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FINAL REPORT

Faster Rebuilds with MRCGE

Professor Shane Cronin (Massey University)

Abstract:

This project aimed to develop a socio-economic model to help businesses, industries and communities to prepare better for, and recover more effectively from, a volcanic event at Mt Taranaki. We developed a multi-regional computable general equilibrium model, based on datasets from Taranaki and around New Zealand, including data obtained from the Canterbury Earthquake Sequence. Volcanic impact scenarios developed by the research team were then tested in the model. Three volcanic scenarios were developed, with one of these tested during Taranaki Regional Council's 'Exercise Pahu' Civil Defence and Emergency Management exercise. The research used a dynamic regional computable general equilibrium (CGE) model for the Taranaki region to investigate the local effects of each scenario, and further, how these local effects flow-on to impact on the national economy of New Zealand. A dynamic model was needed to differentiate the distinctive economic impacts that occur at different stages of a volcanic crisis, including syn-event, medium term adaptation and early recovery phase, and longer term re-establishment of business activity and agriculture. The approach taken was to nest the regional CGE model within, and integrate it with, a national CGE model for New Zealand. This is important when regional-based industries are large enough to impact on the national economy, or are of critical national significance (e.g., energy generation, oil and gas).

A second component of this research was to apply a detailed spatial CGE model to the Auckland Volcanic Field, where only one scenario was evaluated (based on an extension of the Ruaumoko eruption exercise), but with a spatial variability in the location of the eruption based on probabilistic forecasts developed by the Living with Volcanic Risk team. The regional impacts of this on the Auckland economy were determined using high-resolution meshblock data to provide a unique spatial view of hazard impacts and a more interactive tool for economic hazard modelling.

Keywords: Taranaki, Auckland, volcanic hazard, economic impacts, recovery from disaster.

Introduction / Background:

The aim of this research was to develop a socio-economic model that will enable end-users to better prepare for, and achieve a quicker rebuild and recovery following, a volcanic event at Mt Taranaki. The model developed is a dynamic multi-regional computable general equilibrium (CGE) model, with a particular focus on labour-force requirements, and was

based on unique real-world datasets and lessons learned from the recent Canterbury Earthquake Sequence.

Following the 2010-11 Canterbury earthquakes, considerable effort has been directed by government agencies, insurers, construction contractors and educators at forecasting labour force requirements (skills, occupations) associated with the rebuild of buildings and core infrastructure. Several emerging limitations of existing economic assessment methodologies have been identified by team members linked to the rebuild (Drs McDonald and Fairgray and Mr Akehurst). Our research addressed some of these issues through the development of a dynamic multi-regional CGE model tailored to assess the economic and labour force consequences following a Mt Taranaki eruption. CGE models estimate how an economy might react to changes in policy, technology or, as is the case in this research, exogenous influences, such as a natural hazard event. Specifically, a multi-regional Social Accounting Matrix, a necessary prerequisite for creating a CGE model, was created based on the earlier work of Zhang et al. (2008). This incorporates structure/relationships associated with rebuild activities based on Christchurch-related datasets generated for CERA by the socio-economic members of our team. This input was specifically adapted for the Taranaki context, which has uniquely the only oil and gas production in New Zealand, as well as a major reliance on the dairy and related agricultural industry sector. The multi-regional CGE model, building on the earlier work of Yeoman et al. (2009), is fully dynamic (including all relevant critical feedbacks/non-linearities/lags) and multi-regional, covering both the Taranaki region and the rest of New Zealand. Furthermore, the model allows simulation of a range of plausible values for key, but uncertain, parameters using Monte Carlo methods. The model is able to report on a range of time scales to show key economic and labour force requirements, thus showing clearly the rebuild and recovery transition pathway.

Typical eruption scenarios of a range in severity were developed for this research based on the known geological record of Mt Taranaki. These eruption scenarios cover the scale, duration and event characteristics (tephra and ash fall, lava flow etc.) of eruptions and rest heavily on research findings of the Living with Volcanic Risk (MAUX0401) and Robust Estimates of Geophysical Hazard (2010-MAU-01-NHRP) programmes. These scenarios, which will extend at least five years beyond the rebuild stage, are sufficiently varied to ensure thorough validation of the multi-regional CGE and its outputs. The scenarios included:

(1) *The Tahurangi scenario*: a small-scale eruption associated with the growth of a lava dome and its localised collapse, typical of the most common events known from the Mt Taranaki eruption sequence (Turner et al., 2008; Procter et al., 2010; Platz et al., 2012). This scenario produces minimum long-term infrastructure impact.

