Foundations for an Ecological Macroeconomics: literature review and model development

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Contribution to the Project

This milestone provides the foundation for the modelling work in WP205 which supports quantitative understandings of socio-economic transition towards sustainability.

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Beyond GDP, Ecological innovation, Economic strategy, Full employment growth path, Green jobs, Labour markets, Macroeconomic disequilibria, Market economy with adjectives, New technologies, Policy options, Social innovation, Socio-ecological transition, Sustainable growth, Wealth

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Abstract

This milestone provides a broad overview of model development under Work Package 205 of the WWWforEurope project. It describes briefly the challenge of modelling combined economic, ecological and financial systems and sets out a series of objectives for modelling the socio-economic transition towards sustainability. It highlights modelling needs in relation to full employment, financial stability, and social equity under conditions of constrained resource consumption and ecological limits. The paper also provides a broad overview of the literatures relevant to the task in hand. It then describes two separate modelling approaches, developed by two different teams within WWWforEurope. One of these approaches, led by WIFO, uses a Dynamic New Keynesian (DYNK) model to explore the implications of different long-run equilibrium paths for energy consumption. The other approach, led by Surrey in collaboration with York University, is motivated primarily by the desire to integrate a comprehensive model of the financial economy into a model of a (resource and emission-constrained) real economy. This paper sets out the overarching structure of each of these approaches. It discusses the similarities and differences between the two approaches and makes some proposals for the management of subsequent milestones in relation to WP 205.

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1   Introduction

The overall objective of WP205 is to develop models to support a quantitative understanding of the socio-economic transition towards sustainability. The aim of Milestone 38 is to provide an overview of the conceptual foundations for this work, to present some relevant background literature and to describe the development of the modelling work itself. Before engaging in that task, it is worth setting out something of the background to that development and the decisions that were taken in the process of achieving our objectives.

The WWWforEurope project is a large-scale collaborative project with a common interest in the socio-economic transition to sustainability. The WP205 partners consist of teams who had already, to one extent or another, developed or begun to develop individual modelling approaches. An early discussion amongst the partners led to a decision to continue to pursue these individual development paths, rather than to attempt to construct from scratch a single unified model.

The reasons for this decision were four-fold. Firstly, it was felt that with limited resources, more could be achieved by building on the existing accomplishments of the individual teams. Secondly, it was clear that there were substantial differences between modelling approaches amongst the teams, which would prove difficult to resolve in a limited time-frame. Thirdly, the demands of coordinating a common approach across three or four institutions would have overwhelmed the ability of the overall team to make progress in specific areas. Finally, it was felt that more could be learned by comparing different approaches than by attempting to force them together. From that point on, the individual teams followed their own development paths for the different approaches.

This paper offers an overview of the background and motivations for the task as a whole. It also provides a broad review of the literature relevant to the overall aim of developing an 'ecological macroeconomics'. The subsequent two sections then discuss two distinct modelling approaches, under development by two separate teams within the Consortium.

The first is a Dynamic New Keynesian (DYNK) model, led by WIFO, which uses a long-run equilibrium approach to explore consumer demand, the structure of industry and the evolution of energy paths. The second is an approach led by the University of Surrey (in collaboration with York University, Toronto) which uses a systems dynamics framework empirically grounded in the System of National Accounts to explore Stock Flow Consistent (SFC) financial models of the national economy subject to ecological and resource constraints.

The final section of the paper discusses the common aspects of these models as well as their main differences and makes proposals for the future development of the work.

2 Towards an Ecological Macroeconomics

A recent surge of interest in the development of an 'ecological macroeconomics' (Jackson 2009, Jackson and Victor 2010, Rezai et al 2012) speaks to several shortcomings of conventional economics. One of these shortcomings is the inability of conventional economics to integrate a coherent description of the financial economy into its models and policy prescriptions for the so-called 'real economy' (Keen 2011).[2]

The failure of almost all mainstream economists to foresee the global financial crisis of 2008/9 provides abundant evidence for this shortcoming (Bezemer 2010). Just a year before the onset of the great recession the then chairman of the U.S. Federal Reserve Ben Bernanke failed to foresee the financial crisis in a report presented to the U.S. House of Representatives (Bernanke, 2007). In his report he states that "the U.S. economy appears likely to expand at a moderate pace over the second half of 2007, with growth then strengthening a bit in 2008 to a rate close to the economy's underlying trend."

The IMF was similarly blindsided when in August 2007 it stated that "notwithstanding recent financial market nervousness, the global economy remains on track for continued robust growth in 2007 and 2008, although at a somewhat more moderate pace than 2006. Moreover, downside risks to the economic outlook seem less threatening than at the time of the September 2006 World Economic Outlook." (IMF, 2007).

The crisis revealed painfully that the apparent economic success of the 'great moderation'[3] was largely built on a growing fragility in the balance sheets of firms, households and nation states (Barwell and Burrows 2011, Koo 2011). But these risks remained invisible to most economists and unpredicted by the majority of economic models.

In the wake of the crisis, economists have therefore placed a renewed importance on the task of understanding the behaviour (and in particular the stability or instability) of the financial economy and integrating this understanding into the workings of the real economy. A host of new research initiatives and the re-emergence of some earlier schools of thought bears witness to this new turn in economics (Keen 2011, Minsky 1994, Turner 2013, Wray 2012). These new insights provide important foundations for prospective models of the transition to sustainability.

Paradoxically, the expansion in economic activity across most regions of the world over the last three to four decades has been at best ambivalent in terms of human wellbeing outcomes. Increases in economic output are highly correlated with increases in wellbeing in the poorest countries; but the impacts were less pronounced in more developed countries (Kubiszewski et al 2013, Victor 2008). Cross-sectional patterns in life expectancy, infant mortality, maternal morbidity, participation in education and even life-satisfaction all show diminishing returns as incomes rise (Jackson 2009, Layard 2005, Steinberger et al 2013) and there is evidence to suggest that the increased materialism which has accompanied economic growth also undermines wellbeing (Dittmar et al 2014, Pieters 2013).

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[2]   We use the term real economy here to describe the set of relationships that describe the production, and consumption of goods

[3]   The 'great moderation' refers to a period of economic history in which the volatility of business cycles decreased, recessionary pressures were largely averted and inflation was deemed to be tamed.

One important culprit for the diminishing returns to income in terms of wellbeing is a deepening of inequalities both within and between nations (Stiglitz 2013). In some of the richest countries across the world, overall increases in average per capita income have masked falling real wage levels and declining social investment, with both income and wealth increasingly concentrated in the top decile (OECD 2008).

At the same time there has been an improved understanding both of the mechanisms through which this inequality is created (Piketty 2014) and of the impacts it has on human wellbeing (Wilkinson and Pickett 2009). Ultimately, it is clear, prosperity for the few, achieved only at the expense of the many, cannot be regarded as sustainable. Modelling the transition to a sustainable economy must certainly make some attempt to account not just for total output but also for the distribution of incomes, wealth and wellbeing.

Perhaps the most notable shortcoming of traditional economic models, however, is their failure to account properly for the stocks and flows of natural resources on which economic activity ultimately depends. The period of the great moderation also witnessed a progressive decline in environmental quality across the world: in particular, in relation to global climate change, biodiversity loss, the deforestation and desertification of semi-arid regions, the eutrophication of water supplies and the over-exploitation of mineral resources (MEA 2005, MGI 2013, Rockström et al 2009, TEEB 2010, IPCC 2014, Wiedmann et al 2013). This limitation is well-rehearsed in the literature from ecological economics (Daly 1972, Meadows et al 1972, Costanza 1989, Daly 1996, Costanza et al 1997). But attempts to redress it have been partial at best.

One of the reasons for this is a fundamental dilemma which haunts debates about a sustainable economy. Conventional formulations for achieving prosperity rely on a continual expansion of consumer demand. More is deemed better in the received wisdom, even when the wellbeing outcomes from increasingly material lives are tenuous. Expanding consumer demand increases the global throughput of material goods and threatens the sustainability of the ecosystems on which prosperity depends. Continued growth of the kind seen hitherto is patently unsustainable.

