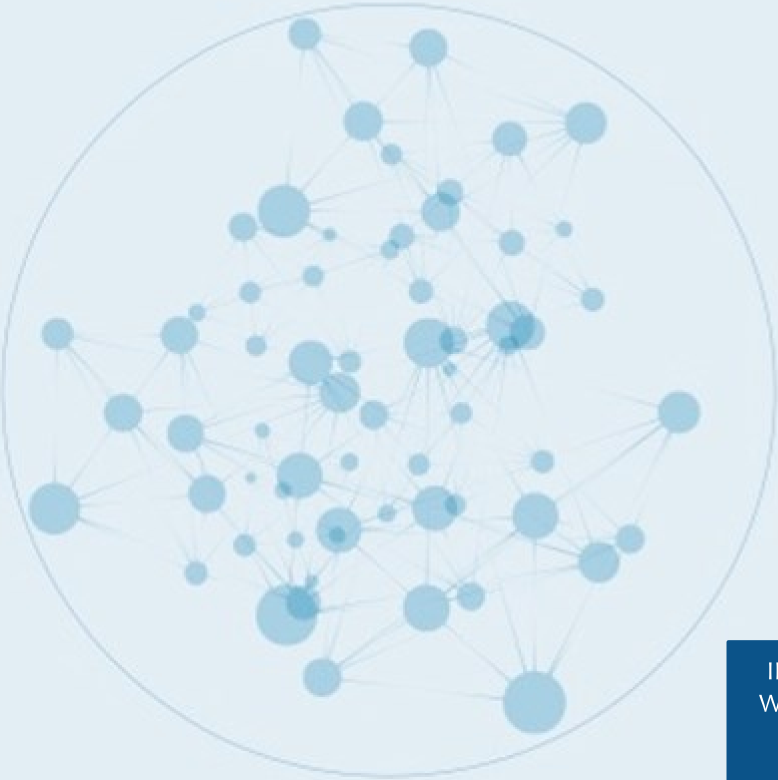
Inquiry: Design of a Sustainable Financial System

UNEP

TOWARDS A STOCK-FLOW CONSISTENT ECOLOGICAL MACROECONOMICS

An overview of the FALSTAFF framework with some illustrative results



INQUIRY WORKING PAPER

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The UNEP Inquiry

The Inquiry into the Design of a Sustainable Financial System has been initiated by the United Nations Environment Programme to advance policy options to improve the financial system's effectiveness in mobilizing capital towards a green and inclusive economy—in other words, sustainable development. Established in January 2014, it will publish its final report in October 2015.

More information on the Inquiry is at: *www.unep.org/inquiry* or from: Ms. Mahenau Agha, Director of Outreach *mahenau.agha@unep.org*.

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About this report

This working paper results from a workshop which the UNEP Inquiry and CIGI held on 2-3 December 2014 in Waterloo, Canada to discuss options for a sustainable global financial system. The workshop included participants from a range of academic and research institutions from the Waterloo region and abroad, including the University of Waterloo, the University of London, the University of Surrey, York University, Harvard University, and the University of Gothenburg. This working paper draws from an ongoing program of work at the University of Surrey in collaboration with York University on Prosperity and Sustainability in the Green Economy (PASSAGE). The work is partly supported by the UK Economic and Social Research Council. The version of FALSTAFF model presented in this paper is a beta version for discussion purposes only and is currently subject to ongoing refinement and calibration. Further details of the ongoing work are available at: *www.prosperitas.org.uk*.

Comments are welcome and should be sent to *t.jackson@surrey.ac.uk*, *pvictor@yorku.ca* **and** *simon.zadek@unep.org*.

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Contents

Abstract

This paper 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 the modelling needs in relation to full employment, financial stability, and social equity under conditions of constrained resource consumption and ecological limits. We outline the development of a dedicated system-dynamics model for describing Financial Assets and Liabilities in a Stock-Flow consistent Framework (FALSTAFF) and present some hypothetical results calibrated for the Canadian economy. The selected scenarios illustrate the complex relationships between real and financial aspects of the macroeconomy and allow us to carry out some initial tests on the financial viability of green investment.

