25th International Congress on Modelling and Simulation, Darwin, NT, Australia, 9 to 14 July 2023
mssanz.org.au/modsim2023

Investment, capital accumulation and the role of money in national energy economy models used for assessing climate and energy policy

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Abstract: This paper reviews national macroeconomic models that assess the impact of climate change mitigation and related energy policies. It highlights a notable deficiency in efforts to model capital accumulation given the potential for financial instability. In Australia, Computable General Equilibrium (CGE) models are typically used for assessing climate and energy transition policy. These models assume market-clearing and full employment in all sectors so that increasing public investment leads to the 'crowding out' of private sector activity, along with negative impacts (in terms of gross domestic product and welfare measures) derived from climate-related policy interventions. However, the majority of these models make the assumption that investment can be financed only either by taking funds sourced from other sectors of the economy, or by increasing rates of saving. This is not necessarily consistent with how the financial system works in reality, as demonstrated by the practice of implementing interest rate policy which would have no impact in these models. The radical transformation of the global energy system required to achieve net-zero carbon emissions in 2050 hinges on a significant expansion in both public and private investment. Accordingly, the current suite of models has limited contribution to current policy debates, sitting, as they do, at odds with the observed reality. As such, there is a need for models which can accommodate these realities.

In this paper, we present Stock-Flow Consistent (SFC) modelling as one possible and promising modelling tool which is more empirically grounded than current suites of policy models. In contrast to CGE models, the proposed modelling approach is broadly consistent with theories with better institutional details and policy interventions on the part of the government with richer behavioural assumptions rather than seeking to impose simplistic and unrealistic theory. In SFC models, money and credit play a central role due to the presence of more realistic linkages of the real economy to financial markets. These models embrace the assumption of endogenous money creation, rejecting the idea of rational profit or utility maximising firms and consumers, and can accommodate interventions associated with the "challenge-oriented" policies advocated by progressive analysts in the US and Europe. In this approach, the monetary system functions in accordance with the statements of central bankers who state that 'credit money is created endogenously via loan origination' Mcleay et al. (2014) & RBA (2023).

To develop an empirical modelling approach that is broadly consistent with theories of institutional structures and policy interventions on the part of the government our review paper will:

- Review macroeconomic models used for energy policy analysis, describing how different models will be required to account for what may be required to reach the Net Zero 2050 target. The study will focus on the treatment of banks, money and the financial sector and role of the government in these models
- Identify the critical gaps in those approaches in terms of their capacity for analysing the transition to renewable energy reduced greenhouse gas emissions.
- Consider an alternative modelling approach, foreshadowing its structure and the interactions between model components.

Keywords: *Computable general equilibrium models, macroeconometric models, stock-flow-consistent*

1. INTRODUCTION

One factor behind our modern society's development and economic growth, ever since the era of industrial revolution, is abundant and cheap energy mainly sourced from fossil fuels. However, according to IPCC (2021), the extensive use of energy has caused unprecedented climatic and ecological damage. There is an increasing global consensus for the need to transition from fossil fuels to renewable energy resources, which are more variable and spatially distributed than traditional fossil fuel-based generation. To meet the Paris Agreement goal of keeping global CO_2 concentrations below 450 ppm will require the introduction of new policy measures to accelerate the transition (Pollitt & Mercure 2018).

A radical transformation of the global energy system is required to achieve net-zero carbon emissions by 2050, and the transformation hinges on significant expansion in both public and private investment and a notable shift in both investment patterns and financial arrangements by institutions. Much climate and energy policy (e.g., renewables, energy efficiency) requires substantial investment via expansionary fiscal or monetary policy by national governments, e.g., Green New Deal policies, the Investment plan for Europe- the Junker Plan.

To estimate the current emissions trajectory and paths for which there is a reasonable chance of staying within the 2^0C target, the Intergovernmental Panel on Climate Change (IPCC) uses computational modelling of climate and energy e.g., large-scale climate models, and Integrated Assessment of Models (IAMs). Climate policy modelling has been increasing steadily as data have improved and additional computer power has allowed the development of more complex tools. Macroeconomic policy models, e, g Computable General Equilibrium (CGE) models are typically used for assessing climate and energy transition policy.

Since the macroeconomic impacts of climate policy are often disparate and not all the impacts are quantifiable, it is necessary to provide both model-based quantitative and qualitative evidence. Given this reality, it is crucial for policy analysts to have a detailed understanding of the underlying theories and inner workings of the models.

