commodity composition of new capital, the economic mechanism at work, i.e. RDP policy inducing extra investment in a sector, can be closely followed in the model, whereas the specific link between say a particular investment and a change in efficiency is much more difficult to specify due to the lack of relevant data. We therefore need to map RDP spending in the region into investments in specific SAM sectors within the models. Data availability and the way the Rural Development Programme has been implemented and interpreted vary considerably in the EU. In fact, in Scotland, regions set rural priorities and total funding is allocated via "Options" which do not map simply into the RDP measures. Hence, the supplementary assumptions required to implement this approach are specific to the region-study of Aberdeen. Further, at least for the time being, the government has not disaggregated the RDP spend by measure at the case study area level (with the exception of Axis 4 - Leader), nor does it collect information identifying the destination of RDP spending by sector. In order to circumvent this, we assume sectoral allocation of RDP spend from discussions with RDP and LEADER local implementing agencies.

Once the assumed allocation of RDP spend to specific sectors has been made, the various simulations are constructed in a series of steps. First, the model is run with all sectors treated as endogenous. This defines the growth rate without RDP spend in the sectors which are assumed to benefit from RDP spending. The growth rate in capital stock in these sectors is calculated after the RDP spend is added and then the model is re-run with these capital growth rates set exogenously. In addition, to account for extra subsidy inflows to the region, the foreign savings inflow is increased by the amount of the RDP spend which is assumed to be funded by EU and/or national government and/or private funds. We consider the total subsidy from both national and EU sources as if it comes from outside the region (with any private sector part funded from within the region). Finally, to allow for possible changes in ownership of factor income as results of the RDP policy, the model has been adjusted to allow for differing patterns of factor ownership by sector. Hence, where new investments associated with the RDP spend are thought to significantly change factor ownership patterns, the effect of this has been explored (e.g. farm diversification investment in various sectors)F[3]F.

3.3 Model calibration and closure rules

Model calibration requires the specification of elasticities, exogenous region-specific trends and closure rules. This parametric calibration reflects the regional economic structure. First, the balance of trade can be satisfied in two ways. The real exchange rate can be endogenised. This allows a change in general purchasing power parity between the region and the rest of the economy. Alternatively, it can be assumed that, because of the small open nature of the regional economies, net savings from the rest of the economy are endogenous. The choice between both closure rules is not straightforward at the regional level as both approaches have been used the literature (see e.g. Espinosa et al., 2013; Psaltopoulos et al., 2011). The problem lies in the fact that with a fixed exchange rate, the regional counterpart of a current account deficit has uncertain significance (Waters et al., 1997) because the definition and determination of regional balance of trade deficits is unclear. While there are reasons to assume that external net savings may adjust at the regional level (Dow, 1986), the alternative seems to be more consistent with the actual workings of regional economic adjustment (Rickman, 1992). Therefore, for the current account it is assumed that the real exchange rate is flexible while foreign savings are fixed[4]. Given that all other items are fixed in the external balance (transfers between the rest of the world and domestic institutions), the trade

[3] Investment-driven savings (with overall investment increased to allow for extra RDP investment) plus exogenous foreign savings are used as closure rules in the base run. This ensures that extra economic activity due to the extra RDP investment and subsidy inflows is not conflated with changes in investment due to changes in savings behaviour in aggregate and/or inflows from other sources.

[4] For the sake of comparison, we also implement the analysis assuming flexible foreign savings and find that the choice for the closure rule does not matter for our results.

balance is also fixed. For the Savings/Investment balance, investment is considered fixed while savings adjust. For the government balance, as in the case of several CGE models on small regional economies, it was assumed that government savings (the difference between current government revenues and current government expenditures) is a flexible residual while all tax rates are fixed. In other words, level of direct and indirect tax rates, as well as real government consumption, are held constant. As such the balance on the government budget is assumed to adjust to ensure that public expenditures equal receipts.

As for the factors closure rules, for capital we assume that it is sector-specific for the agricultural sector (can move between agricultural farm-sectors), while for the non-farm economy, it is mobile between sectors and between the rural and urban parts. In the case of land, it is assumed as mobile between agricultural sub-sectors. Finally, for labour, a segmented labour market by skill level and free movement of labour between the rural and the urban areas are assumed. Further, we assume an upward-sloping supply curve for highly-skilled labour, which indicates that highly-skilled labour supply is driven by changes in real wages. For unskilled labour, a neoclassical closure rule was chosen. The choice of closure rules is selected so as to reflect the manner in which the regional economy operates. In this particular case, the choice of government account balance and the external balance was selected mainly due to the size of the region. In the case of labour markets there are very low unemployment rates for skilled labour. To some extent the closure rule for savings and investment is driven in part by the focus of the report and the manner in which RDP investment shocks are simulated in the model while, in the case of the capital market, the level of sectoral aggregation in the model made the assumption of capital immobility more suitable than the alternatives available.

Table 3 summarises the elasticities used in the model. A base elasticity of substitution between factors (bottom level) of 0.8 was selected for all production sectors apart from the six farm types where an elasticity of 0.2 was selected. The top-level factor elasticity is set at 0.4 for all sectors. Elasticities of factor substitution were assumed the same in the rural and urban parts of the study area. Armington elasticities of 2 were assumed for all commodities in the model apart from Construction, Distribution, Hotels and catering, Transport, Public Sector and Other Services where an elasticity of 0.5 was used. Similarly, a CET elasticity of 3 was assumed for all sectors but

Construction, Distribution, Hotels and catering, Transport, Public Sector and Other Services where a CET elasticity of 0.5 was used. LES elasticities for market demand for Crops, Livestock, Forestry and Fishing were set at 0.33 for domestic households and tourists while all other household, tourist and NPISH elasticities of demand were initially set as unitary. The household Frisch parameters (which measure the elasticity of the marginal utility of income) were set at the default level of -1 for all household types.