On the other hand, slowing down, or reversing economic growth appears unpalatable too. Income growth is clearly still needed in the poorest countries at least, where it is highly correlated with real wellbeing outcomes. Even in the richest economies, growth in GDP is regarded as the single most important policy indicator of progress. When growth falters, as it did in the crisis of 2008/9 incomes fall, high-street spending is reduced and production output falls. Businesses have less to invest, governments have lower tax revenues, social investment is withdrawn, people lose their jobs and the economy begins to fall into a spiral of recession. In short, growth may be unsustainable, but de-growth appears to be unstable.[4]

Responding to the dilemma of remaining within ecological limits in a growth-based society has often been construed primarily as a microeconomic task — one that governments can address with conventional fiscal instruments of tax and subsidy. The 'external' costs associated with environmental and social factors should be 'internalized' in market prices, according to familiar axioms (Pigou 1920, Pearce et al 1989, Pearce and Turner 1990, Ekins 1992). Incorporating 'shadow prices' for environmental goods into market prices will send a clear signal to consumers and

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[4]   The growth dilemma is described in more detail in Jackson 2009, Chapter 3.

investors about the real costs of resource consumption and ecological damage, and incentivize investment in alternatives, according to this conventional wisdom.

But this prescription has been hard to implement over the last decades. This was in part due to the theoretical and practical problems of estimating shadow prices and implementing shadow markets (Victor 2008: 41-42). Even before the crisis, it proved difficult either to forge agreement on fiscal measures to internalize environmental costs or indeed to stimulate appropriate levels of private investment in alternative technologies. The financial crisis has certainly made both of these tasks harder. Despite an early focus on 'green stimulus' as a way of invigorating the global economy (DB 2008, GND 2008), subsequent policy responses have consistently failed to address the ecological challenges.

Fears of damaging economic growth have led politicians to shy away from both ecological taxation and green investment. In fact, fragile private and public sector balance sheets have slowed down investment in the real economy generally, let alone the additional (and less familiar) investment needed to make a transition to a low-carbon economy. Conventional responses have focussed instead on cutting public spending (austerity) and stimulating consumption growth (consumer spending) as the basis for economic recovery. Unfortunately, these responses tend to ignore the structural problems of the conventional paradigm and delay further the investment needed in the green economy.

The scale and nature of this dilemma suggest that the combined challenges of climate change and resource scarcity require macroeconomic as well as microeconomic responses. In fact, as several of the authors of this paper have argued elsewhere, there is a need to develop a fully consistent ecological macroeconomics in which it is possible to maintain financial stability, ensure high levels of employment, improve the distribution of income and wealth and yet remain within the ecological constraints and resource limits of a finite planet.[5]

There are several requirements (and challenges) for such a modelling approach. The remaining paragraphs in this section set out these challenges in more detail.

In the first place, it must be possible of course to integrate ecological and resource variables into the model. This can be achieved in various ways, ranging from simple parametrisation of resource and emission intensities, to the development of integrated assessment models which provide feedback into the economy as a result of ecological cost or resource price changes in the wider environment.

The approach taken in the two modelling exercises in this project use a fully-fledged macro-economic input output (IO) analysis to track not only the resource (eg energy) needs of different sectors, but also the emissions (eg carbon emissions) associated with economic activity. Scientifically-based emission targets (IPCC 2014 eg) can then be imposed exogenously on the model, and used to test the success of different scenarios.

Input-output models of national economies were first proposed by Wassily Leontief in the 1930s. Such models start from a set of inter-industry accounts that record the transactions among each

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[5]   For a summary of our arguments for an ecological macroeconomics, see for instance: Jackson, T 2009. *Prosperity without Growth*. (New York: Routledge); Victor, P 2008. *Managing without Growth*. Cheltenham: Edward Elgar.

industry (or sector) as well as the transactions between each sector and final consumers (i.e. households, investment in fixed capital, government expenditures on goods and services, and net exports). By assuming that the input requirements per unit of output for each sector are constant, the table of inter-industry accounts can be used to generate a predictive model of the economy.

The main appeal of input-output models lies in the comparatively high level of empirical detail that they provide for entire economies and the internal consistency that they maintain by virtue of the fact that they are derived from balanced tables of accounts. Conventional input-output models are typically used for estimating the direct, indirect and total output requirements of any actual or projected level of final demand.

In the late 1960s and early 1970s several economists, including Leontief, suggested ways in which input-output models could be used for analyzing various economic aspects of environmental pollution. Victor (1972) showed how input-output models could be extended systematically to include material flows to and from economies and the environment by applying the principle of materials balance. In this way, economies could be understood and modelled as sub-systems of the biosphere in which they are embedded. Victor developed the theoretical framework for this approach and produced the first estimates of the direct, indirect and total material flows (resource inputs and waste outputs) for a national economy. The approach has subsequently been adapted to explore a variety of environmental features of the economy, including: the 'carbon trade-balance' of a national economy (Proops et al 1993, Jackson et al 2007); the distribution of carbon emissions attributable to different socio-economic groups and expenditures (Druckman and Jackson 2009); and the extent of the rebound effect from efficiency savings (Druckman et al 2011).

The static input-output model has been developed in two different directions. One is the construction of fully fledged macroeconomic multi-sectoral models such as Barker (1976) and Barker and Peterson (1987) for the UK economy or the INFORUM (Inter-industry Forecasting and Modelling at the University of Maryland) model family, first described in Almon et.al. (1974). The other line of development consisted of large CGE models like the GREEN model of OECD (Burniaux, et.al., 1992; Lee, et.al., 1994). The situation in Europe during the decade after 1990 was characterized by the parallel development and application of the CGE model GEM-E3 (Conrad and Schmidt, 1998) and the EIO model E3ME (Barker, 1999, Barker, et.al., 1999). Both models integrated energy and emissions in the economic model (E3) and have been used for evaluation of energy tax policies and emission trading at the EU level in standardized simulations (for comparison of results see: Barker, 1999).

As a consequence of these parallel developments of very different models, there has been an ongoing discussion between the EIO- and the CGE-community focussing on the following issues: calibration vs. econometric estimation, the choice of functional forms in relation to the behavioural assumptions (economic rationality of agents), the role of equilibrium mechanisms and the benchmark year, as well as the meaning of time and the modelling of adjustment towards equilibrium.

One of the advantages of using an input-output structure is that this also allows the model to account systematically for employment at a sectoral level. Empirically derived employment intensities for production can be used to assess the induced employment implied by any particular composition of final demand.

Exploring the changing distribution of incomes and wealth requires an additional framework within the model. Segmenting populations into income classes allows the possibility to explore different distributions of income, different constitutions of final demand and different savings behaviours across income classes. Though it adds a degree of complexity to the model, and increases the challenge of empirical calibration, distributional aspects of the economy are receiving an increasing attention across economics and are clearly relevant to the challenge of sustainability (Stiglitz 2013, Wilkinson and Pickett 2009).

Piketty's work on income and wealth inequality highlights a potentially pernicious challenge for ecological macroeconomics. The dilemma of growth suggests that lower growth rates (perhaps even de-growth) will be essential to avoid over-exploitation of resources and the protection of ecological assets and services. Piketty (2014) argues that lower growth rates will tend to lead to a higher share of income going to capital, and an increasing inequality across the population. Being able to test for and if possible avoid such unsustainable outcomes has a heightened importance within an ecological macroeconomics.

Finally, a fully consistent ecological macroeconomics must be able to address questions of financial stability and instability. Arguably this is an important requirement for any form of macroeconomics, and one which was notably missing from conventional macroeconomics in the run-up to the financial crisis. Conventional equilibrium models are constructed around assumptions about rational economic agents, optimising their objective functions – consumption for households and profits for firms (Bezemer, 2009). Central banks use a certain type of equilibrium model known as a 'Dynamic Stochastic General Equilibrium Model' (or abbreviated DSGE) (Bezemer, 2010). However, these models were unsuccessful in predicting the global financial crisis.

One reason for the inability of neoclassical equilibrium models to predict the great recession is that the financial sector is not explicitly modelled. This means that the build-up in wealth and debt is not explicitly modelled in these models (Bezemer, 2010) such that the dependency of economic growth on continued accumulation of debt relative to GDP was not explicitly recognised. The economists who were able to foresee the recession were largely able to do so as a result of taking a more explicit approach to the modelling of the financial sector.