1.1. Understanding model mechanisms and underlying theories

Since the global financial crisis (GFC), macroeconomic policy models (e.g., Computational General Equilibrium (CGE), Dynamic Stochastic General Equilibrium (DSGE) models), on which many policy makers generally relied, have been heavily criticised and scrutinised, with recommendations for greater openness to more eclectic approaches, and co-existence of other modelling approaches e.g., Blanchard (2018), Stiglitz (2018).

The fundamental notion that grounds our critique of existing macroeconomic policy models is that changes to the institutional structure of the economy should influence both the characteristics of economic modelling and policy interventions on the part of government.

Accordingly, we draw on the insights of both Joseph Schumpeter and John Maynard Keynes, who saw the economy as a complex (non-equilibrium) and time-dependent system, "where finance precedes production precedes exchange". According to this view, monetary factors "cannot be added on after a prior or dominant model has determined the basic output and relative price variables" see Minsky (1990).

In contrast, the assumption of full employment and full utilization of productive capacity is inherently built-in to the foundations of typical models, e.g CGE models, which have been established on neoclassical foundations by Sargent, (1986). In his model, monetary interventions only influence the aggregate price level thus imposing neutrality and super-neutrality of money. This occurs because the model incorporates Tobin's q-ratio as the driver of investment (Tobin, 1970). Consequently, the return on investment in non-financial assets is calculated by aggregating the discounted streams of future revenue that are, in turn, derived from the marginal value product of capital due to the presence of unavoidable adjustment lags, Sargent's model fluctuates around, but never deviates far from, a growth path where resources are fully utilized. Of course, this simple presumption was the target of criticism mounted by Piero Sraffa that helped to launch the famous "debates in capital theory" (Harcourt, 1969)

More generally, a common presumption of representative-agent models with a single good (like corn), is that the corn, not consumed, automatically becomes the 'seed-corn' automatically invested—i.e., there is no 'slip betwixt cup and lip'. In other words, the process of capital investment is smoothly regulated through the rapid elimination of any gaps opening-up between the user-cost-of-funds and the marginal revenue product of capital (Rogers, 1989).

The post-Keynesian approach generally draws a distinction between notional or unconstrained supply and demand functions and effective or constrained supply and demand functions as opposed to neoclassical

foundations. This approach entails persistent involuntary unemployment, which is matched by an excess demand for real wage which was criticised by neoclassical economists, e.g., Sargent (1989). In this and similar criticism Pally (1998) introduced a distinction between Walrasian and non-Walrasian equilibria, with the latter achieved when the expectations of firms about the proceeds to be derived from selling output obtained by applying labour to production are fulfilled rather than disappointed. Under these conditions, there is no incentive for firms to increase their employment of workers.

By the same token, it is common for CGE models to assume 'Loanable Funds Theory' i.e., that there is a given pool of savings available to fund investment and non-accelerating inflation rate of unemployment (NAIRU). Accordingly, an increase in deficit spending on the part of government will 'crowd-out' any spending by the non-government sector that might otherwise occur (Robertson,1934).

In contrast, post-Keynesian economists generally assume that the government must deficit-spend if the non-government sector wishes to net-save, otherwise unutilized resources will be created. Under these conditions, deficit spending promotes growth in income and wealth, so that debt levels can increase in proportion (Watts et al. 2022).

1.2. The framing of energy policy models

The macroeconomic considerations discussed above are also of importance for framing energy policy. Minsky (1986) believed that the economy's institutional structure is a fundamental determinant of the particular path of development; this structure—which is itself evolving—facilitates, influences, regulates and constrains economic activity. Furthermore, he insisted that the economy would react to both exogenous and endogenous factors. In particular, driven by the profit-motive, private agents seek to actively transform the institutional structure of the economy. Minsky warned that Money Manager Capitalism (MMC) was represented by aggressive asset management and financing on the part of institutional investors, where the main players included mutual funds, bank trust funds, and pension funds (Minsky, 1986). Financing under MMC promoted precariousness (as workplace flexibility) in labour markets, while being disconnected from major product and process innovations (Whalen, 2010). As a consequence, macroeconomic and financial fragility would set in very quickly.