Table 3. Summary of elasticities used in CGE model of Aberdeen City and Shire

Elasticity type	Value
Production Block	
Top: Substitution between VA and intermediate inputs	0.4 for all sectors
Bottom: Substitution between factors of production	Activity-specific (range: 0.2-0.8)
Output aggregation	6
Trade Block	
Armington	Commodity-specific (range: 0.5-2)
CET	Commodity-specific (range: 0.5-3)
Household Consumption	
Frisch	-1
Home	n/a
Market	Commodity-specific (range: 0.33-1)

The procedure for performing Monte Carlo simulations is to randomly choose a sample value for all elasticities from their specified probability distributions, run the model with this set of parameters and store the model outcomes. This procedure is repeated for a specified number of times. Given a certain number of simulations, the output distributional information approximates the true probability density function of the model output. While there is little evidence regarding the estimation of regional elasticities, the specification of distributions for the Monte Carlo procedure is not straightforward. In the literature, several studies have assumed uniform distributions (e.g. McGregor et al., 1996). However, Partridge and Rickman (1998) suggest that because elasticities in CGE models are traditionally econometric estimates, normal (or t-) distributions may also be assumed. In addition, the latter type has the advantage of not considering all nearby potentially drawn values as equally probable. Therefore, for each of the Armington, transformation and production elasticities, 550 values are drawn randomly from a normal distribution, with a standard deviation of 50 per cent, and independently from one another. As a result to the lack of econometric estimation, it is cumbersome to judge the uncertainty surrounding the use of regional elasticities. For this reason, the standard deviations are relatively large with respect to the benchmark elasticity value to account for this issue. The means of the distribution are either the best corresponding estimate within the range of estimates found in the literature (e.g. Ha et al., 2010) or alternatively the "best guess" taking into account commonly expressed intuitions in the literature (Partridge and Rickman, 1998; Holland, 2010).

4. Identification of key elasticities

This section details the implementation of the MCF and presents the results of the identification step. In the literature, parametric methods (e.g. regression-based approach), which assume a priori an underlying structure of the relationship under study, have been used to reveal the link between elasticities and model outputs in a CGE model (see Belgodère and Vellutini, 2011). However, as discussed in the introduction parametric methods suffer from their arbitrary nature as their assumptions with respect to the structure of the model/relationship may make results less powerful.

4.1 Monte Carlo Filtering

The basic idea of MCF is to divide the output sample obtained from a MC analysis in two subsets according to a base criterion and testing whether the inputs associated to those subsets are different. Consider the samples obtained via MC simulations for a given parameter X and an output variable Y, respectively $(x_1, x_2,..., x_n)$ and $(y_1, y_2,..., y_n)$. Note that before using the MC filtering approach, it is necessary to sort the output sample $(y^{(1)}, y^{(2)},..., y^{(n)})$ and re-order the corresponding input sample $(x^{(1)}, x^{(2)},..., x^{(n)})$. The first step is then to divide the output sample based on a criterion – $y^{(c)}$ – and divide it two corresponding subsamples $(y^{(1)}, y^{(2)},..., y^{(c)})$ and $(y^{(c+1)}, y^{(c+2)},..., y^{(n)})$. Then, the input sample is divided accordingly into two corresponding subsamples $(x^{(1)}, x^{(2)},..., x^{(c)})$ and $(x^{(c+1)}, x^{(c+2)},..., x^{(n)})$. These latter subsamples are used to perform the two-sample Kolmogorov-Smirnov testF [5] F, which considers whether both subsamples are statistically different and therefore if the input parameter is either important or not. With the p-values associated with the Kolmogorov-Smirnov tests, it is possible to classify the influence of the parameters given the following decision rule (Saltelli *et al.*, 2004):

i. If the p-value is lower than 0.01, the input parameter is critical (or highly important);

ii. If the p-value is between 0.01 and 0.1, the input parameter is important;

iii. If the p-value is greater than 0.1, the input parameter is not important.

In this application, the MCF is applied on the following groups of elasticities[6]: Armington elasticities, transformation elasticities, elasticities of substitution between production factors and elasticities of substitution between production factors and intermediate inputs, with base criterion being the agricultural GDP. The choice of the base criterion translates our interest in the main objective of Pillar 2, which is to support growth and diversification of rural areas.

4.2 Identification results

Table A3 (Appendix A4) summarises the results from MCF and show that out of all 136 elasticities, 66 influence the model outcome (i.e. agricultural GDP). Among those, 17 are deemed to be critical (or highly important) in the relationship between inputs and output and are distributed across the different groups of elasticities (Table 4). We focus

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[5] It is noteworthy that for each input parameter, a Kolmogorov-Smirnov test should be implemented.

[6] The total number of elasticities tested is 136.

the discussion on these highly important elasticities which illustrate the usefulness of the MCF method in providing information which helps validate the model, and illustrating the key linkages in the model. The Table 4 results are being driven by two essential elements, i.e. the structure of the economy and the nature of the policy shock. In view of the nature of the shock (i.e. a shift from a diversification of rural development (RD) policy to a much more agriculture-centered RD policy), we find as we would expect that trade elasticities, which are directly linked to agricultural commodities and commodities directly affected by the policy change (i.e. Crops, Livestock, Forestry, Public services for Armington/Transformation elasticities), are among the most important in the model. Similarly, production and substitution elasticities that are related to Large Cereal/Other farms in the rural area are deemed critical.