Introduction

The broad aim of this paper is to address the challenge of developing an "ecological macroeconomics": that is to say a macroeconomics consistent with the need to remain within environmental and resource limits. The work addresses in particular the following question raised by the UNEP Inquiry into the Design of a Sustainable Financial System:

"What are the relative merits of deploying financial over real economy[1] *policies and regulations to address environmental and equity issues and outcomes?"*

Our broad answer to this question is that financial policies are essential for several reasons. In the first place, the transition to a green economy depends crucially on new patterns of investment and the viability of these investments depends in turn on the financial landscape. Secondly, performance in the real economy is linked in complex ways to the health and stability of the financial economy – even if these links are largely invisible within headline real economy indicators. Assessments of economic performance which neglect shifts in the financial landscape are at best incomplete and at worst misleading. Finally, the pattern and distribution of financial assets and liabilities is an essential component of economic and social sustainability.

If these points are to be taken seriously, we argue that there are two immediate requirements in terms of understanding the transition to sustainable investment. The first is a "stock-flow consistent" account of the relationship between real and financial economies, without which the implications of a shift in investment patterns cannot be assessed or influenced. The second is a systematic attention to the institutional architecture of the financial system and its interactions with the real economy, particularly in the context of green investment goals and requirements for social equity.

A full response to both these requirements lies beyond the scope of this paper. We address primarily the first concern. In fact our main aim in this paper is to outline the development of a dedicated system dynamics model to explore Financial Assets and Liabilities in Stock-Flow consistent Framework (FALSTAFF) and to illustrate the use of this model, in particular in the context of shifts in the pattern of investment. We are able to illustrate both real and financial implications of this shift and identify danger signals for existing financial architectures in the context of shifting investment patterns.

FALSTAFF also offers the possibility of modelling explicit policy interventions and developing alternative financial architectures. A full elaboration of such interventions lies beyond the scope of the current paper, but we offer some qualitative suggestions for future work using the same framework. We also discuss briefly the implications of this exercise for the question of "growth-based" economics.

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

1 Background and Motivation

One of the clearest lessons from the financial crisis is that a narrow focus on real economy indicators and policies was insufficient to avert the potentially disastrous consequences triggered by weaknesses in the US housing market and the subsequent collapse of Lehman Brothers in September 2008. The fragility instilled within the financial system as a result of overheated asset markets, over-leveraged balance sheets, and over-complex financial instruments went largely unnoticed in a policy environment focussed primarily on aggregate indicators such as the GDP, employment rates, inflation and consumer spending.

The failure of almost all mainstream economists to foresee the global financial crisis of 2008/9 represents a remarkable failure of financial governance (Bezemer, 2010). Just a year before the onset of the great recession the then chairman of the US Federal Reserve Ben Bernanke reported to the US House of Representatives (Bernanke, 2007) that "the US 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." Global financial institutions were also taken unawares. In August 2007, the IMF was able to argue 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).

These oversights amount to a systematic failure to integrate a coherent description of the financial economy into models and policy prescriptions for the real economy (Keen, 2011). The crisis revealed painfully that the apparent economic success of the "great moderation"[2] 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 bear witness to this new turn in economics (Keen, 2011; Minsky, 1994; Turner, 2013; Wray, 2012).