One of the more vocal economists to raise the alarm was Australian economist Steve Keen (1995, 2011). He went public with his prediction of financial crisis through his monthly debtwatch reports from 2006 to 2009 (Keen, 2009) and through media interviews (Keen, 2006). Veteran British economist, the late Wynne Godley, had also warned of impending balance sheet problems. One of the key elements within Godley's work is the principle of 'stock-flow consistent'(SFC) accounting, particularly as applied to monetary flows.

The over-arching axiom of this approach is that all monetary flows come from somewhere and go to somewhere. One agent's expenditure is another agent's income. One sectors asset is another sector's liability. Moreover changes in stocks of financial assets are consistently related to flows within and between economic sectors. These simple understandings lead to a set of accounting principles with implications for actors in both the real and financial economy which can be used to ground truth economic models and scenario predictions.

The origin of the SFC model is to be found in the work of Morris Copeland who applied a social accounting perspective to the study of money flows (Copeland, 1949). Copeland attempted to identify where money comes from in order to finance increases in national product, and where money goes when national product declines. These attempts laid the groundwork for a theoretical methodology capable of integrating real and financial flows of the economy. But it was to be several decades before SFC models found a firmer conceptual and theoretical basis, in particular through the ground-breaking work of Godley and his colleagues.

The SFC model is capable of analysing the economic impact of a variety of policies. For instance, Godley and Lavoie (2007) investigate the dynamics of the Eurozone by constructing a three country-two currency model, Izurieta (2003) investigate the impact of dollarization while Lavoie and Zhao (2010) analyse the impact of two scenarios of Chinese reserve diversification. In addition, Arestis and Sawyer (2012) use a SFC model to see how an economy reacts to fiscal, monetary or mixed policy, while Ryoo and Skott (2011) analyse the impact of fiscal policy on employment. The flexibility of the SFC model is best illustrated in Godley and Lavoie (2012) where nine models are described in detail ranging from a simple model with government money (chapter 3) to more advanced models such as an open economy model (chapter 6) and a model with private bank money, inventories and inflation (chapter 9).

As yet, little of the literature on stock flow consistency has been concerned with the ecological or social dimensions of economic activity. Moreover much of the literature in ecological economics has ignored the finer workings of financial markets, let alone the intricacies of stock-flow consistency. A key aim in the modelling work in WP205 is therefore to establish the relevance of stock flow consistent financial modelling as an invaluable element within the emerging work on ecological macroeconomics and to illustrate this relevance with some empirical examples.

In summary, the challenge of achieving a transition to a sustainable society, requires the development of a functional ecological macroeconomics, capable of articulating the links between the ecological sphere, the real economy and the financial economy. One of the aims of WP205 has been to develop some of the elements of such an approach. The two following sections describe two of these approaches in more detail.

3   A Dynamic New Keynesian Model

The model approach pursued by WIFO under the leadership of Prof Kurt Kratena can be characterized as a DYNK (DYnamic New Keynesian) model with rigidities and institutional frictions. In that aspect, the DYNK model bears some similarities with the DSGE (Dynamic Stochastic General Equilibrium) approach.

The model explicitly describes an adjustment path towards a long-run equilibrium. This feature of dynamic adjustment towards equilibrium is most developed in the consumption block and in the macroeconomic closure via a fixed short and long-term path for the public deficit.

The term 'New Keynesian' refers to the existence of a long-run full employment equilibrium, which will not be reached in the short run, due to institutional rigidities. These rigidities include liquidity constraints for consumers (deviation from the Permanent Income hypothesis), wage bargaining (deviation from the competitive labour market) and imperfect competition. Depending on the magnitude of the distance to the long-run equilibrium, the reaction of macroeconomic aggregates to policy shocks can differ substantially.

The model describes the inter-linkages between 59 industries as well as the consumption of five household income groups by 47 consumption categories. The model is closed by endogenizing parts of public expenditure in order to meet the mid-term stability program for public finances in EU member states. The DYNK model is an input-output model in the sense that it is demand driven: everything that is demanded is produced. The main differences between DYNK and static IO models refer to the following features (Kratena et al 2013, Kratena and Streicher 2014).

The price and the quantity side of the input-output model are linked in different ways, demand reacts to prices and the price of labor reacts to demand. This latter aspect represents the integration of factor markets (labour). The price block in the DYNK model is equally elaborated as in a CGE model, with user-specific prices and a proper account of margins, taxes less subsidies, and import shares that are different for each user.

A large part of the DYNK model has specifications similar to a dual CGE model, for example Conrad, Schmidt (1998) or Lofgren et al. (2002). The dual model is based on price and cost functions instead of production functions and therefore these models in a certain sense are also 'demand driven', especially if constant returns to scale do not allow for price setting on the supply side. In this kind of CGE model the supply side enters mainly via the following channels: (i) total factor productivity terms and other technical change components (bias of technical change), (ii) a CET (constant elasticity of transformation) function between domestic output and exports, and (iii) factor markets (labour and capital, sometimes land).

In the DYNK model, the treatment of demand is especially elaborated. That captures consumption, investment and exports (i.e. the main categories of final demand), which are endogenous, explained by consumer behavior (demand system), import demand functions (differentiated by intermediate and final use) and producer behavior (K,L,E,M model with M split up into domestic and imported). Therefore, the aggregates of the column of IO coefficients (total intermediates, energy goods, value added components) are endogenous and explained in the K,L,E,M model, whereas in the IO price model they are taken as exogenous.

While the DYNK approach shows several similarities with computable general equilibrium (CGE) models, it also deviates from specifications in CGE models in some important aspects. Output is demand driven and the supply side is represented with the help of a cost function that also comprises total factor productivity (TFP). The growth of TFP is the most important long-term supply side force in that sense in the DYNK model. Though a number of CGE models also apply the cost function approach, the supply side is then additionally represented by the CET (constant elasticity of transformation) function. In our approach, exports are also fully demand driven via foreign demand.

As described in Kratena and Streicher (2009), the differences between econometric IO modeling and CGE modeling have often been exaggerated and can be reduced to certain features in the macroeconomic closure rules. Econometrics vs. calibration cannot be seen as a main differentiation criterion (cf McKittrick 1998), as calibration is also based on econometric results. Therefore everything boils down to using recent and representative econometric results from the literature.

Summing up, we can identify several features, which allow for a differentiation of our approach from a dynamic CGE model, like the IGEM model for the U.S. economy (Jorgenson et al 2013) or the 'classical' GTAP model (Hertel and Tsigas, 1997). In the CGE model the price mechanism equilibrates supply and demand and iterative price changes bring about equilibrium in all markets. This equilibrium is in the static model defined by the reproduction of the base-year data. It is, however obvious that in general, the base-year data are not necessarily consistent with the concept of economic equilibrium in its strict sense. The notion of equilibrium in our DYNK approach is described by the interaction of goods and factor demands with supply that is determined under the restrictions given at factor markets. The latter are mainly represented by an exogenous benchmark interest rate and liquidity constraints, as far as the input of capital is concerned, and by the institution of union wage bargaining at industry level, as far as the input of labor is concerned.

Savings in the economy (domestic plus external) are not fixed by a fixed current account balance, but are determined in the buffer stock model of consumption, taking into account the wealth position of households. The public sector takes into account mid-term fiscal stabilization targets (for public net lending and public debt as percentage of GDP). The public sector budget constraint is applied by endogenizing public consumption, given the target path of net lending as a percentage of GDP.

The remainder of this section is organized as follows. The first subsection describes household behavior and private consumption. The second subsection deals with firm behavior and the production structure, as well as prices. The third subsection wraps up the remaining model blocks: the labour market, the government sector including model closure and the environmental features.