(2) *The Inglewood scenario*: a medium-large scale eruption associated with widespread lahars, pyroclastic flows and a large tephra fall, based on the typical sub-plinian eruptions known from the Taranaki record (Platz et al., 2007; Turner et al., 2012). This scenario produces medium-term impacts, some of which require remediation action to be undertaken.

(3) *The Opua scenario*: a medium-small scale flank-collapse event producing a debris avalanche. This scenario is based on the common and repeated occurrence of volcano edifice collapse at Mt Taranaki (Procter et al., 2009; Zernack et al., 2012)

and results in permanent loss to pastureland and infrastructure in its path.

In a further extension of this work, the same modelling approach was developed to determine the spatial variability of economic hazard forecasting across the city of Auckland based on a single eruption scenario (a new small-medium scale monogenetic volcano). Spatial variability of the potential economic consequences is a highly important consideration, in part due to the concentrations of different economic activities in different urban sectors (e.g., industrial areas, financial districts vs. dominantly suburban sites). Furthermore, in volcanic fields spatial variability of eruption likelihood is considerable. Here we demonstrate also how multiple model runs at varying eruption locations, combined with a spatial hazard probability map for the AVF (Bebbington and Cronin, 2011), lead to a novel spatial economic vulnerability evaluation for Auckland City.

Objectives or Research Aims

Objective No. 1

Developing a dynamic MRCGE for assessing socioeconomic impacts of eruptions

This research led to the development of a multi-regional and dynamic Computable General Equilibrium model which robustly assesses the socio-economic, and, in particular, labour force requirements, during the rebuild phase following a fictional eruption at Mt Taranaki.

Deliverables:

- An article accepted for publication in a peer-reviewed international journal of a high standard
- A technical report providing a full mathematical specification of the model, its inputs, and outputs, as applied to the Mt Taranaki volcanic eruption scenarios.
- Presentation of the methods/results at the annual Volcanic Advisory Committee Meetings held in Taranaki, Central North Island and Auckland, and similar fora.

Budget: $250,000 (excl GST)

Objective Due Date: 30 June 2015

Objective Achieved? Yes

Discussion

By applying the new multi-regional, dynamic CGE model, the three volcanic scenarios developed for this research (described above) revealed severe business disruption to the Taranaki region, particularly with the initial shock to the economy, and in the ensuing first year after the volcanic event. Examining the monthly average GDP levels for five years, the recovery pathway expected is similar in shape for all three scenarios, with a sharp early drop, followed by a rapid recovery to varying degrees of the original state. For the Tahurangi

scenario, the Taranaki economy returns to its pre-event GDP in only eleven months after the cessation of volcanism. For the larger, longer and more explosive Inglewood eruption scenario, the Taranaki economy takes five years to return to its original level. The most severe impacts associated with semi-permanent land damage occur within the Opua scenario. This debris avalanche scenario, which is based on one of the smallest-volume cases known (Zernack et al., 2012), permanently changes the structure of the Taranaki economy, and its output does not return to pre-event GDP levels within 5 years ($307m less GDP per annum than pre-volcanic event levels). The Opua scenario is also the only one of the three scenarios where there is a decline in overall economic activity after five years compared to the pre-volcano levels of economic activity. This scenario interestingly also showed substitution between sectors that can be attributed to the volcanic event. Within the Taranaki region, the Opua scenario showed substitution between agricultural sectors – a reduction in forestry, while horticulture and fruit growing grew in industry size. This was due to the relative price changes between the factors of agricultural production, with the loss of forestry and farmland. The Opua scenario also showed an increase in retail for necessities, such as food and clothing and accommodation, after five years.