Also, the structure of the regional economy also plays a key role in determining results in Table 4. For example, the fact that Armington elasticities for food processing and other food industries are highly important reflects the large importance of the regional economy in Scotland's food and drink processing sector (about 30%). To a lesser extent, the Armington elasticity for oil and the production/substitution elasticities for the urban activity of mining are among the most important ones, possibly due to the sizeable oil extraction and drilling activities in the region (but registered in the urban centre). Armington elasticities for oil and financial services are also logically critical or important (due to their weight in intermediate consumption of agriculture) as well as transformation elasticities for the main commodities used in the processing of agricultural goods, e.g. machinery, drink, transport. Considering both critical and important production and trade elasticities, the predominant activities and commodities involved are both agricultural (e.g. Crops), reflecting the nature of the scenario implemented, and from other sectors (e.g. food processing, mining, oil), reflecting the structure of the regional economy. More importantly, this result shows that the impact patterns of a relatively marginal and redistributive shock in the rural area of Aberdeen, will be significantly determined by the structure of sectors, which are predominantly located in the urban area of the region (e.g. financial services, food processing). In other words, Table 4 implicitly suggests the existence of strong linkages between rural and urban areas.

Table 4. Most important elasticities in CGE model

Armington	
	Crops
	Livestock
	Financial services
	Public services
	Food processing
	Other food industries
Transformation	
	Crops
	Machinery
	Hotels
	Transports
Substitution between production factors and intermediate inputs	
	U-Mining
	R-Hotels
	R-Large Cereal Farms
	R-Large Other Farms
Substitution between production factors	
	U-Mining
	R-Large Cereal Farms
	R-Large Other Farms

Note: U and R stand respectively for Urban and Rural

5. Comparing SSA outputs

As explained in Section 3, we model a redistribution of Axis 3 funds towards Axes 1 and 2, i.e. funds will be taken away from measures which aim at improving the quality of life in rural areas and encouraging diversification of economic activity, to be proportionally reallocated towards improving the competitiveness of agriculture and forestry and improving the environment and the countryside. This policy scenario is expected to lead to several impacts. First, the removal of Axis 3 will negatively impact on non-agricultural rural GDP with capital stocks reduced in affected sectors, e.g. tourism and energy. This scenario may decrease output levels in these sectors, leading to a GDP decrease in the secondary (e.g. energy) and tertiary sectors (e.g. tourism). To a lesser extent, the Other Primary (Forestry) sector may also be affected. Depending on the linkages to labour markets, this may put downward pressure on wages, particularly for unskilled workers if the impact on the tourist industries is significant. This type of effect may spill-over into the urban part of the region. On the other hand, increased funds in Axes 1 and 2 will increase agricultural output via both the coupled nature of the payments and increases in agricultural capital stock. This may lead to a decline in regional agricultural prices leading to positive impacts on downstream industries and agricultural exports as well as for farmers' income.

5.1 Analysing basic simulation results

Table 5 presents the simulation results based on the standard MC analysis (second column). The effects of the shock are measured as deviations from model-specific baseline values. Given the redistributive and limited nature of the policy shock, the overall impact of the transfer of the Axis 3 funds to Axes 1 and 2 would have very small effects on regional GDP both in the urban area (+0.25) and in the rural area (-0.19), leading in turn to a marginally positive aggregate effect on the economy of Aberdeen (+0.10). As expected, we can see that the concentration of Pillar 2 funds solely on Axis 1 and 2 measures and the associated higher investment benefits for local farming and higher coupled support would indeed boost agricultural GDP (+2.63). The policy scenario would also have some unexpected effects. For example, GDP for the rural tertiary sector, e.g. hotels, would also increase by 0.33%. This result appears rather counter-intuitive with respect to the nature of the policy scenario, which implies decreased investments in this sector and will be further discussed below.

Regarding employment effects, we find similar patterns of impacts as those described above for GDP. For instance, associated to the increase in rural agricultural activity, agricultural employment would strongly increase in the rural area (+2.89). The contrary impacts on rural and urban employment (respectively +0.24 and -0.44) result logically from the impacts on the economy activity in both areas, and would offset each other to lead to the absence of any impact on total employment.

For most sectors, the pattern of employment impacts remains directly connected to the impacts on GDP, except for the rural tertiary sector. Surprisingly, rural employment in the tertiary sector would decrease by 0.61 per cent, while the GDP of the sector would increase by 0.33 per cent. Finally, despite the fact there would be an increase in agricultural output, the impact on revenue for agricultural households would be partly mitigated (-0.72/-3.21 per cent) due to the combination of reduced agricultural prices and reduced factor income flows from non-agricultural activities associated with Axis 3 investment.

5.2 Comparing sensitivity analyses

We now proceed to the comparison of SSA approaches using Table 5. Column 3 presents the results obtained via the MC filtering approach (i.e. we run the Monte Carlo procedure, but this time, with the elasticities identified as highly important or critical as reported in Appendix Table A3). As a reference point to compare the different approaches, we also compute the results obtained via a Gaussian Quadrature (Stroud, 1957). Standard deviations are shown in brackets in Table 5.