3.1 Household behaviour and private consumption

The consumption decision of households in the DYNK model is modeled along the lines of the 'buffer stock model' of consumption (Carroll, 1997), including consumption of durables and nondurables (Luengo-Prado, 2006). Consumers maximize the present discounted value of expected utility from consumption of nondurable commodity and from the service provided by the stocks of durable commodity. The budget constraint in this model without adjustment costs for the durables stock contains income, assets and the durable stock. This latter aspect differentiates this model from the

traditional dynamic optimization models of consumption. The derivation of disposable household income takes into account that profit income is a consequence of past savings decisions as well as all the interactions between households and the public sector (taxes and transfers). For policy analysis, unemployment benefit transfers are dealt with separately. The following taxes are charged on household income: social security contributions, which can be further decomposed into an employee and an employer's tax rate and income taxes. Wage income of households is determined by total hours demanded by firms and wage bargaining between firms and unions over the employee's gross wage.

Financial assets of households are built up by saving after durable purchasing has been financed. Part of the durable stock needs to be held as equity. The consideration of this collateralized constraint is operationalized in a down payment requirement parameter, which represents the fraction of durables purchases that a household is not allowed to finance.

Luengo-Prado (2006) has shown that though the model has no analytical solution, it can be used to derive policy functions for nondurable and durable consumption and formulate both as functions of the difference between cash on hand (the household's total resources) and the equity that the consumer wants to hold in the next period. A non-linear consumption function for durables, similar to the function described in Luengo-Prado and Sørensen (2004) for nondurables, is assumed, stating that consumers seek for an equilibrium relationship of durables per household. Therefore, with higher levels of durables per households, the marginal propensity of investment in durables, with respect to cash on hand decreases.

The demand function for total nondurable consumption is modeled with a positive marginal propensity of nondurable consumption to 'cash on hand' and a negative marginal propensity of total nondurable consumption to the product of the down payment (in percentage of durables) and durable demand.

The energy demand of households comprises fuel for transport, electricity and heating. These demands are part of total nondurable consumption and are modeled in single equations, therefore assuming separability from non-energy nondurable consumption. According to the literature on the rebound effect (e.g.: Khazzoom, 1989), the energy demand is modeled as (nominal) service demand and the service aspect is taken into account by dealing with service prices. The durable stock of households (vehicles, houses, appliances) embodies the efficiency of converting an energy flow into a service level linked by the efficiency parameter of converting the corresponding fuel into a certain service. For a given conversion efficiency, a service price can be derived, which is a function of the energy price and the efficiency parameter. Any increase in efficiency leads to a decrease in the service price and thereby to an increase in service demand ('rebound effect').

The non-energy demand of nondurables is treated in a demand system. The one applied in this DYNK model is the Almost Ideal Demand System (AIDS), see: Deaton and Muellbauer, (1980) . The AIDS model is represented by budget share equations for the *i* nondurable goods in each period.

The commodity classification *i* = 1...*n* in this model comprises the *n* non-energy nondurables:

(i) food, and beverages, tobacco, (ii) clothing, and footwear, (iii) furniture and household equipment, (iv) health, (v) communication, (vi) recreation and accommodation, (vii) financial services, and (viii) other commodities and services.

The household model described determines in three stages the demand for different categories of durables, energy demand and different categories of nondurables. The total consumption vector of categories of consumption in National Accounts (according to the COICOP classification), is transformed into a consumption vector by commodities of the input-output core in the DYNK model in purchaser prices, by applying the consumption bridge matrix. After this conversion, in a first step, taxes less subsidies are subtracted in order to arrive at consumption vectors net of taxes. Tax policies which imply taxation of commodities (also environmental consumption taxes) can be implemented at this stage.

3.2   Firm behaviour and production structure

The production side in the DYNK model is analysed within the cost and factor demand function framework, i.e. the dual model, in a Translog specification. The representative producers in each industry all face a unit cost function with constant returns to scale that determines the output price (unit cost), for given input prices. The input quantities follow from the factor demand functions, once all prices are determined. The Translog specification chosen in the DYNK model comprises different components of technological change. Autonomous technical change can be found for all input factors (i.e. the factor biases) and also as the driver of TFP (total factor productivity), measured by a linear and a quadratic component. The Translog model is set up with inputs of capital (K), labor (L), energy (E), imported (M^m) and domestic non-energy materials (M^d), and their corresponding input prices p_K, p_L, p_E, p_{Mm} and p_{Md}.

Applying Shepard's Lemma yields the cost share equations in the Translog case, which in turn are used to derive the quantities of factor demand for (K), (L), (E), (M^m) and (M^d). For this production system the input prices can be viewed as exogenous. One part of the input prices is determined in national or global factor markets, which applies to the prices of (K), (L), and (E). The price of labour is determined in the labour market via wage functions by industry (see below). The price of capital is formulated as a simple static user cost price index with the following components: (i) the price of investment by industry, (ii) the smoothed interest rate, and (iii) the fixed depreciation rate. The financial market and monetary policy are not described in detail in the DYNK model, therefore the interest rate is assumed as exogenous and is approximated by the smoothed benchmark interest rate. The depreciation rate by industry is fixed and the price of investment by industry is endogenously derived from the price system in the DYNK model. The price of energy carriers is assumed to be determined in world markets for energy and is therefore treated as exogenous.

The factors E, M^m, and M^d are aggregates of the use matrix from the supply and use table system, which is the framework of this DYNK model. The aggregate E comprises four energy industries/commodities, and M^m, M^d the other 55 non-energy industries/commodities. In a second nest, the factor E is split up into aggregate categories of energy (coal, oil, gas, renewable,

electricity/heat) in a Translog model. This set of energy categories is directly linked to the energy commodities/industries of the use table.

3.3   Other model blocks

The main factor market that has important repercussions in the case of policy simulations in the DYNK model is the labour market. In CGE modeling, different labour market approaches can be integrated (Boeters and Savard, 2013) and calibrated. In this exercise, the theoretical approaches need to be confronted with the results from empirical wage curve estimation, which can be seen as a robust empirical relationship (Card, 1995 and Blanchower and Oswald, 1994). The wage curves in the DYNK model are specified as the employee's gross wage rate per hour by industry. The labour price (index) of the Translog model is then defined by adding the employers' social security contribution to that. Combining the *meta-analysis* of Folmer (2009) on the empirical wage curve literature with a basic wage bargaining model from Boeters and Savard (2013) gives a base specification for the sectoral hourly wages. These functions describe the responsiveness of hourly wages to labour productivity (industry, aggregate), consumer prices, hours worked per employee, and the rate of unemployment. The inclusion of the variable ' hours worked per employee' corresponds to a bargaining model, where firms and workers (or unions) bargain over wages and hours worked simultaneously (Busl and Seymen, 2013). The basic idea is that the gains in labour productivity can be used for cutting hours worked and wage increases simultaneously. We specify the wage function in a way that the hours can be determined in a first step and then the hourly wage rate is determined. A bargaining over hours that leads to less hours worked per employee increases the hourly wage rate, so income per year does not fall in the proportional amount of working time reduction. The parameter estimated for labour productivity is conditional on this impact of working time on hourly wages.

An important aspect of the wage curve is the term that considers the unemployment elasticity of the wage rate. In the DYNK model this is specified in terms of the difference to the equilibrium rate, measured in that case as the minimum rate in the sample used for estimation. The estimation of the corresponding parameter yields the same result as the parameter of the unemployment rate elasticity in the traditional wage curve, because all the variance in the term stems from changes in the unemployment rate. The specification of the unemployment term as a gap to full employment yields a NAWRU characteristic: wage inflation increases with approximation to full employment.

Labour supply is given by age and gender specific participation rates of age groups of the population at working age (16-65) and evolves over time according to demographic change (age group composition) and logistic trends of the participation rates. Therefore, labour supply does not react endogenously to policy shocks. Unemployed persons are the difference between labour supply and employment, for given hours worked per person.

The public sector balances close the model and show the main interactions between households, firms and the general government. As we put special emphasis on labour market policies, unemployment benefits are separated from the other social expenditure categories. Taxes from households and firms are endogenized via tax rates and the path of the deficit per GDP share according to the EU stability programs is included as a restriction.

Wage income of households is taxed with social security contributions and wage income plus operating surplus accruing to households are taxed with income taxes. Additionally, households' gross profit income is also taxed. Taxes less subsidies are not only levied on private consumption, but also on the other final demand components in purchaser prices as well as on gross output. The expenditure side of government is made up of unemployment transfers and other transfers to households, public investment and public consumption. Additionally, the government pays interest on the stock of public debt. The change in this public debt is equal to negative government net lending.

