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**Written evidence submitted by Professor Karen Turner and Gioele Figus, Centre for Energy Policy,
University of Strathclyde International Public Policy Institute**

A. Introduction: CGE models for Energy-Economy-Environment (EEE) analyses

Multiple sector, multiple market economy-wide computable general equilibrium (CGE) simulation models are increasingly used in research and policy communities to analyse a range of energy-economy-environment (EEE) inter-dependencies. This ranges from global analysis by the OECD, for example, **how climate change effects key drivers of economic growth**, such as labour productivity, and how this then impacts throughout the global economy, to analysis of economic and energy use impacts within a national economy of, for example, **energy efficiency and European carbon policies** by Statistics Norway.¹

Our own CGE research has focussed in particular (but not exclusively) on impacts of increased efficiency in the energy use of both consumers and producers in the UK economy, and how these develop over different timeframes. In this respect we have recently provided expert and peer review input to an IEA project on the 'multiple benefits of energy efficiency'² and produced numerous research reports and publications.³

CGE models have become popular in energy and environmental policy analyses because they permit focus on a wide range of both **direct and indirect, anticipated and unanticipated, economic responses** to a range of changes and disturbances that impact prices and incomes throughout the economy. With their particular focus on modelling impacts on **macroeconomic indicators, fiscal balances and distributional consequences**, CGE analyses permit a more holistic view to be taken on how various climate and energy targets should be approached. This has motivated the use of the HMRC/HMT CGE model for DECC analysis of the **Fourth Carbon Budget**. However, it has not yet played a role in some key decision-making, for example the recent **withdrawal of support for the UK CCS Commercialisation project**.

A key issue in applying CGE methods to analysis of energy and environmental issues, targets and policies is that the **underlying general equilibrium foundations and framework need to be tailored and adapted to the problem at hand**. This is true for CGE modelling of any specific area of policy concern and in different geographical and geopolitical contexts. A lack of tailoring/adaptation of the HMRC/HMT CGE model (to date) may be a key underlying problem in some of the criticism that, for example, analysis of the Fourth Carbon Budget has attracted. If a CGE model is tailored to incorporate EEE interactions it can produce **considerable information relevant to policy formation**. This includes effects of any given policy action or economic disturbance on **affordability/competitiveness** of energy (and other) services, along with impacts on **emissions levels** in different sectors and aspects of **energy security** (i.e. the 'energy trilemma'). It also permits tracking of impacts on levels of **economic activity** (including employment) and **public budgets** over time so that **trade-offs** and **potential 'double dividend' opportunities** can be identified and appropriately assessed.

B. Comment on previous evidence to the committee: modelling efficiency and imperfect markets

¹ The OECD (2015) report 'The Economic Consequences of Climate Change' can be accessed at <https://www.oecd.org/env/the-economic-consequences-of-climate-change-9789264235410-en.htm>. The Statistics Norway Research Department (2015) publication 'Residential energy efficiency and European carbon policies: A CGE-analysis with bottom-up information on energy efficiency technologies' can be accessed at https://www.ssb.no/forskning/discussion-papers/_attachment/239058?_ts=14fdb6dd360.

² For information on the IEA 'multiple benefits' project, visit <http://www.iea.org/topics/energyefficiency/energyefficiencyiea/multiplebenefitsofenergyefficiency>.

³ See Karen Turner's web-page, <https://www.strath.ac.uk/staff/turnerkarenprof/#>, for details of research papers. Electronic or hard copies of particular papers are available on request from karen.turner@strath.ac.uk.

One of the authors of this paper, Karen Turner, has been indirectly engaging with the current enquiry via discussions with Dr Aaron Gouter (Energy Adviser, Parliamentary Office of Science and Technology) about CGE, and potential links to other models. However, we are prompted to contribute directly having read the transcripts of oral evidence from Tuesday 28th June and Tuesday 5th July, where there is some reflection of **basic misunderstanding of CGE models**. This is most likely related mainly to limited witness knowledge of more ‘classical’ and less developed/refined CGE modelling approaches and applications.

A common misunderstanding is reflected in the response by Dimitri Zenghelis to Q28 on 28th June where he notes that “general equilibrium models [-] assume that the economy is optimised and efficient”. While this is basically true, the implications drawn regarding (specifically) modelling of efficiency improvements from innovation in new technologies, export markets and unemployment are not (in general).