Perhaps the most notable shortcoming of traditional economic models is the 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 overexploitation 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 well-being outcomes from increasingly material lives are tenuous. Expanding consumer demand increases the global throughput of

[2] *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.*

materials 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 well-being 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.[3]

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 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). 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. Recent attempts to overcome this fear have largely focused on arguing that the impacts of green investment will be either negligible or even positive in terms of stimulating growth (NCE, 2014). But it remains an uncomfortable fact that 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 we have argued elsewhere, there is a need to develop a fully consistent ecological macroeconomics in which it is possible

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

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.[4]

In short, it is clear that an approach to macroeconomics configured only by "real economy" aggregates such as output, productivity, employment, consumption and public spending, is insufficient to ensure economic sustainability, let alone social or ecological sustainability. Nor is it sufficient for monetary policy to consist largely in laissez-faire regulation of financial markets combined with central bank interest rate policy aimed solely at inflation targeting. These forms of monetary policy were plainly deficient in averting the crisis and insufficient to provide recovery from it. For two decade before the crisis, this same architecture had signally failed to provide a financial landscape amenable to the investment needs of a low carbon economy. Building a more appropriate financial system needs to start from a clear understanding of the investment needs associated with the transition to sustainable economy.

This transition demands a quite specific investment portfolio which is quantitatively and qualitatively different from the investment portfolio that has characterised the prevailing economic system. Existing investment portfolios are dominated by speculation in asset prices and by the extraction and depletion of natural capital resources. Easy returns in the first category are gained at the cost of unstable asset prices and rising inequality. Easy returns in the second are achieved only at the expense of resource depletion and environmental degradation. As these easy returns begin to dissipate, the dominance of extractive investments leads to portfolios weakened by stranded assets (HSBC, 2012) with potentially destabilising effects on future financial markets.

By contrast, the investment portfolio for a sustainable economy consists in building long-term assets in low carbon technology and infrastructure, in resource-efficient manufacturing, in service provision, in health care, in education, in public spaces and social goods, and in the protection and restoration of habitats, forests, wetlands, soils and other natural capital assets. Some of these asset types may offer very conventional benefits with rates of return comparable to existing portfolios. Others however will impose considerable challenges on existing institutional structures and financial architectures.

Numerous questions emerge as a result of this analysis. These include questions: about the organisation and structure of asset portfolios; about the balance between public and private finance; about the balance between equity and debt; about the structure and distribution of asset ownership; about the impacts of elevated investments on prices, on wages and on consumer demand; and about the appropriate forms of horizontal and vertical money supply. In short, addressing these questions demands attention to both the real and the financial economy. Explicitly, it also requires a framework that integrates both of these aspects of the economy – in the context of ecological and resource constraints. The next section describes the development of such a framework.

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

2 Overview of the FALSTAFF Model

Working together over the last four years, the authors of this paper have begun to develop a consistent approach to an ecological macroeconomics. Our broad approach 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.[5]

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 system 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. System 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 our 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 limitations of the GDP as an indicator of well-being are now well rehearsed (e.g. Stiglitz et al., 2009). However the growth of GDP or national income in a particular country remains a significant policy indicator in its own right. More importantly, 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 supranational or subnational level. Since the development of a unified System of National Accounts (UN, 1993 and 2008) however, the most comprehensive, reliable and consistent data sets tend to be available at country and national level.

An important intellectual foundation for our work comes from the insights of post-Keynesian economics and modern money theory. We draw in particular from an approach known as Stock-Flow Consistent (SFC) macro-economics, pioneered by Copeland (1949) and developed extensively by Godley and Lavoie (2007). The over-arching axiom of the SFC approach is that all monetary flows come from somewhere and go to somewhere. One agent's expenditure is another agent's income. One sector's 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 (Lavoie and Godley, 2001).