There are a few things to consider when analysing the results in Table 5[7]. First, as explained above, some of the Monte Carlo analysis results were somewhat counter-intuitive. In particular, the MC estimate of the expected impact on Rural GDP in the tertiary sector suggested that the impact of the reduction of investment in this sector would increase GDP. However, we see that the impact patterns significantly change for the MCF and Stroud results. Specifically, while the rural tertiary GDP estimate increases by 0.33 per cent according the Monte Carlo analysis it decreases when the Monte Carlo filtering or Stroud analysis are used (respectively, -0.53% and -0.62%).

[7] For the analysis, we use an Intel Xeon X5680 running under the 32-bit version of Windows XP Professional 2002 (with 6 CPU at 3333 MHz and 3 GB RAM).Computation times for the MC analysis, the MCF and the Stroud analysis are respectively 36 hours 43 minutes, 25 hours 42 minutes, and 11 hours 29 minutes.

Table 5. Average impacts in Aberdeen City and Shire, 2006-2020

	Monte Carlo analysis Change, %	Monte Carlo filtering Change, %	Stroud analysis Change, %
GDP			
Total	0.10	0.01	-0.04
	(1.556)	(1.410)	(0.009)
Urban	0.25	0.18	0.16
	(2.535)	(4.677)	(0.138)
Rural	-0.19	-0.31	-0.41
	(4.232)	(1.899)	(0.035)
Agriculture	2.63	2.57	2.47
	(2.855)	(1.919)	(0.025)
Other Primary	0.18	-0.03	-0.16
	(12.761)	(1.472)	(0.032)
Rural Secondary	-0.06	-0.09	-0.22
	(2.217)	(1.670)	(0.016)
Rural tertiary	0.33	-0.53	-0.62
	(2.711)	(1.833)	(0.023)
Urban secondary	0.12	0.16	0.04
	(1.684)	(1.605)	(0.018)
Urban tertiary	0.27	0.20	0.21
	(1.505)	(1.445)	(0.019)
Employment			
Total	-0.01	0.00	0.00
	(0.168)	(0.121)	(0.001)
Urban	0.24	0.22	0.24
	(11.682)	(8.008)	(0.185)
Rural	-0.44	-0.43	-0.49
	(4.838)	(1.815)	(0.041)
Agriculture	2.89	2.98	3.26
	(2.944)	(1.536)	(0.038)
Other Primary	0.16	-0.07	-0.14
	(2.880)	(1.007)	(0.104)
Rural Secondary	-0.08	0.09	-0.01
	(2.232)	(1.104)	(0.069)
Rural tertiary	-0.61	-0.59	-0.67
	(2.295)	(1.687)	(0.037)
Urban secondary	0.05	0.01	0.00
	(1.850)	(0.823)	(0.039)
Urban tertiary	0.28	0.29	0.32
	(1.121)	(0.474)	(0.036)
Income			
Rural households	0.00	0.07	0.03
	(1.934)	(1.265)	(0.004)
Small farm households	-0.72	-0.90	-0.93
	(1.250)	(1.739)	(0.147)
Large farm households	-3.21	-3.77	-3.89
	(2.303)	(2.691)	(0.343)

This suggests the approximation error in the MC results in this case are large, while the results obtained with MCF and Stroud analyses are consistent with the expected a priori impacts of the policy shock. A similar result can be found for GDP and employment in the Other Primary sector. The signs of other GDP, employment and income impact patterns remain in line with those obtained using MCF or Stroud analysis.

We have assessed the results from a structural perspective (with respect to potential sign changes in the impact patterns) and now turn to a more quantitative approach in order to evaluate the overall relative quality of MC and MCF analyses. Using results from the GQ as a reference point, a quick look at Table 5 does not allow confirming whether MCF outperforms MC. To clarify this conjecture, we calculate the standard percentage error (STPE) and a simple absolute difference (AD) to evaluate the proximity of results obtained via MC analysis and MC filtering to those obtained using a GQ (in Table 5). Calculations are made on average for each sub-group of results in Table 5 (i.e. GDP, employment, income). For the AD, smaller numbers indicate close proximity between MC-based results and GQ results. For the STPE, values close to 1 indicate very close proximity, while values above (or below) 1 display an over(under)-estimation of the impact patterns obtained via Stroud analysis. Table 6 presents the calculated proximity measures.

Table 6. Proximity measures to Stroud results

		MC	MCF
GDP	STPE	0.393	1.007
	AD	0.246	0.083
Employment	STPE	5.787	0.573
	AD	0.106	0.074
Income	STPE	0.553	1.384
	AD	0.305	0.062

Across all results provided, we find that the MCF gives ADs that are much smaller than those given by MC analysis. Similarly, STPE values confirm that MCF outperforms MC analysis. Last, we can examine the precision of results of each approach when looking at standard deviations in Table 5. Overall, the main finding in Table 5 is that relative to the MC case the MCF gives more precise results in most cases, especially for employment and GDP effects. Consequently, policy implications which are drawn from the MCF are relatively more reliable.

6. Concluding remarks

This report develops and applies MCF as an alternative approach to SSA for CGE modeling. This both identifies the most influential parameters in the model in terms of their influence on model outcomes and provides robust policy impact estimates. The approach has the flexibility of the MC approach in that dealing with non-symmetric and general non-independent distributions is not difficult. By limiting the dimensionality considered, it reduces the MC approximation error. The report illustrates the proposed MCF approach (and how its results compare to the alternative standard Monte Carlo and Gaussian Quadrature approaches to SSA) in relation to an analysis of the impact of EU rural development policies using a regional CGE model of Aberdeen City and Aberdeenshire. We find that MC provides counter-intuitive results possibly due to the approximation error, and more fundamentally that MCF outperforms MC, making it a viable option for SSA.