The dramatic effects of the Opua volcanic event extend strongly to other regions to the tune of $309m after 5 years, showing the strong inter-linkages between the Taranaki region and the New Zealand economy. At a national level, industries that did not recover to pre-volcanic levels included dairy farming, oil and gas, water sewage and drainage, and arts and recreation services. Furthermore, owner-occupied dwellings also did not recover, due to the permanent evacuation of some areas. The national economy effects are less pronounced for the Inglewood scenario, although the impact on oil, gas and electricity generation and supply is initially very severe at a national level. There is very little impact on the agricultural industry of New Zealand as a whole soon after the volcanic event.

Constructing a multi-region dynamic CGE model enabled a relative analysis of the effects of different volcanic events from Mt Taranaki. Within the three different scenarios of different intensity, the CGE model showed how the economy, from an initial steady state, responded to impulses or shocks brought about by the volcanic activity. Optimisation within CGE showed the economy attempting to revert back to the steady state (the economy prior to the volcanic activity). For the Inglewood and Tahurangi scenarios, this steady state was attained within one year after the end of the volcanic sequence. For the Opua scenario, the Taranaki economy did not return to the steady state levels; the price changes within the CGE modelling process determined the recovery pathways of different industries. In particular, there was substitution of land uses evident.

A further outcome of this research was the use of the geological and (aspects of) the economic scenarios to design specific geological and impact injects for Exercise Pahu – a volcanic eruption exercise for Mt Taranaki held on 20 November 2013. The inputs to this scenario rested on research from the Massey University group into past eruption processes and scenarios, as well as the preliminary results from the economic studies described above, especially as they applied to the operation of the agricultural and gas sector and the behaviour of local businesses. This inter-regional table-top exercise tested the responses of

a huge range of volunteer, government and private organisations. Members of the project team were also present on the main day of the Exercise, playing the roles of a scientific advisory group along with colleagues from GNS Science.

Spatial evaluation of economic impacts of potential eruptions in Auckland

An extension to this research approach was applied to Auckland City, but combining aspects of the ongoing nested economic models, spatial variability in the range of economic activities across the City and a probabilistic evaluation of the spatial likelihood of new eruptions. Using only a single event scenario approach, this work extended from the Taranaki part of the project by examining the granularity of detailed spatial economic impact across a complex economy. This provides a new tool to evaluate potential impacts of a volcanic event to all sectors of an economy and provides information that can be used to concentrate spatially relevant mitigation measures.

A realistic socio-economic assessment of volcanic impact, however, must take into account dynamic properties of communities, workforces and businesses and extend beyond a direct infrastructure/property loss approach. In this research we developed a dynamic economic model to assess the economic impacts of a hypothetical volcanic event occurring at 7,270 spatial locations throughout the Auckland Volcanic Field. The field of at least 53 volcanoes underlies New Zealand's largest urban area of Auckland City, home to 1.4 million people. We applied event characteristics obtained from a small-medium scale volcanic eruption scenario (derived from knowledge of the geological history of this field) to test the impacts of an "average" eruption in Auckland. Data on business and emergency management decision-response mechanisms for this scenario were collected during the civil defence and emergency management exercise Ruaumoko. Losses were quantified both including, and without, business mitigation measures in place. This response information was combined with a recent spatial hazard probability map (Bebbington and Cronin, 2011), to produce a novel estimate of the spatial variability of economic vulnerability for Auckland City. This approach can be applied to all similar settings and demonstrates how economic information must be evaluated alongside a potential direct life and property damage assessment to enhance our understanding of uncertainty in volcanic risk mitigation.

Interestingly, the highest calculated value-added losses are for areas situated near to the core industrial suburbs (for Auckland, these are Penrose, Onehunga, Otahuhu and East Tamaki), rather than the CBD. Note, however, that these results do not include direct economic losses due to damage of assets. On average the "industry zone" areas generate inoperability losses over the one-year study period of around $10 billion, or nearly one quarter of the total regional value added. This analysis and the Ruaumoko business responses show that manufacturing businesses are particularly vulnerable to a volcanic event, due to their limited ability to adapt, and long timeframes required for relocation of plant and labour to resume production activities. Added to this are the high level of interconnections between manufacturing businesses and other activities within the regional economy.

In Auckland there is strong emphasis in planning documents to realise a compact urban form, where urban growth and development is focused within the existing metropolitan area. This is a common strategy in many parts of the world where expansion goals are aligned with efficient transport systems, as well as to reduce the impacts of urban sprawl on the natural and rural environment. From the perspective of risk management, however, there is also a clear argument to develop cities such as Auckland in a way that minimises economic vulnerability to natural hazards. Achieving a compact urban form, as well as minimising hazard vulnerability, will not necessarily align.