From these foundations, two somewhat distinct models have so far been constructed, and are currently being calibrated against National Accounts data from the UK and from Canada. The Green Economy Macro-Model and Accounts framework (GEMMA) is a system dynamics input-output model incorporating

[5] *Our primary modelling platform is a system dynamics software platform known as STELLA. Data collation organised in Excel and econometric calibration is carried out in Eviews.*

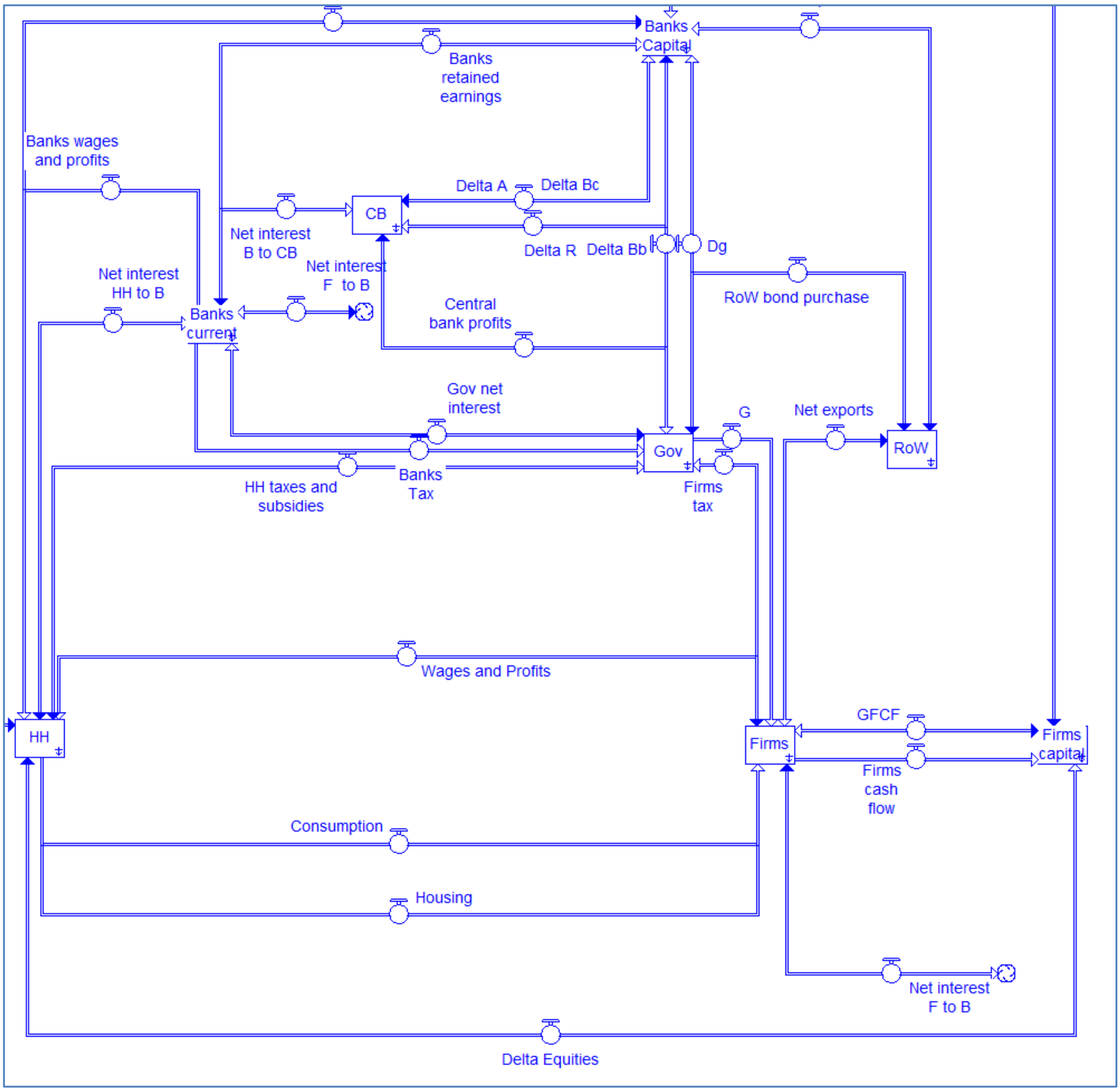
12 industry sectors (and the interactions between them) and six accounting sectors. Early results from GEMMA were reported during the Rio Summit in June 2012. It was possible to establish simple scenarios for the decarbonisation of the economy, with and without de-growth, and to explore the implications 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 representation of the real economy 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, we developed what is currently a separate system dynamics model. Financial Assets and Liabilities in a Stock- Flow consistent Framework (FALSTAFF) has a simplified representation of the real economy (it incorporates only one industry sector as opposed to 12 in GEMMA), but contains a more complete representation of the financial economy. In particular, FALSTAFF is able to simulate various aspects of financial behaviour and to report the key accounting identities of SFC theory.