Furthermore, by identifying the important and critical parameters within the modeling, it provides an additional method to both validate the CGE model and to understand the key linkages of the model and the economy to which the model has been applied. In this case, we find that that the impact patterns of the policy change is significantly determined, on one hand, by elasticities that are directly affected by the shock and, on the other hand, by elasticties which reflect the structure of the regional economy. Given the geographical location of activities in Aberdeen, this result strongly suggests the existence of linkages between rural and urban areas.

More generally, developing the approach and in particular how it can be applied in a structured way to examine linkages within the economy would appear to be a fruitful area for future research. Similarly, further comparisons of the three SSA approaches across other models and situations, e.g. where non-standard distributions where important, would provide further useful evidence of the relative potential of the MCF approach.

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Appendices

Appendix A1: Classification sectors

Table A1. Production sectors in the Aberdeen and Aberdeenshire SAM

SAM Code	Name	NACE
1	Small cereal farms	01 (part)
2	Large cereal farms	01 (part)
3	Small livestock farms	01 (part)
4	Large livestock farms	01 (part)
5	Small other farm types	01 (part)
6	Large other farm types	01 (part)
7	Forestry	02
8	Fishing and service activities incidental to fishing (incl fish farming)	05
9	Extraction of crude petroleum and natural gas plus associated services; mining	11,12
10	Other Mining	10,14
11	Processing and preserving of fish and fish products; fruit and vegetables	15.2,15.3
12	Other food products	15.1, 15.4 - 15.8
13	Alcoholic and soft drinks	15.9
14	Wood and paper products (except furniture)	20, 21.1, 21.2
15	Machinery	29
16	Other manufacturing	16-19, 22-28, 30-37
17	Utilities	40, 41
18	Construction	45
19	Wholesale and retail trade	50-52
20	Hotels and restaurants	55
21	Transport and communications	60-64
22	Financial services	65-67
23	Public service activities	75-90
24	Other services	70-74, 91-95

Table A2. Commodity accounts in the Aberdeen and Aberdeenshire SAM

SAM Code	Name	Standard Industry Classification of economic activities 2003
1	Crops	01 (part)
2	Livestock	01 (part)
3	Forestry	02
4	Fishing and service activities incidental to fishing (incl. fish farming)	05
5	Extraction of crude petroleum and natural gas plus associated services; mining	11,12
6	Other Mining	10,14
7	Processing and preserving of fish and fish products; fruit and vegetables	15.2,15.3
8	Other food products	15.1, 15.4 - 15.8
9	Alcoholic and soft drinks	15.90
10	Wood and paper products (except furniture)	20, 21.1, 21.2
11	Machinery	29
12	Other manufacturing	16-19, 22-28, 30-37
13	Utilities	40, 41
14	Construction	45
15	Wholesale and retail trade	50-52
16	Hotels and restaurants	55
17	Transport and communications	60-64
18	Financial services	65-67
19	Public service activities	75-90
20	Other services	70-74, 91-95

Table A3. Modelling Pillar 2 Measures in Aberdeenshire and City

Measures	Title	Sectors Benefiting from Investment	Ownership of New Investment	Other Type of Shock
Axis 1				
111	Vocational training	Agricultural sub-sectors. Allocation of investment flows on the basis of their shares in base year farm output.	Small and Large farm households.	
112	Setting up young farmers			
114	Use of advisory services			
121	Modernization of agricultural holdings			
122	Improvement of the economic value of forests	Forestry		
123	Adding value to agricultural and forestry products	Agricultural sub-sectors. Allocation of investment flows on the basis of their shares in base year farm output.		
125	Infrastructure related to the development and adaptation of agriculture and forestry			
Axis 2				
214	Agri-environment payments		Small and Large farm households.	Coupled payment to agricultural sub-sectors. Allocation of investment flows on the basis of their shares in base year farm output.
223	First afforestation of non-agricultural land	Forestry		
225	Forest-environment payments			
227	Non-productive investments			Coupled payment to agricultural sub-sectors. Allocation of investment flows on the basis of their shares in base year farm output.
Axis 3				
311	Diversification into non-agricultural activities	Rural Energy, Rural Hotels & Restaurants Forestry	Small & Large farm households.	
312	Support for business creation and development	Rural Energy, Rural Hotels & Restaurants	Rural, Urban, Small & Large farm households.	
313	Encouragement of tourism activities	Hotels & Restaurants	Rural, Urban, Small & Large farm households.	
321	Basic services for the economy and rural population			Exogenous Increase in Investment Commodity Demand without adding to productive capital stock.
323	Conservation/upgrading of the rural heritage			
331	Training and information			
341	Skills-acquisition			

Appendix A4: Sensitivity analysis with respect to alternative closure rules

Table A4. Simulation results of policy scenario in Aberdeen City and Shire (IS-3)
Savings-driven closure rule

	% change Filtered CGE	% change CGE Production
GDP		
Rural Agriculture	1.15	1.25
	(0.001)	(0.036)
Rural areas (total)	-0.28	-0.19
	(0.000)	(0.035)
Employment		
Rural Agriculture	1.81	4.79
	(0.001)	(0.367)
Rural areas (total)	-0.38	-0.40
	(0.000)	(0.027)
Income		
Rural households	0.01	0.08
	(0.000)	(0.034)

Standard deviations in brackets. Estimates are obtained using Monte Carlo analysis.