In this specification, tax revenues and unemployment benefits are endogenous and can from a policy perspective be influenced by changing tax rates or the unemployment benefit replacement rate. The model is closed by further introducing a public budget constraint, specified via the stability program for public finances of each EU member state that defines the future path of government net lending to GDP.

The results of the second nest in production (energy) for energy demand (coal, oil, gas, renewable, electricity/heat) is split into 20 energy categories and the converted into physical units of energy by applying detailed prices. These physical quantities of energy are the base for the derivation of GHG emissions by industries as well as by the household sector.

4   A Stock-Flow Consistent System Dynamics Framework

The modelling approach pursued by Surrey builds on an on-going project led by Prof Tim Jackson and Prof Peter Victor (York University, Toronto). Working together over the last four years, Jackson and Victor have begun to develop a stock-flow consistent (SFC) ecological macro-economics. The broad approach has several distinct features.

In the first place, it draws together three primary spheres of modelling interest and explores the interactions between them. These spheres are: 1) the ecological and resource constraints on economic activity; 2) a full account of production, consumption, employment and public finances in the 'real economy' at the level of the nation state; 3) a comprehensive account of the money economy, including the main interactions between financial agents, and the creation, flow and destruction of the money supply itself. Interactions within and between these spheres of interest are modelled, using a system dynamics framework.[6]

Systems modelling has a long pedigree within ecological economics, stemming most notably from the work of Jay Forrester and the Club of Rome's ground-breaking *Limits to Growth* report (Meadows et al 1972). In the context of this research, it offers a number of advantages. Most obviously, the structural form of systems dynamics employs a consistent understanding of stocks and flows, and the relationship between them. It is therefore well-suited to capturing the importance of stocks and flows in all three spheres of interest in this exercise. Systems dynamics is particularly useful in exploring scenario development over time. It allows considerable user-interaction in the specification of exogenous variables and facilitates a collaborative (visual) understanding of both the model structure and the scenario results (van den Belt 2004).

A further key feature of the Surrey approach is the focus of attention on the individual nation state. A premise of the work is that the 'dilemma of growth' has particular ramifications for national policy and is best explored at that level. The growth of GDP or national income in a particular country is not just a significant policy indicator in its own right, it is also a measure of production output and consumption possibilities, as well as being related to a country's ability to provide citizens with work, finance its social investment, and compete in global markets. Admittedly, all of these questions could also be (and often are) asked at supra-national or sub-national level. Since the development of a unified System of National Accounts (UN 1993, 2008), however, the most comprehensive, reliable and consistent data sets tend to be available at country and national level.

Finally, in addition to ideas and frameworks that have a long pedigree in ecological economics (such as system dynamics) Jackson and Victor have drawn substantially on insights adopted recently by post-Keynesian economics and modern theory and in particular the approach known as Stock-Flow Consistent macro-economics, pioneered by Copeland (1949) and developed extensively by Godley and Lavoie (2007). From these foundations and starting points, two somewhat distinct models have so far been constructed, and are currently being calibrated against National Accounts data from the UK and from Canada.

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[6]   The primary modelling platform used by the research team is a system dynamics platform known as STELLA. Data collation organised in Excel and econometric calibration is carried out in Eviews.

The Green Economy Macro-Model and Accounts framework (GEMMA) is a systems dynamics input-output model incorporating 12 industry sectors (and the interactions between them) and six 'accounting sectors'. Early results from GEMMA were reported during the Rio Summit in June 2012. It was possible to establish simple scenarios for the decarbonisation of the economy, with and without de-growth, and to explore the implications of these scenarios for employment, public debt, and sector balance sheets. Comprehensive materials, energy and emission databases have now been compiled (and estimated) at 12-sector level for eventual use in the model.

Though it includes a comprehensive division of the economy and an accounting framework which imposes stock-flow consistency on monetary flows, the GEMMA framework so far lacks a full articulation of the SFC approach of post-Keynesian economics and modern money theory.

To explore the financial elements of the economy more thoroughly, Jackson and Victor developed what is currently a separate systems dynamics model. Financial Assets and Liabilities in a Stock and Flow consistent Framework (FALSTAFF) contains a simplified version of the real economy. The real economy in FALSTAFF consists of only one sector defined in terms of the national economy and simple import-export trade relationship with the rest of the world. However, it creates more detail in the financial relationships within and between sectors than GEMMA, and is able to simulate and report the key accounting identities of SFC theory. Early results from FALSTAFF were presented at the Canadian Ecological Economics Conference in Toronto in November 2013.

The following subsections in this report provide more detail on the various components of GEMMA and FALSTAFF and set out a programme for further development in the context of WWWforEurope and beyond.

4.1   Real Economy in FALSTAFF and GEMMA

GEMMA and FALSTAFF are essentially both demand-driven system dynamic simulation models. Both are constructed on the systems-modelling platform STELLA and both are calibrated to 2012 data in financial flows and end 2011 data in financial stocks. Household demand is driven in both models by an econometrically estimated consumption function C (based on the specification in Godley and Lavoie 2007) of the form:

$$C_t = \alpha_1 . Yd_t + \alpha_2 . NW_{t-1} \qquad\qquad 1)$$

where Yd_t is expected disposable income at time t, NW is the net worth of households at time t-1 and $\alpha_{1,2}$ are econometrically estimated coefficients. Currently both GEMMA and FALSTAFF have a single consumption function for all households. Work is ongoing to estimate this consumption function for separate income groups.

Overall demand is constructed in both models according to the conventional national accounts identity:

$$Y = C + G + I + X - M + IC \qquad\qquad 2)$$

Where I is investment (gross fixed capital formation), G is government spending, X-M is net exports and IC is inventory change. Government spending G is modelled exogenously in both models.[7]

Production, investment and employment are currently estimated differently in the two models. FALSTAFF employs a simple demand driven assumption for domestic output based on domestic demand (net of the trade balance). Employment is accounted for in FALSTAFF through an econometrically estimated labour productivity function. Investment is estimated with a capital accumulation rate g which is deemed to be dependent on an exogenous constant factor associated with 'animal spirits' (Lavoie and Godley 2001), the rate of cashflow (calculated from the ratio of retained earnings to capital), the rate of interest on business loans (moderated by a leverage ratio), Tobin's q ratio[8] and the rate of capacity utilisation.

Broadly speaking, investment in FALSTAFF is expected to increase with increasing cash flow, to decline with increasing interest rates, to rise as Tobin's q rises (because the value of equity is high in relation to capital), and to increase with the capacity utilisation rate. This last factor reflects the impact of rising demand on investment. As demand rises, spare capacity diminishes, encouraging new investment.

By contrast, investment I_j for each sector in GEMMA is currently estimated on the basis of a simple accelerator model of the form:

$$I_j = \gamma.(K^T_j - (1-\delta_j).K_j) \tag{3}$$

Where K_j is the actual capital stock, K^T_j is the target capital stock and δ_j is the depreciation rate on capital for sector j. GEMMA distinguishes between two types of capital stock: 1) buildings and infrastructure; 2) machinery and equipment, each of which is expected to have different characteristics in terms of depreciation rate and accelerator coefficient γ.

Induced employment from any given vector of final demand is derived from sector specific employment coefficients via the input-output framework. GEMMA also contains a differentiated green investment model which is currently calibrated against reductions in greenhouse gas emissions from estimates of national abatement costs. An exogenous adjustment allows for different assumptions about the productivity of this investment.

The principal feature distinguishing the representation of the real economy in GEMMA from that in FALSTAFF is the use of a 12-sector input-output model in GEMMA to estimate total production output, simulate interactions between industry sectors, and estimate the labour requirements, resource requirements and emissions associated with final demand. The IO model is calibrated using data from the OECD input output accounts supplemented by data from the system of national accounts data in respective case study countries (the Office for National Statistics in the UK and CANSIM in Canada).

The OECD publishes input-output tables for its member countries in a standardized format of 37 input-output sectors, 8 categories of final demand, 2 categories of value added and 2 categories of

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[7] GEMMA includes an endogenous correction to government spending in the event that the government debt rises above or falls below a certain level.