In terms of **efficiency and innovation**, it is not the case that a general equilibrium model cannot be used. While the assumption may be made producers and consumers are behaving efficiently in a long-run ‘steady state’, this is **based on current technology**. However, if there is **potential for increased efficiency through availability of new technologies**, then **the set of possibilities for what we can consume and/or produce expands**. This process, and the resulting impacts throughout the economy **can be simulated using a CGE model**. Indeed, this has been a major area of focus in EEE CGE research over the last decade, with particular interest lying in unanticipated ‘rebound’ effects in energy use as prices change and incomes are stimulated throughout the economy in response to an efficiency improvement.⁴

In terms of treatment of **export markets**, impacts via changes in competitiveness in the context of a wide range of policy issues (not limited to energy) has been a key area of insight from numerous CGE modelling studies. We note that the current HMRC CGE model used by HMT does incorporate treatment of both export and import markets, though it does impose strong assumptions in terms of the balance of trade.⁵ These assumptions are not general to CGE modelling studies in the wider academic and policy literature. Analysis of **potential changes in competitiveness, export demand and an improving balance of trade** has proven to be particularly important in our own work to consider impacts of energy efficiency in the UK economy.⁶ We have engaged in work (linked to the current EPSRC project and in collaboration with the ZEW Centre for European Economic Research in Germany) on assessing global economy impacts of increased energy efficiency in German industry.⁷ Specifically, in several studies⁸ we have considered how **the nature of economic expansion is related to changes in competitiveness as efficiency of and activity in different production and consumption sectors of the economy changes**. We have shown that where energy efficiency improves in production, a key trigger for economic expansion is improved competitiveness both in the more efficient sector or activity and its downstream supply chain. On the other hand, when efficiency increased in household energy use, expansion is driven by increased demand, which (depending on supply conditions in the wider economy) may put upward pressure on prices and reduce competitiveness.

⁴ The use of a UK CGE model in this context was the subject of one of two projects commissioned by DEFRA in 2006 under the title of ‘The Macroeconomic Rebound Effect and the UK Economy’. See download via the UK Energy Research Centre (UKERC) for the CGE contribution at http://ukerc.rl.ac.uk/pdf/ee01015_final_a.pdf. This is also the context that our own current EPSRC funded research is set in (see Footnote 1 above).

⁵ Documentation on the HMRC CGE model has been downloaded from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/263652/CGE_model_doc_131204_new.pdf.

⁶ Impacts on exports is a key focus in the aforementioned (Footnote 5) study for DEFRA, and in several other papers (see Karen Turner publications via link in Footnote 4).

⁷ Paper available via open access at <http://www.sciencedirect.com/science/article/pii/S0140988315003631>.

⁸ Not all published papers are available via open access; however, authors’ pre-publication versions are available on request from karen.turner@strath.ac.uk.

Finally (in terms of the issues identified above), while the current HMRC/HMT CGE model does treat the **labour market** as a perfectly competitive market, this need not be the case. More commonly in the sub-national regional CGE literature, but increasingly commonly in national level CGE modelling analyses, **treatments of imperfect competition in labour markets have been introduced and related to unemployment**. For example, this may be through consideration of firm vs. worker ‘market power’ and how this changes as the unemployment rate changes.⁹ In our own work, we have found that **treatment of the labour market is indeed very important in determining both the nature and magnitude of the economy-wide impacts** of almost all policy and non-policy disturbances.

We would concur with the response of Dimitri Zenghelis on his points in response to Q29 on 28th June about exercising caution when modelling particularly over long time frames. In our experience, **dynamic adjustment over time is very important in terms of how the economy adjusts to different disturbances** including, but not limited to, uptake of efficiency-enhancing technologies, with shorter run impacts often being quite different in both nature and magnitude to long run outcomes. However, and specifically in an economy-wide context such as that considered in CGE analyses, the **complexity of potential changes to economic conditions** make it difficult, in our view, to consider scenarios relative to a ‘business as usual’ baseline. For this reason, it may be advisable to set dynamic analyses of a given scenario relative to a ‘nothing else changes’ baseline so that the potential impacts of a specific change can be isolated and understood, with careful consideration of the impacts of changing key assumptions etc. That is, **a CGE model should not be viewed or used as a predictive or forecasting tool**, rather it is best applied in the context of ‘what if’ **scenario analyses**.

We would also concur with the response of Karen Ellis in response to Q31 on 28th June about exerting caution in what models are taken as dominant in delivering answers to policy questions on issues such as climate change. Different models give greater or lesser attention to different things. For this reason, **it is important that a CGE model is viewed as part of a suite of models** that interact and/or each provide component inputs to, for example, the type of **(social) Cost Benefit Analysis advised in the HMT Green Book**. This issue arises again in the context of evidence provided during the 5th July session, particularly with respect to Q27-Q29, and it is one that we return to in our recommendations below.