Table A5. Simulation results of policy scenario in Aberdeen (GOV-2)
Exogenous government savings rule

	% change Filtered CGE	% change CGE Production
GDP		
Rural Agriculture	1.12	1.10
	(0.001)	(0.022)
Rural areas (total)	-0.43	-0.23
	(0.000)	(0.032)
Employment		
Rural Agriculture	1.69	2.19
	(0.001)	(0.093)
Rural areas (total)	-0.60	-0.58
	(0.000)	(0.025)
Income		
Rural households	0.02	0.26
	(0.000)	(0.025)

Standard deviations in brackets. Estimates are obtained using Monte Carlo analysis.

Appendix A4: Version of model

Table A6. Abridged Mathematical Version of RURAL ECMOD Model

	Within Period CGE Model (IFPRI, 2002)	
Prices		
Absorption:	$PQ_c(1-tq_c)QQ_c = PDD_cQD_c + PM_cQM_c$	(A1)
Marketed output value:	$PX_cQX_c = PDS_cQD_c + PE_cQE_c$	(A2)
Import price	$PM_C = pwm_c(1+tm_c)EXR$	(A3)
Export price	$PE_c = pwe_c(1-te_c)EXR$	(A4)
Activity revenue/costs	$PA_a(1-ta_a)QA_a = PVA_aQVA_a + PINTA_aQINTA_a$	(A5)
Production and Trade		
CES Technology: Activity Production Function:	$QA_a = \alpha_a^a(\delta_a^aQVA_a^{-\rho_a^a} + (1-\delta_a^a)QINTA_a^{-\rho_a^a})^{-\frac{1}{\rho_a^a}}$	(A6)
Leontief technology: Demand for aggregate value-added:	$QV_a = iva_aQA_a$	(A7)
Leontief technology - Demand for aggregate intermediate input:	$QINTA_a = \mathrm{int}a_aQA_a$	(A8)
Value added and factor demands:	$QVA_a = a_a^{va}(\sum_{f\in F}\delta_{fa}^{va}QF_{fa}^{-\rho_a^{va}})^{-\frac{1}{\rho_a^{va}}}$	(A9)
Output transformation (CET function):	$QX_c = \alpha_c^t(\delta_c^tQE_c^{\rho_c^t} + (1-\delta_c^t)QD_c^{\rho_c^t})^{\frac{1}{\rho_c^t}}$	(A10)
Composite supply (Armington function):	$QQ_c = \alpha_c^q(\delta_c^qQM_c^{-\rho_c^q} + (1-\delta_c^q)QD_c^{-\rho_c^q})^{-\frac{1}{\rho_c^q}}$	(A11)
Output aggregation function:	$QX_c = \alpha_c^{ac}(\sum_{\alpha\in A}\delta_{ac}^{ac}QXAC_{ac}^{-\rho_c^{ac}})^{\frac{1}{\rho_c^{ac}-1}}$	(A12)
Institution Block		
Factor income:	$YF_f = \sum_{a\in A}WF_f\overline{WFDIST}_{fa}QF_{fa}$	(A13)
Institutional factor	$YIF_{if} = shif_{if}[(1-tf_f)YF_f - trnsfr_{ROWf}EXR]$	(A14)

incomes:		
Income of domestic non-government institutions	$YI_i = \sum_{f \in F} YIF_f + \sum_{i \in INSDNG} TRII_{ii'} + trnsf_{igov} + trnsfi_{ROW} EXR$	(A15)
Household consumption expenditure	$EH_h = (1 - \sum_{i \in INSDNG} shii_{ih})(1 - MPS_h)(1 - TINS_h) YI_h$	(A16)
Household consumption demand for marketed commodities (similar for home commodities):	$PQ_c QH_{ch} = PQ_c \gamma^m_{ch} + \beta^m_{ch}(EH_h - \sum_{c \in C} PQ_c \gamma^m_{ch} - \sum_{a \in A} \sum_{c \in C} PXAC_{ac} \gamma^h_{ach})$	(A17)
Government revenue:	$YG = \sum_{i \in INSDNG} TINS_i YI_i + \sum_{f \in F} tf_f YF_f + \sum_{a \in A} tva_a PVA_a QVA_a + \sum_{a \in A} ta_a PA_a QA$ $+ \sum_{c \in CM} tm_c pwm_c QM_c EXR + \sum_{c \in CE} te_c pwe_c QE_c EXR +$ $+ \sum_{c \in C} tq_c PQ_c QQ_c + \sum_{f \in F} YIF_{govf} + trnsf_{govROW} EXR$	(A18)
Government expenditure	$EG = \sum_{c \in C} PQ_c QG_c + \sum_{i \in INSDNG} transf_{igov}$	(A19)
System Constraint Block		
Factor Market:	$\sum_{a \in A} QF_{fa} = \overline{QFS}_f$	(A20)
Upward Sloping Labour Supply (Thurlow, 2008)	$\frac{QFS_f}{QFS^0_f} = \left(\frac{RWF_f}{RWF^0_f}\right)^{etas_f}$	(A21)
Average Real Wage	$RWF_f = \left(\frac{YF_f}{QFS_f}\right) \Big/ \left(\frac{CPI_f}{CPI^0_f}\right)$	(A22)
Composite commodity markets:	$QQ_c = \sum_{a \in A} QINT_{ca} + \sum_{h \in H} QH_{ch} + QG_c + QINV_c + qdst_c$	(A23)
Current account balance:	$\sum_{c \in CM} pwm_c QM_c + \sum_{f \in F} trnsfr_{ROWf} = \sum_{c \in CE} pwe_c QE_c + \sum_{i \in INSD} trnsfr_{iROW} + \overline{FSAV}$	(A24)
Government balance:	$YG = EG + GSAV$	(A25)
Saving-Investment Balance:	$\sum_{i \in INSDNG} MPS_i (1 - TINS_i) YI_i + GSAV + EXR\overline{FSAV} = \sum_{c \in C} PQ_c QINV_c + \sum_{c \in C} PQ_c qdst_c$	(A26)
Total absorption:	$TABS = \sum_{h \in H} \sum_{c \in C} PQ_c QH_{ch} + \sum_{a \in A} \sum_{c \in C} \sum_{h \in H} PXAC_{ac} QHA_{ach} +$ $+ \sum_{c \in C} PQ_c QG_c + \sum_{c \in C} PQ_c QINV_c + \sum_{c \in C} PQ_c qdst_c$	(A27)