To counter the adverse effects identified by Minsky, "challenge-oriented" financing of new infrastructure and innovation have been advocated for to reduce precariousness in labour-markets, smooth investment flows, and help to overcome the disconnection of investors from major product and process innovations (Wray & Mazzucato 2015). An example of this kind of financing is afforded by Green New Deal (GND) policies. For Nersisyan and Wray (2019), the main motivation for GND interventions is to avoid inflationary pressures that would arise when the government attempts to gain disposition over a larger proportion of goods and services produced by the non-government sector. Anti-inflationary measures they consider include well-targeted taxes, wage and price controls, rationing, and voluntary saving, the latter encouraged by the sale of 'green bonds' to all classes in society.

The remainder of the paper is structured as follows. Section 2 briefly reviews the existing macroeconomic energy policy models by paying particular attention on the underlying theory and philosophy used in the model. We then set out the ground for building a new model as an additional tool in the energy policy makers toolbox in Section 3. Section 4 discusses key elements and structures of the proposed model using flow diagrams and theoretical arguments. Section 5 concludes.

2. A BRIEF REVIEW OF ENERGY POLICY MODELS

To assess the implications of climate and energy policy on the wider society E3 (Energy-Environment-Economy) models are used to estimate impacts on indicators such as gross domestic product (GDP), welfare, and employment. These E3 models are essentially macroeconomic models where extensions have been made to include some physical relationships to analyse climate and energy policy impacts. Computable General Equilibrium models (CGE), include GEM-E3 by Capros, et al. (2013) and MONASH model by Dixon & Rimmer (2002); and large-scale Macro-econometric models, e.g., E3ME models by Cambridge Econometrics, (2014) and GINFORS by Lutz & Wolter (2010).

There are also some models that fall between these two definitions, although their treatment of finance will generally follow the neoclassical approach, e.g small-scale Integrated Assessment Models (IAMs) such as Dynamic Integrated Climate Economy model (DICE) by Nordhaus 2017 also fall into this category

In the Australian context, CGE models that are generally used for energy policy analysis stemmed from GEM-E3, MONASH model by Dixon & Jorgensen (2012). For example, KPMG-EE by Verikios et al. (2021), GTEM

by Cai et al. (2015). The Victoria University Regional Model (VURM) is a multi-regional CGE model. Its origin lies with the Monash Multi Regional Forecasting (MMRF) model. Accordingly, VURM, MMRF and MONASH have evolved from the Australian ORANI general equilibrium model.

Energy system models have also been used to examine climate and energy policies (e.g., TIMES). In the TIMES model, demand drivers (population, GDP, households, etc.) are obtained externally, via other models or from accepted other sources. As one example, several global instances of TIMES use the GEM- E3 to generate a set of coherent (national and sectoral) output growth rates in the various regions. Note that GEM-E3 or GEMINI-E3 themselves use other drivers as inputs, in order to derive GDP trajectories. These drivers consist of measures of technological progress, population, degree of market competitiveness, and a few other (perhaps qualitative) assumptions.

Table 1 shows some underlying theories and mechanisms in some selected macroeconomic policy models. A check in the column means the model represents that economic principle.

Table 1. Underlying theory and mechanisms in some selected macroeconomic policy models

Model Name	Author(s)/Publisher	Effective demand	Loanable fund theory	Market imperfections	Endogenous money theory	Automatic stabilizers	NAIRU
GEM-E3	Capros et al. (2013)	×	√	×	×	×	√
MONASH	Dixon & Jorgensen (2012)	×	√	×	×	×	√
VRUM	Horridge (2000)	×	√	×	×	√	√
E3ME	Cambridge Econometrics (2014)	√	×	√	√, implicit	√	×
KPMG-EE	Verikios et al. (2021)	×	√	×	×	×	√
DICE/RICE	Nordhaus (2017)	×	√	×	×	×	√
GTEM	Cai et al. (2015)	×	√	×	×	×	√
TIMES	Loulou (2016)	×	√	×	n/a	√	n/a
n/a	Godley and Lavoie (2012)	√	×	√	√	√	×
DIFINE	Dafermos et al. (2018)	√	×	√	√	×	×
TEMPLE	Godin et al. (2022)	√	×	√	√	√	×
This model	This paper	√	×	√	√	√	×