[8] Tobin's q measures the ratio of the value of equity to the value of the capital stock,

taxes and subsidies. (OECD, 2013) Input-output tables are available online for OECD member countries for the mid-1990s, the early 2000s and the mid 2000s.[9] Figure 1 shows a simplified schematic for this framework (with 8 rather than 12 sectors shown).

| | | INTERMEDIATE DEMAND | | | | | | | | FINAL DEMAND | | | | |
		Agric	Mining	Constr	Manuf	Trade	Transp	Services	Other	Personal Consumption Expenditure	Gross Domestic Investment	Govt Purchases of Goods & Services	Net Exports of Goods and Services	Total
PRODUCERS	Agriculture													
	Mining													
	Construction													
	Manufacturing													
	Trade													
	Transportation													
	Services													
	Other													
VALUE ADDED	Government	Indirect business taxes less subsidies								GROSS DOMESTIC PRODUCT				
	Employees	Employee compensation												
	Business owners and capital	Profit and capital consumption allowances												
	Total													

Figure1: Simplified Input-Output Table
Source: adapted from Miller and Blair (2009) p. 3

Demographic changes are also handled separately in GEMMA and FALSTAFF. FALSTAFF includes a simple exogenous population growth factor. For GEMMA we have developed a more sophisticated demographic model which accounts for different possible assumptions about birthrate, death-rate, immigration, emigration and gender balance. When fully integrated into the GEMMA framework, the demographic module will allow for an estimation of workforce dependencies and dependency ratios, an exploration of housing demand and a fuller examination of the needs for pension savings and other welfare functions.

4.2   *Ecological and resource accounting in FALSTAFF and GEMMA*

As indicated above, the IO framework in Gemma allows for an estimation of the resource requirements associated with any given matrix of final demand. The broad framework for this approach is now well-known (Leontief 1966, Victor 1972, Proops et al 1993, Jackson et al 2007, Victor and Jackson 2013). The basic form for an environmentally extended input-output model can be described in a straightforward manner as follows. The output **x** associated with a given final demand **y** can be described by:

$$\mathbf{x} = \mathbf{A.x} + \mathbf{y} \qquad\qquad 4)$$

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[9]   The actual year depends on the country. Not all countries publish annual input-output tables.

where **A** is an inter-industry matrix of intermediate demands with components a_{ij} – equal to the demand by sector j for goods produced from sector i. In the familiar Leontief form (Millar and Blair 2009), the Input Output equation is written as:

$$x = (1 - A)^{-1}.y \qquad\qquad 5)$$

(with **1** as the identity matrix), allowing the model to solve for **x** given any final demand **y**. This structure can also be used to identify the environmental impacts or to compute the labour requirements associated with final demand **y**. So for example, the greenhouse emissions g_i associated with each final demand sector i is described by a vector **g** given by:

$$g = \hat{u}.X = \hat{u}.(1 - A)^{-1}.y \qquad\qquad 6)$$

where **û** is a diagonalised matrix of the direct greenhouse gas intensities: $\hat{u}_{ii}$ is the emissions per unit of output for IO sector i in the economy and $\hat{u}_{ij} = 0$ for $i \neq j$. Similarly, to derive a vector **e** describing the direct and indirect employment attributable to each final demand sector, we can write:

$$e = \hat{w}.x = \hat{w}.(1 - A)^{-1}.y \qquad\qquad \mathbf{7)}$$

where **ŵ** is a diagonalised matrix of the direct employment intensities: $\hat{w}_{ii}$ is the number of people employed per unit of output for each sector i in the domestic economy and $\hat{w}_{ij} = 0$ for $i \neq j$. It should be noted that **g** and **e** refer to the greenhouse gas emissions and employment (respectively) associated with the output **x** from domestic production facilities. Neither the emissions nor the labour associated with overseas production needed to meet domestic final consumption are included in these calculations. Adjusted calculations can be made to exclude that part of domestic production relating to exports and include emissions and employment related to imports.
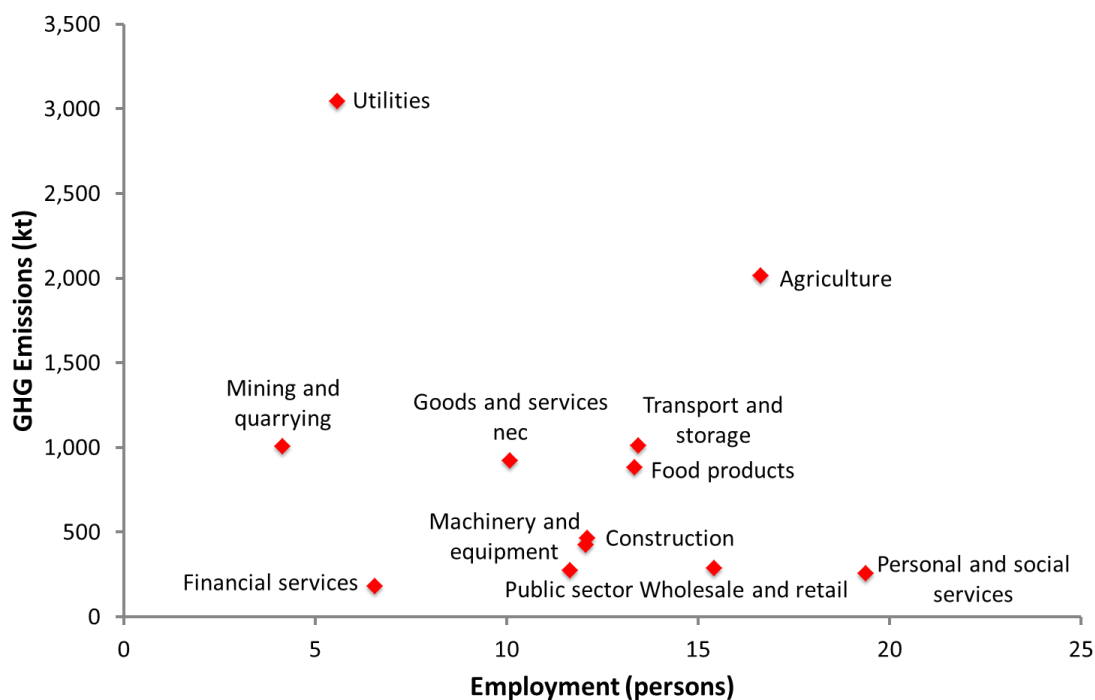

Figure 2: Employment intensities vs Greenhouse gas emissions per $m final demand in 2010
Source: output from the IO module in GEMMA.

These estimates can be used to examine the implications for greenhouse gas emissions and employment of changes in the pattern of final demand, subject to caveats regarding the stability of the input-output relationships over time. Furthermore, the impact of green investment on the direct emissions of greenhouse gases from each sector would also have to be accounted when using these results to explore longer-term possibilities. Figure 2 illustrates how this methodology can be used to explore the relative employment and greenhouse gas intensities of different industry sectors. These differences can in principle be exploited as part of a strategy aimed at maximising employment while minimising greenhouse gas emissions (Jackson and Victor 2011).

4.3 Monetary Flows and the Financial Economy in FALSTAFF and GEMMA

A common feature of both GEMMA and FALSTAFF is the attempt to integrate a comprehensive model not just of the financial sector of the economy, but of the financial economy itself – taking into account the monetary flows between accounting sectors, the accumulation of flows in the assets and liabilities of different accounting sectors and a creation and destruction of the money supply itself.

These features are currently more fully developed in FALSTAFF than in GEMMA. In particular FALSTAFF contains an econometrically-calibrated Portfolio Allocation Module which estimates the allocation of household net savings to financial assets and liabilities. FALSTAFF also contains a better articulation of the relationship between the central bank and other financial institutions, and is able to simulate social and financial sector innovations such as an increase in the reserve requirement.