Outputs

Publications

Murray, C., McDonald, G., Cronin, S.J., 2015: Interpreting Auckland's volcanic hazards governance through an institutional lens. Natural Hazards 75: 441-464.

Submitted and in review:

Kim, J., Murray, C., McDonald, G., Procter, J.N., Cronin, S.J., Smith, N., in review: Dynamic Computable General Equilibrium Modelling of economic impacts from volcanic eruption scenarios at regional and national scale, an example from Mt. Taranaki, New Zealand. Journal of Applied Volcanology.

McDonald, G.W., Smith, N.J., Kim, J.H, Cronin, S.J., Procter, J., in review: Quantifying Business Inoperability Losses: Economic Vulnerability Mapping for the Auckland Volcanic Field, Auckland City, New Zealand. Bulletin of Volcanology.

Conference Abstracts and Presentations

McDonald, G., Cronin, S., Smith, N., 2014: Quantifying business inoperability losses: economic vulnerability mapping for the Auckland Volcanic Field, Auckland City, New Zealand. IAVCEI Cities on Volcanoes 8, Yogyakarta, Indonesia, September 2014. cov8-abs-116

Presentations to End Users

Cronin has presented on updates to this project to the Taranaki Seismic and Volcanic Advisory Group at their annual meetings in New Plymouth.

News releases associated with this work include the New Zealand Herald feature on Mon 11 May 2015: http://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=11446448

Reports

Smith, N.J., Zhang, Y., Cardwell, R.J., McDonald, G.W., Kim, J.H., Murray, C.F., 2015: Development of a Regional Social Accounting Framework for New Zealand. ERI Research Report 2015/01. GNS Science, Wellington. ISBN 976-0-478-19911-5

Data sharing and Advice

Preparation of injects (geological, economic and agricultural/infrastructure impacts of volcanic processes and deposits) for Exercise Pahu for the Taranaki Regional Council and participation of team members in the Exercise.

http://www.trc.govt.nz/big-exercise-to-test-civil-defence-systems/

End-Users

- Department of Conservation
- Taranaki Regional Council
- Taranaki Seismic and Volcanic Advisory Group
- Exercise Pahu participants
- Auckland Council

Conclusions & Recommendations:

The two components of this study concentrated on spatial aspects of economic impact to the dynamic economy (Auckland) and temporal impacts of volcanic events of differing severity. In both cases, regional impacts are great, but extra-regional impacts are also significant. The Taranaki study showed that with medium to small hazard events, the long term recovery consequences are significant. Certain volcanic scenarios, especially those involving debris avalanches, will result in a permanent change to the landscape and may lead to a permanent abandonment of part of the Taranaki peninsula. Most eruption scenarios that do not involve flank collapse will, however, result in an up to 5-year dip in the regional economy, which can be planned for with well-timed economic incentives from outside the region. The unknown factor includes the duration of eruptions. This study assumed that eruptions would be complete within days to weeks. In some eruption examples with similar volcanoes to Taranaki (e.g., Merapi, Indonesia) or Auckland (e.g., Paricutin, Mexico), eruptions have lasted for several years. Longer durations of impacts will magnify the economic losses considerably and potentially lead to long-term outward transfers of labour and capital into neighbouring regions. Economic modelling and testing of incentives to support both declining and corresponding rapidly growing areas (where labour and capitals relocate) are needed.

Future work needs to extend both the temporal and spatial hazard forecasting approaches here to incorporate alternative mitigation strategies and test economic incentives for recovery. In the case of Taranaki, the regional economy is heavily dependent on the commodities of dairy and oil/gas production, both of which are highly vulnerable to disruption by volcanism.

For Auckland, the high economic vulnerability of the manufacturing sector appears primarily related to the production sector (excluding long-term asset values of any destroyed housing or building stock).

In both case studies, the next iteration of economic modelling must incorporate both the fixed asset value potentially affected, and the dynamic aspects of the economy. Furthermore, mitigation tools and techniques need to be developed to explore alternative recovery paths that take a holistic view of recovery both within and outside the region of main impact.

Acknowledgements

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