However, specifically relating to Q27, which is concerned with the **wider benefits (on health, innovation etc.) of decarbonisation**, and Q23, which focussed on the removal of support for the CCS Commercialisation competition, we would highlight the fact that **there is more that the HMRC/HMT CGE model could be developed and tailored to do**. For example, there is a need to consider the infrastructure and economic service nature of particularly transport and storage elements of CCS and a multi-sector CGE model would be an appropriate framework within which to do this. However, in considering the potential economic return on any public investment, as noted in Caroline Lucas’s question, there is a need to consider the **benefits of avoiding the release of CO₂ into the atmosphere**. At the most basic level, this may be considered in terms of the UK meeting her climate change commitments. However, there are other possibilities. We noted in our introduction that the OECD global CGE model does focus on impacts of climate change on labour productivity as a key driver of growth. This is a less well-researched area at a sub-global level. However, where there are causal relationships between economic activity and energy use on human health, which in turn impacts not just labour productivity but also things like health spending, it is possible, at least in principle, to model these in a general equilibrium context. The problem with climate change and CGE modelling at a national level is that **the geographical (and geopolitical) location of emissions generation**

⁹ This (increasingly common) treatment of imperfect completion in labour markets and wage determination in CGE models is based on seminal theoretical and empirical work by the UK economists Danny Blanchflower (now Dartmouth College in the US and University of Stirling in the UK) and Andrew Oswald (now University of Warwick) on ‘the wage curve), see <http://www.nber.org/papers/w11338> for a recent publication.

may differ from the location where health impacts are actually felt. That is, UK citizens and public budgets may not be the beneficiaries of reduced release of CO₂ in the UK.

On the other hand, in **the case of physical waste management (and recycling), health concerns are more localised** and a CGE modelling approach to consider the wider benefits delivered by economic service activity in this area would be **more straightforward to motivate and model**.¹⁰

C. Lessons and recommendations

1. Need for transparency and clarity in designing and reporting CGE modelling analyses

If we take, for example, the Ackerman and Daniel (2014)¹¹ critique on the use of CGE modelling in UK Climate Policy analysis (commissioned by Friends of the Earth and WWF), crucial points are made in the Recommendations on p.3 regarding transparency, noting that “Any changes to the model made for environmental analyses should be described in public documents”. Current documentation in the public domain on the HMRC model used by HMT and DECC, particularly (but not exclusively) in the context of the fourth carbon budget assessment, is limited. This adds fuel to the common critique of CGE models being considered to be somewhat ‘**black box**’ in terms of a lack of transparency and explanation of how different elements of model specification are treated and what the implications of alternative treatments may be.

Given the complexity of CGE model specification and use set against the need to convey information to a wide range of stakeholder groups, we recognise that this is not an easy problem to address, particularly in the context of the resource constraints of practical policy analysis. Therefore, our recommendation would be that HMT develop an **appropriate mix of advisory input and peer review on both model specification and reporting of results**. There are mechanisms adopted elsewhere (e.g. the ESRC peer review college, systems of peer-reviewed journals) that may offer lessons on how genuinely impartial and independent external input could be introduced to the process of CGE (and other) modelling for UK policy analysis.

2. Developing institutional capacity and skills to build, use and interpret CGE models and results

It is our understanding that HMT are currently in the process of recruiting civil service staff to work on CGE modelling, including focus on energy and environmental issues. This is a very welcome development in terms of developing institutional capacity and skills for CGE modelling at HMT. However, particularly given the complexity and resource-intensity of whole economy multi-sector CGE model development, there remains a need for independent and impartial external expert input to aid and improve the quality, credibility and transparency of modelling work.

In particular, we are concerned that the HMRC/HMT CGE modelling programme has not made sufficient use **of expertise and resources made available via Research Councils UK (RCUK) investments**. For example, in the case of one of the authors here, Karen Turner, over the last decade RCUK has invested just under £750k of public funds on three projects that have involved development of UK CGE modelling frameworks for analysis of energy and environmental issues.¹² Learning lessons from such projects need not require further investment by HMT or other Government departments in the researcher or research programme.¹³ Rather,

¹⁰ The CEP team at Strathclyde are currently engaged in internally funded research activity in this area, which we would be happy to discuss. Please contact karen.turner@strath.ac.uk.

¹¹ Available to download at <https://www.foe.co.uk/sites/default/files/downloads/synapse-misunderstanding-climate-policy-low-res-46332.pdf>.