3. A STOCK-FLOW-CONSISTENT APPROACH CLIMATE- CHANGE MODELS

While CGE and large-scale macro-econometric models are the approaches most used at present for informing policymaking, it is important to note that there are other methods being developed. These approaches include, systems dynamics models (similar in structure to macro-econometric models), stock-flow-consistent (SFC) models based on post-Keynesian economic principles and agent-based approaches. SFC models have parallels with the way that 'systems dynamics' approaches that are used in accounting of physical stocks and flows. This as a very active modelling research area and has received a significant consideration in the recent decade, particularly in the wake of the GFC since they are generally built by better linking the real economy to finance Minsky (1982). SFC models have recently been developed to be applied to climate and energy policy analysis, e.g Tilting Economic Momentum for Progress to Low-carbon Energies (TEMPLE) by Godin et al (2022); General Monetary and Multisectoral Macrodynamic for the Ecological Shift (GEMMES) by Bovari et al. (2018).

In contrast to CGE models, money plays a central role in the SFC models. The substantial body of work of post-Keynesian monetary theory are aligned with the statements of central bankers who state that credit money is created endogenously via loan origination (Mcleay et al. 2014). SFC models embrace the assumptions of endogenous money creation, reject the idea of rational profit or utility maximising firms and consumers, and advocate policies that support large "green investments" or increased regulation of finance. International capital mobility and capital accumulation are important phenomena where SFC models have significant advantages over CGE-models.

In summary, in terms of the contribution of the policy interventions and financial sector, a CGE modelling approach represents a worst-case context for policy makers; the starting point is one of an economically optimal use of resources (including in the financial sector). The results must therefore show a negative impact of

intervention and a reallocation of limited resources, and the policy implications are then that no intervention in the financial sector is justified (Lee, H et al. 2022).

Therefore, this study argues that SFC modelling is a line of research that should be of interest to both CGE and large-scale macro-econometric modelers. The study proposes to develop a multi-sectoral SFC model capable enough to analyse the complex macroeconomic dynamics of the energy transition and climate change policies.

4. KEY ELEMENTS OF THE MODEL

4.1. The flow diagram of the proposed model

The Figure 1 flow diagram gives an overview of the model and summarises some of the main interactions between different sectors of the economy. The dotted line shows the financial interactions in between sectors and the solid line is used to demonstrate all other flows.

The government sector consists of Treasury and Central Bank (State and Local governments are part of the government). However, unlike the Federal government, these branches of the governments do not have the sovereign monetary capacity. Rather they have vertical and horizonal relationships in terms funding stocks and flows.

The production sector is assumed to be divided into six categories. The energy sector produces energy and meets its own energy consumption demand and the demand from other sectors of the economy, for instance, household sector, transport sector.

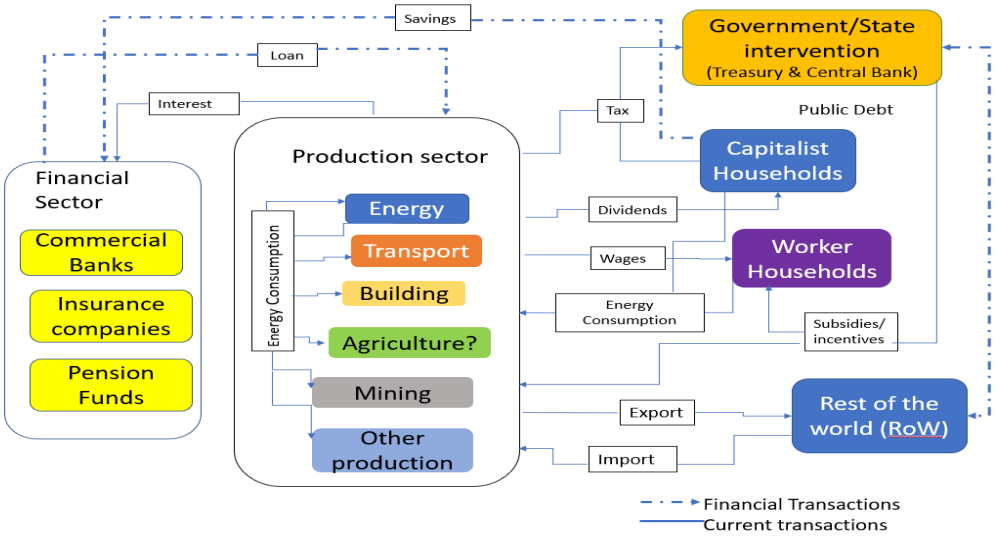

Figure 1. Flow diagram of proposed macroeconomic energy model

The Household sector is divided into two main categories to distinguish and portray some realistic behaviour, e.g., investor households, income differentials, profit earners and wage earners. However, it is acknowledged that one household may receive both wage and capital/financial income.