Between Period Capital Updating *(Thurlow, 2008)*

Average Capital Rental Rate	$AWF_{ft}^{a} = \sum_{a \in A}\left[\left(\frac{QF_{fat}}{\sum_{a \in A} QF_{fat}}\right) WF_{ft}.WDIST_{fat}\right]$	(A28)
Share of New Capital	$\eta_{ft}^{a} = \left(\frac{QF_{fat}}{\sum_{a \in A} QF_{fat}}\right)\left(\beta^{a}\left[\frac{WF_{ft}.WDIST_{fat}}{AWF_{ft}^{a}} - 1\right] + 1\right)$	(A29)
New Investment	$\Delta K_{fat}^{a} = \eta_{ft}^{a}\left[\frac{\sum PQ_{ct}.QINV_{ct}}{PK_{ft}}\right]$	(A30)
New Capital by Sector	$QF_{fat+1} = QF_{fat}\left[1 + \frac{\Delta K_{fat}^{a}}{QF_{fat}} - \nu_{f}\right]$	(A31)

DEFINITIONS OF MODEL PARAMETERS/VARIABLES

Sets

$a \in A$	activities (disaggregated according to rural-urban status)
$c \in C$	commodities
$c \in CM$	imported commodities
$c \in CE$	exported commodities
$f \in F$	factors (disaggregated according to rural-urban status)
$i \in ISNDNG$	domestic non-government institutions
$h \in H$	households (disaggregated according to rural-urban status)

Parameters

α_a^a	efficiency parameter in the CES activity function
α_a^{va}	efficiency parameter in the CES value added function
α_c^t	CET function shift parameter
α_c^q	Armington function shift parameter
α_c^{ac}	shift parameter for domestic commodity aggregation function
β_{ch}^m	marginal share of consumption spending on marketed commodity *c* for household *h*
δ_a^a	CES activity function share parameter
δ_{fa}^{va}	CES value-added share parameter for factor *f* in activity *a*
δ_c^t	CET function share parameter
δ_c^q	Armington function share parameter
δ_c^{ac}	share parameter for domestic commodity aggregation function
γ_{ch}^m	subsistence consumption of marketed commodity *c* for household *h*
γ_{ach}^h	subsistence consumption of home commodity *c* from activity *a* for household *h*
ρ_a^a	CES production function exponent
ρ_a^{va}	CES value-added function exponent
ρ_c^t	CET function exponent
ρ_c^{ac}	domestic commodity aggregation function exponent

iva_a	quantity of value-added per activity unit
$\text{int}\, a_a$	quantity of aggregate intermediate input per activity unit
tq_c	rate of sales tax
tf_f	direct tax rate for factor f
tva_a	rate of value-added tax for activity *a*
tm_c	import tariff rate
te_c	export tax rate
$shif_{if}$	share for domestic institution *i* in income of factor *f*
$trnsfr_{if}$	transfer from factor *f* to institution *i*
pwm_c	import price (foreign currency)
pwe_c	export price (foreign currency)
$qdst_c$	quantity of stock change
$etas_f$	labour supply elasticity factor *f*
v_f	capital stock depreciation rate
β^a	capital sector mobility factor

Exogenous Variables

$\overline{QFS}_f$	quantity of factor supplied
$\overline{WFDIST}_{fa}$	wage distortion factor for factor *f* in activity *a*
$\overline{FSAV}$	foreign saving (foreign currency unit)
MPS_i	marginal propensity to save for domestic non-government institution
$\overline{CPI}$	consumer price index (normalized)

Endogenous Variables

PQ_c	composite commodity price
PDD_c	demand price for commodity produced and sold domestically
PE_c	export price (domestic currency)
PM_c	import price (domestic currency)
PX_c	aggregate producer price for commodity
$PXAC_{ac}$	producer price of commodity *c* for activity *a*
PDS_c	supply price for commodity produced and sold domestically
PVA_a	value-added price (factor income per unit of activity)
QA_a	quantity (level) of activity
QQ_c	quantity of goods supplied to domestic market (composite supply)
QD_c	quantity sold domestically of domestic output
QE_c	quantity of exports of commodity
QM_c	quantity of imports of commodity
$QXAC_{ac}$	quantity of marketed output of commodity *c* from activity *a*
QX_c	aggregate marketed quantity of domestic output of commodity
QVA_a	quantity of (aggregate) value-added