As discussed in Section 2, the stock-flow consistent (SFC) approach to macroeconomic modelling was developed mainly by Godley and his collaborators and has more recently been employed as the basis for modern monetary theory (Godley and Lavoie 2007, Wray 2012). The basic principle of SFC models[10] is to construct a consistent and exhaustive map of all monetary flows within the national economy. This means that within every SFC model the expenditure within a given sector of an economy is fully reflected as income in other sectors, while conversely an income within a given sector of an economy is represented as expenditure in other sectors. This accounting approach to money flows within an economy is illustrated in Table 1.[11]

It will be noticed that the production firms account is split into a current account, where revenue and costs are settled, and a capital account where the funds for investment reside. In GEMMA and FALSTAFF this split between current and capital account is extended also to financial firms (banks) to the Central Bank and to the Rest of the World sector.

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[10]   SFC models are also sometimes referred to as 'accounting' or 'flow-of-funds' models,

[11]   Table 1 includes only four sectors of the economy: households, production firms, banks and government. The accounts structure in both GEMMA and FALSTAFF includes two additional sectors – the Central Bank and a Rest of the World sector to map the trade positions of the national economy with respect to overseas trading partners.

The transaction matrix incorporates an account of the incomes and expenditures in the national economy, reflecting directly the structure of the system of national accounts. Thus the first six rows in Table one illustrate the flow accounts of each sector. In terms of the household sector, it can be seen that households receive money in the form of wages and distributed profits from production firms, while spending money on consumption and taxes. Note also that the five non-trivial rows of column 2 present a simplified form of the conventional GDP accounting identity:

$$C + G + I = GDP_e = GDP_i = W + P \qquad\qquad 8)$$

where GDP_e represents the expenditure-based formulation of the GDP and GDP_i represents the income based GDP formulation.

	Households (1)	Production Firms		Banks (4)	Gov't (5)	Σ
		Current (2)	Capital (3)			
Consumption	-C	+C				0
Investment		+I	-I			0
Gov't expenditures		+G			-G	0
Wages (W)	+W	-W				0
Profits (P)	$+PD_f$	$-P_f$	$+PU_f$			0
Taxes-transfers (T)	-T				+T	0
Change in loans (L)			$+\Delta L_f$	-ΔL		0
Change in deposits (D)	-ΔD			+ΔD		0
Change in bonds (B)	$-\Delta B_h$			$-\Delta B_b$	+ΔB	0
Change in equities (E)	$-\Delta e \cdot p_e$		$+\Delta e \cdot p_e$			0
Σ	0	0	0	0	0	0

Table 1: Illustrative Transaction Matrix for a Closed Economy
Source: Adapted from Godley and Lavoie (2012)

The bottom five rows of the table represent the transactions in financial assets and liabilities between sectors. So for example the net savings of the households sector (the sum of rows 1 to 6) are distributed amongst four different kinds of financial assets in this illustration: deposits, government bonds and equities. Note that this Table is for illustrative purposes only. Actual allocations in FALSTAFF and GEMMA include other options, including the taking of loans by households. The allocation of household assets and liabilities in FALSTAFF is described in more detail below. One of the key financial axioms illustrated in this Table is that the sum of all financial assets

and liabilities in the economy is zero. The only net assets are non-financial, derived from fixed (and non-produced) capital.

A key feature of the transaction matrix, indeed the core principle at the heart of SFC modelling is that each of the rows and each of the columns must always sum to zero. If the model is correctly constructed, these zero balances should not change over time as the simulation progress. The accounting identities shown in Table 1 therefore allow for a consistency check, to ensure that the simulations actually represent possible states of the monetary economy.

Associated with the transactions illustrated in the bottom five rows of Table 1 are changes in the balance sheet of the economy. For each transaction in financial assets between two sectors of the economy there is an associated change in the balance sheet of the same two sectors. For instance, a decision by the household sector to increase deposits at banks will increase the deposit assets of households while simultaneously increasing deposit liabilities at banks.

The balance sheet of an economy (Table 2 below) may be thought of as providing a record of all previous transactions upon which the transactions in the current period are added. Changes in the balance sheet from the end of period t-1 to the end of period t are therefore the result of transactions occurring in period t (typically balance sheets are constructed at yearly intervals). This relationship between financial flows and the changes in the stocks of assets and liabilities is what gives the name stock flow consistency to this type of model.

	Households	Production firms	Banks	Gov't	Σ
Loans		$-L$	$+L$		0
Deposits (D)	$+D$		$-D$		0
Bonds (B)	$+B_h$		$+B_b$	$-B$	0
Equities (E)	$+e \cdot p_e$	$-e_f \cdot p_e$	$-e_b \cdot p_e$		0
Fixed capital (K)	$+K_h$	$+K_f$			$+K$
Sum (net worth)	NW_h	NW_f	NW_b	NW_g	K

Table 2: Illustrative Balance Sheet Matrix for a Closed Economy
Source: adapted from Godley and Lavoie (2012)

A key element in the establishment of stock flow consistent monetary flows is the need to model the portfolio allocation decision of households. These decisions have been modelled in FALSTAFF using an econometrically estimated Portfolio Allocation Module based on a framework originally developed by Brainard and Tobin (1968) – part of the work for which Tobin later received a Nobel prize. The approach was later adopted (and adapted) by Godley and Lavoie (2007) as a key element within a post-Keynesian SFC approach.

The broad thrust of the approach is to suppose that the desired holdings of a particular asset depend both on the rate of return on that asset and also on the rates of return (or interest rates) on other

assets (or liabilities). So for example, if the rates of return on equities rise, households would be expected to allocate more of their savings to equities than say government bonds. Conversely if the return on equity falls (or is expected to fall), households would tend to sell equities in favour of some other asset.

For each asset (liability) A_i, the desired proportion A_i^* is therefore given by:

$$A_i^* = \lambda_{i0} + \Sigma_j \lambda_{ij}^* r_j + \lambda_{iY}^* Yd/NW \qquad \qquad 9)$$

where r_j are the rates of return (or interest) on the various assets (or liabilities) and the λ_{ij} are constant coefficients, to be derived from a (constrained) econometric analysis of past trends.[12]

FALSTAFF's Portfolio Allocation Module estimates the portfolio allocation behaviour of households with respect to seven distinct asset/liability classes: deposits, bonds, equities, housing wealth, mortgages, loans and pensions. Balance sheet data for the Portfolio Allocation Module were obtained from the OECD balance sheets, supplemented where necessary from country-specific data. After some experimentation our estimation technique differs slightly from that shown in equation 6). Statistical estimation showed a high degree of dependency on the first lag of A_i, ie, it seems as though people's portfolio allocations are relatively sticky on aggregate. Consequently, a better fit to historical data was obtained by estimating (subject to constraints) the equation:

$$A_i^* = \lambda_{i0} + \Sigma_j \lambda_{ij}^* r_j + \lambda_{iY}^* Yd/NW + \lambda_{iA} A_{i(t-1)} \qquad \qquad 10)$$

The model in this form was relatively successful in replicating historical trends in the holdings of different asset types. Figure 3 illustrates for example the estimated and actual holdings of equities by households in Canada between 1991 and 2013. In particular it is to be noted that the model successfully predicts both the impact of the financial crisis on equity holdings and also the subsequent recovery as well as the results of the earlier dot.com bubble and subsequent market fall. This is an important validation of the model's ability to reflect financial stability and instability – a core goal of our approach.