The financial sector consists of three main categories: commercial banks, insurance companies and pension funds), creates and provides loans to credit worthy firms (and households but not shown here), receives savings and interest and principal payments from loans. The government sectors receive taxes from the production sector, capitalist households and creates public debts. It provides incentives and subsidies e.g., tax breaks, regulation, subsidies on the different sectors of the economy.

The portrayed model for the Australian economy is assumed to be an open economy. Flows into the Rest of the World (RoW) consists of imports, firms, and bank dividends as well as interest earned on government bonds and bank bonds. Outflows consist of exports and dividends paid on RoW shares.

4.2. Behavioral aspects of the stock-flow-consistent model

The SFC models adopt a “balance-sheet” approach where transactions matrices and balance sheets for households, firms, government, and the banking system are coherently linked together by flow-of-funds accounts. Theoretical precursors for this modelling tradition go back to Marx’s famous analysis of the monetary

circuit from the purchase by firms of labour and the means of production through to final sales and distribution. SFC modelling conforms to Morris A. Copeland's principles of 'quadruple entry' (Minsky 1993).

Zezza (2015) identifies four principles characterising the SFC approach to modelling in accounting for Stocks and Flows, "everything comes from somewhere and goes somewhere, namely, there are no black holes (e.g. someone's spending is someone else's income)"; debt for someone is a credit for someone else; flows imply stocks, e.g. a positive saving, which is a flow item, implies an increase in net wealth, a stock item; and stocks feedback on flows, for instance, higher debt (stock) implies higher future interest payments (flow).

In contrast to, CGE models, in which "deposits make loans", SFC models are based on observed reality which follows the post-Keynesian endogenous money approach which insists "loans make deposits". Godley and Lavoie (2012) noted, "SFC method guarantees that we will always be learning to live in a logically coherent world. And we are prepared to conjecture that, given that there are limits to the extent to which stock-flow ratios can change, the system dynamics of whole economies will pin down their overall behaviour in a way that can override the findings of econometrics as to the putative behaviour of bits and pieces".

The subsequent modelling methodology will build on Kaczynski and Juniper's (2023) extended abstract motivated by Piero Sraffa's pricing equations to construct a multi-sectoral model.

5. CONCLUSIONS

This study has aimed to review the national macroeconomic models used for assessing the impact of climate-change mitigation and related policies. The study critically assessed the roles of these macroeconomic E3 (Energy-Environment-Economy) models play in informing policy decisions in terms of their underlying mechanisms, theory, and philosophy. To this end, the study has discussed and identified the substantial differences between two major traditions: neoclassical CGE models and post-Keynesian based large-scale macro econometric models. These models are generally used in Australia and across the world by the major policy making authorities. There is little doubt the radical transformation of the global energy system required to achieve net-zero carbon emissions in 2050 hinges on a significant expansion in both public and private investment. Accordingly, the current suite of models has limited contribution to current policy debates, sitting, as they do, at odds with the observed reality. As such, there is a need for models which can accommodate these realities.

The study presented Stock-Flow Consistent (SFC) modelling as one possible and promising modelling tool which are more empirically grounded than the current toolbox of energy macroeconomic policy models. In contrast to CGE, these approaches allow imperfect markets, agents heterogeneity with high levels of individual and macro uncertainty and disequilibrium, bounded rationality instead of model consistent expectations, greater integration between real and financial sides of the economy and can accommodate interventions associated with the "challenge-oriented" policies advocated by progressive analysts across the nations.

A great deal of work will have to go into integrating the rudimentary sectors to be calibrated with Australian data. A series of policy scenarios will need to be prepared as well, of relevance to the current policy frameworks and instruments applied by governments. All these steps are likely to lead to further modification of the existing model. Accordingly, the subsequent study will identify some novel additional features that will be added to the framework.

ACKNOWLEDGEMENTS

This work has been benefitted from discussions and helpful comments of internal reviewers, Thomas Brinsmead, David Green, Paul Graham, James Foster whom we thank for their support. The authors also thank CSIRO Energy for funding and support. Responsibility for any errors or omissions lies with the authors.

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