$QINTA_a$	quantity of aggregate intermediate input
$QINT_{ca}$	quantity of commodity *c* as intermediate input to activity *a*
QF_{fa}	quantity demanded of factor *f* from activity *a*
QH_{ch}	quantity consumed of commodity *c* by household *h*
QHA_{ach}	quantity of household home consumption of commodity *c* from activity *a* for household *h*
$QINV_c$	quantity of investment demand for commodity
QG_c	government consumption demand for commodity
YF_f	income of factor *f*
WF_f	average price of factor *f*
YIF_{if}	income to domestic institution *i* from factor *f*
YI_i	income of domestic nongovernment institution
EH_h	consumption spending for household
EXR	exchange rate (local currency unit per foreign currency unit)
$TINS_i$	direct tax rate for institution *i*
YG	government revenue
EG	government expenditures
$GSAV$	government savings
$TABS$	total nominal absorption
RWF_f	average real wage by factor
η_{ft}^{a}	share of new capital time *t* factor *f*
ΔK_{fat}^{a}	New Investment by factor, activity and period
AWF_{ft}^{a}	Average Capital Rental Rate by factor and period

Appendix A5: Elasticities for model calibration

A base elasticity of substitution between factors (bottom level) of 0.8 was selected for all production sectors apart from the six farm types where an elasticity of 0.2 was selected. The top-level factor elasticity is set at 0.4 for all sectors. Elasticities of factor substitution were assumed the same in the rural and urban parts of the study area.

Armington elasticities of 2 were assumed for all commodities in the model apart from Construction, Distribution, Hotels and catering, Transport, Public Sector and Other Services where an elasticity of 0.5 was used. Similarly, a CET elasticity of 3 was assumed for all sectors but Construction, Distribution, Hotels and catering, Transport, Public Sector and Other Services where a CET elasticity of 0.5 was used.

LES elasticities for market demand for Crops, Livestock, Forestry and Fishing were set at 0.33 for domestic households and tourists while all other household, tourist and NPISH elasticities of demand were initially set as unitary. The household Frisch parameters (which measure the elasticity of the marginal utility of income) were set at the default level of -1 for all household types.

Appendix A6: Results of Monte Carlo filtering

Table A10. Identification of elasticities in the CGE model

Elasticity type	Kolmogorov-Smirnov test p-value	Influence of elasticity
Armington		
Crops	0.000	**critical**
Livestock	0.000	**critical**
Forestry	0.046	**important**
Fish	0.059	**important**
Oil	0.077	**important**
Food processing	0.005	**critical**
Other food industries	0.003	**critical**
Financial services	0.007	**critical**
Public services	0.001	**critical**
Other services	0.013	**important**
Transformation		
Crops	0.000	**critical**
Forestry	0.020	**important**
Fish	0.071	**important**
Other food industries	0.058	**important**
Drink	0.044	**important**
Machinery	0.001	**critical**
Other manufacturing	0.018	**important**
Energy	0.037	**important**
Hotels	0.001	**critical**
Transports	0.008	**critical**
Pubic services	0.057	**important**
Substitution between production factors and intermediate inputs (PRODUCTION)		
U-Large Cereal farms	0.013	**important**
U-Large Livestock farms	0.093	**important**
U-Small Livestock farms	0.022	**important**
U-Large Other farms	0.027	**important**
U-Small Other farms	0.019	**important**
U-Oil	0.025	**important**
U-Mining	0.005	**critical**
U-Food processing	0.018	**important**
U-Other food industries	0.094	**important**
U-Drink	0.073	**important**
U-Wood	0.018	**important**
U-Financial services	0.073	**important**
U-Public services	0.022	**important**
R-Large Cereal farms	0.001	**critical**
R-Small Livestock farms	0.090	**important**

Table A10 (continued)

R-Large Other farms	0.000	**critical**
R-Small Other farms	0.092	**important**
R-Forestry	0.037	**important**
R-Mining	0.068	**important**
R-Wood	0.015	**important**
R-Machinery	0.071	**important**
R-Construction	0.063	**important**
R-Hotels	0.003	**critical**
Substitution between production factors (SUBSTITUTION)		
U-Large Cereal farms	0.016	**important**
U-Large Livestock farms	0.093	**important**
U-Small Livestock farms	0.022	**important**
U-Large Other farms	0.023	**important**
U-Small Other farms	0.013	**important**
U-Oil	0.021	**important**
U-Mining	0.006	**critical**
U-Food processing	0.015	**important**
U-Other food industries	0.081	**important**
U-Drink	0.073	**important**
U-Wood	0.015	**important**
U-Financial services	0.063	**important**
U-Public services	0.022	**important**
R-Large Cereal farms	0.001	**critical**
R-Large Other farms	0.000	**critical**
R-Small Other farms	0.079	**important**
R-Forestry	0.043	**important**
R-Mining	0.058	**important**
R-Wood	0.015	**important**
R-Machinery	0.083	**important**
R-Construction	0.074	**important**
R-Hotels	0.044	**important**

Note: U and R stand respectively for Urban and Rural

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Abstract
Parameter uncertainty has fuelled criticisms on the robustness of CGE results and has led to the development of alternative approaches to sensitivity analyses. Researchers have used Monte Carlo (MC) for systematic sensitivity analysis (SSA) because of its flexibility. However, MC may provide biased simulation results. Gaussian quadratures (GQ) have then been developed, but they are much more difficult to apply in practical modelling and may not always be desirable. This report applies an alternative approach to SSA, Monte Carlo filtering, and examines how its results compare to MC and GQ approaches, in an application to rural development policies in Aberdeenshire.

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