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[12]   In order for this procedure to work correctly, it should be noted that liabilities (mortgages and loans) must be counted in a negative sense within the framework.
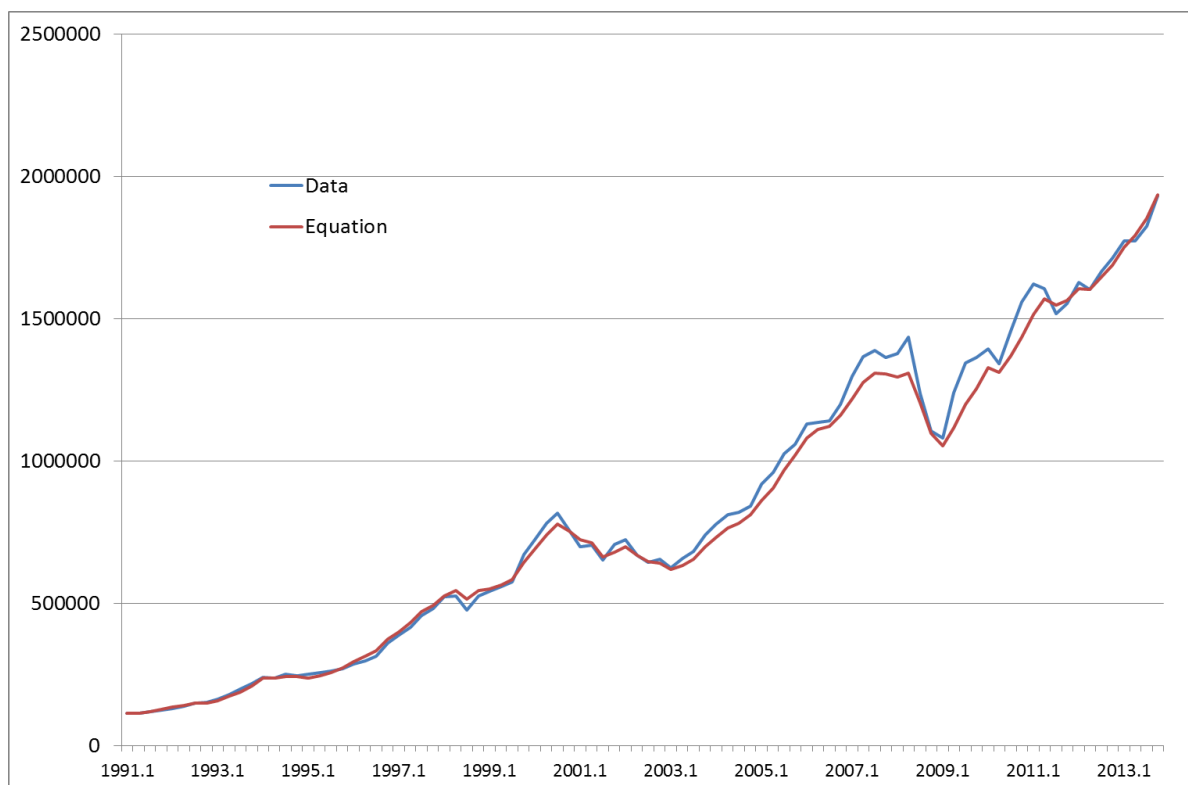
Figure 3: Estimated and actual holdings of equities by Canadian households 1991 – 2013
Source: output from the Portfolio Allocation Module in FALSTAFF.

Summary of current and future development of FALSTAFF/GEMMA

It is important to note again here that the development of GEMMA and FALSTAFF constitutes a long-standing project developed by Profs Jackson and Victor over a period of more than four years. Resources for development under WP205 of the WWWforEurope project have been limited.

Specifically, they have enabled the appointment of a research assistant (Dr Ben Drake) who has been in place only since September 2013 and will contribute in total 2 researcher years to the project. Dr Drake's main responsibilities have been to update the data collated from National Accounts data for the UK and Canada and to assist in some of the econometric estimation. In addition he has contributed to an earlier milestone (MS 33) on transition policy and to the literature review for this milestone.

The bulk of the development of both GEMMA and FALSTAFF lies outside the funded research time at Surrey from WWWforEurope and the possibilities for developing the work further under WWWforEurope are somewhat limited by the remaining researcher time (around 15 months) on the project. Nonetheless, considerable progress is likely to be possible as a result of the additional resources brought to bear through the inputs of Profs Jackson and Victor, a PhD student funded via another project and the possibility to appoint other researchers to work on the model development in the course of time.

The main priorities for the next period of model development are as follows:

1) To complete the development, calibration and consistency checking of FALSTAFF for the UK and Canadian economies, including further calibration of the Portfolio Allocation Module;

2) To complete a reference scenario for FALSTAFF including realistic assumptions about the uptake of green investment possibilities;

3) To develop a range of alternative scenarios for FALSTAFF to test in particular the impact of enhanced levels of green investment, a shift from products to services and the effect of different savings rates, and tax regimes; these scenarios will also test for changes in monetary policy including potentially a shift in the role of the sovereign state in the creation of the money supply;

4) To expand the range of countries for which FALSTAFF is calibrated to include at least one further European country;

5) To enable the disaggregation of industry sectors within FALSTAFF by importing carbon and employment 'multipliers' from GEMMA to establish a quasi input-output capability in FALSTAFF;

6) To integrate the relative advantages of FALSTAFF and GEMMA into a single consistent modelling framework (GEMMA+) with full IO capability, the ability to report on a variety of environmental and resource balances and a comprehensive SFC model of the financial economy.

7) To develop the data set required for this expanded model for at least one other EU nation.

8) To develop a reference scenario for GEMMA+ to include realistic assumptions about the uptake of green investment possibilities and the likelihood of shifts in the structure of industry;

9) To develop a range of alternative scenarios for GEMMA to test the impact of enhanced green investment, a shift from products to services, and the effects of different savings rates, tax regimes and monetary policy.

10) To expand the capability of the modelling framework to address the distribution of incomes and of wealth.

5   Concluding Discussion

This paper has provided a broad review of the development of quantitative macroeconomic models relevant to WP205. It has proposed (Section 2) a specific 'ecological' approach to macroeconomics – taking into account the need for substantial investment, structural change and potentially constrained consumer demand.

In the process the paper has highlighted relevant literature, explored conceptual challenges and outlined the development of two specific initiatives to develop macroeconomic models. The first of these (Section 3) is a Dynamic New Keynesian model being developed at WIFO. The second (Section 4) is the stock-flow consistent systems dynamic model being developed jointly by the University of Surrey and York University Toronto.

It is clear from this paper that the two approaches are quite distinct in their intellectual origins, in their conceptual approaches and in their empirical foundations. Nonetheless there are some similarities between the approaches. In the first place, both approaches attempt to go beyond conventional equilibrium based models. Both acknowledge the critical role of environmental and resource constraints on economic activity.

Furthermore, both models employ an input-output framework to model the structure of industry and its implications in terms of resource requirements and ecological impacts. Both approaches also pay some attention to the distribution of incomes, spending and wealth. This feature is more fully developed in the DYNK model than in GEMMA/FALSTAFF, as is the detailed exploration of the energy sector. Conversely GEMMA/FALSTAFF incorporates a more comprehensive account of the monetary flows, financial sector behaviours and financial sector balance sheets.

Clearly both of these approaches offer important innovations to many conventional approaches to macroeconomics. An ideal approach to the future might be to explore how and where the two approaches could be combined. Within the resources of WWWforEurope however, this remains an unlikely scenario. Different conceptual foundations, different model structures and different empirical bases constitute too much distance for an easy reconciliation of approaches within a short remaining timescale.

It is therefore proposed that the two approaches will continue their work separately within WP 205, and that future milestones separate the two approaches. Milestone 39 (which aims to set out reference scenarios absent of specific policy) should therefore be divided to create two new Milestones 39a (covering the DYNK approach) and Milestone 39b (covering GEMMA/FALSTAFF).

Similarly it is proposed that Milestone 40 (which aims to report on alternative policy scenarios) should be divided to create two new Milestones 40a (covering the DYNK model) and 40b covering GEMMA/FALSTAFF.   This separation of outputs will certainly aid clarity in the presentation of results and avoid confusion between the different approaches. In addition, however, it is proposed to create a new milestone 40c which provides an overview of the different approaches and compares the findings.

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Project Information

Welfare, Wealth and Work for Europe

A European research consortium is working on the analytical foundations for a socio-ecological transition

Abstract

Europe needs change. The financial crisis has exposed long-neglected deficiencies in the present growth path, most visibly in the areas of unemployment and public debt. At the same time, Europe has to cope with new challenges, ranging from globalisation and demographic shifts to new technologies and ecological challenges. Under the title of Welfare, Wealth and Work for Europe – WWWforEurope – a European research consortium is laying the analytical foundation for a new development strategy that will enable a socio-ecological transition to high levels of employment, social inclusion, gender equity and environmental sustainability. The four-year research project within the 7th Framework Programme funded by the European Commission was launched in April 2012. The consortium brings together researchers from 34 scientific institutions in 12 European countries and is coordinated by the Austrian Institute of Economic Research (WIFO). The project coordinator is Karl Aiginger, director of WIFO.

For details on WWWforEurope see: www.foreurope.eu

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