¹² See information on all three grants from RCUK at <http://gtr.rcuk.ac.uk/person/E11D715B-FD2D-459F-8B12-D60C6C382281>. Note also that Gioele Figus, the second author of this submission is a PhD student whose fees are being paid by ESRC via the Scottish Graduate School of Social Science.

¹³ Indeed RCUK is effectively funding Karen Turner’s contribution to the writing of this submission, which will be considered as an output of the current EPSRC investment in the project detailed under Footnote 1 and within the

engagement with RCUK research would serve the dual outcomes of **increasing return to public funds invested by RCUK** (via “impact”¹⁴) and **aiding development of institutional capacity and skills in UK Government departments** (i.e. HMT itself and other departments, such as the new Department of Business, Energy and Industrial Strategy, that may use CGE modelling results in conducting and reporting policy analysis).

3. Suggested priorities for HMT CGE model development

Appropriate specification of a CGE model to focus on any given area of policy concern is all about identifying and modelling relevant relationships and transmission mechanisms (from initial cause to ultimate effect). At an economy-wide scale many of these will be **indirect (and potentially unanticipated)**, such as how labour market or energy supply responses may impact economic activity and energy use across the economy following a policy action to action to reduce energy use and/or emissions in the most energy-intensive industries. In this respect, and reflecting on the comments made above regarding institutional capacity to build, use and interpret CGE models and results, it is important that the research community play a role in leading on investigating, identifying and considering alternative specifications for the range of transmission mechanisms that may be relevant.

However, again, there is an existing evidence base for the UK that has been developed through RCUK and other research programmes. It is not clear that this has been considered in development of the HMRC/HMT CGE model. For example, and linking to some of the areas of concern highlighted in the evidence sessions on 28th June and 5th July (see Section 3 above), our own research has highlighted the importance of appropriate labour market specification and treatment of trade.¹⁵ These are areas that are crucial in CGE model development more generally.

In terms of considering energy and environmental issues in particular there are a range of potential focuses for appropriate CGE model development (depending on the nature of policy concerns and potential instruments). At a very minimum **it is necessary to identify how energy is used in different production and consumption activities**. Again, this is an area that our own RCUK-funded work has provided evidence on in the past and continues to do so through our current EPSRC project. We are happy to share information on model specifications including model codes developed to enable practical simulation of CGE models. The other key, but to date less well researched area is treatment of energy supply. Our own research has shown that CGE model results are sensitive to what is assumed about **energy supplier responses** – particularly in capacity and pricing decisions – to any policy action that impacts energy demand. However, in this respect it may be necessary to consider whether the CGE model can be informed by the outputs of other more detailed models of energy supply, an issue that is the subject of our final recommendation.

4. Viewing and using CGE as one of a (potentially inter-linked) suite of tools/models

It is important that **CGE should not be regarded as the only or most important model in providing information for policy analysis**. One issue is that the full range of information required to inform, for example, the type of social cost-benefit analysis using the framework recommended in the HMT Green Book, cannot be provided by a CGE model alone.

However, a second issue is that it may often be the case that another model can provide better information than even quite sophisticated economic specification within the CGE on some specific area, for instance within the energy system, that will impact the outcome of CGE simulations. Recognition of the limitations of

information under the link in Footnote 13.

¹⁴ See <http://www.rcuk.ac.uk/innovation/impact/> on RCUK definition and implications of “impact”.

¹⁵ The report to DEFRA referenced in Footnote 5 includes evidence on these issues in the context of energy efficiency, with fuller investigation in papers available via Karen Turner’s web-site and/or on request (Footnote 1).

individual models is widely recognised in an energy system context.¹⁶ On the other hand, **consideration of how *economic system* models such as CGE may interact with energy system models has been limited.**¹⁷

In response to this, and as part of our current EPSRC project, we are arranging a workshop (in November 2016) involving various international experts in CGE and/or energy systems models along with identified policy stakeholders. Again, there are a range of issues – including but not limited to consistency in data and assumptions – on which the research community can provide valuable capacity and expertise to support HMT and other Government departments. However, it also raises issues in terms of inter-disciplinary focus and investment in capacity that RCUK and other funding bodies must address if this is agreed to be a priority issue in informing policy.

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¹⁶ See, for example, the IEA Energy Technology Systems Analysis Programme (ETSAP) at <http://www.iea-etsap.org/>.

¹⁷ For an example of what has been attempted in linking CGE and TIMES, see the link to the work of Statistics Norway in Footnote 2 above.