The basic principle of SFC models[6] is to construct a consistent and exhaustive map of all monetary flows within the national economy. This means that any 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. Figure 1 shows a partial snapshot of the model structure in STELLA, with the familiar circular flow of the economy visible towards the bottom of the diagram. The rather more complex structure shown (partially) above and around the circular flow represents financial flows of the monetary economy in the banking, government and foreign sectors.

[6] *SFC models are also sometimes referred to as "accounting" or "flow-of-funds" models.*

Figure 1: Schematic diagram illustrating monetary flows between financial sectors in FALSTAFF



The stock-flow consistent approach to money flows within an economy can also be represented in tabular form, as illustrated in Tables 1 and 2.[7] Table 1 shows an illustrative (and simplified) transaction flows matrix for a closed economy (FALSTAFF models an open economy.) The matrix is supposed to represent all transactions between different financial sectors. 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 FALSTAFF this split between current and capital account is extended also to financial firms (banks) to the Central Bank and to the foreign sector.

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 1 illustrate the flow accounts of each sector. In terms of the household sector, it can be seen that

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

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:

$$C + G + I = GDP_e = GDP_i = W + P \quad 1)$$

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

Table 1: Illustrative Transaction Matrix for a Closed Economy

	Households (1)	Firms		Banks(4)	Gov't(5)	Σ
		Current(2)	Capital(3)			
Consumption (C)	$-C$	$+C$				0
Investment (I)	$-I_h$	$+I$	$-I_f$			0
Gov't expenditures (G)		$+G$			$-G$	0
Wages (W)	$+W$	$-W$				0
Profits (F)	$+FD_f$	$-F_f$	$+FU_f$			0
Taxes-transfers (T)	$-T_h$	$-T_f$			$+T$	0
Change in loans (L)			$+\Delta L_f$	$-\Delta L$		0
Change in deposits (D)	$-\Delta D$			$+\Delta D$		0
Change in bonds (B)	$-\Delta B_h$			$-\Delta B_b$	$+\Delta B$	0
Change in equities (E)	$-\Delta e \cdot p_e$		$+\Delta e \cdot p_e$			0
Σ	0	0	0	0	0	0

The bottom five rows of the table represent the transactions in financial assets and liabilities between sectors. So for example the net lending of the households sector (the sum of rows 1 to 6) is 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 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. 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.[8]

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 sheet data is collated and reported on an annual basis in the national accounts. One of the key financial axioms illustrated in Table 2 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.

Table 2: Illustrative Balance Sheet Matrix for a Closed Economy

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

The base year chosen to calibrate FALSTAFF's initial position is 2012, with an initial stylised[9] balance sheet drawn from end 2011 data.[10] The following subsections provide an overview of the structure of the individual financial sectors in FALSTAFF.

2.1 Households

Households make three kinds of decisions in FALSTAFF. First they decide how much to spend and how much to save. Second, they decide how much to invest in fixed capital assets (housing). Finally they decide how to allocate savings/borrowing to different asset classes. In relation to the first decision, the model allows the user to choose between a simple savings ratio based on a proportion of disposable

[8] *Annex 1 includes a numerical transaction flow matrix, reported for the first and final year of FALSTAFF's "base run".*

[9] *The problem of calibrating SFC models with a complete consistent balance sheet is non-trivial (e.g. Barwell and Burrows, 2011). Our approach started from the accessible OECD national balance sheet data and adopted a series of assumptions to simplify the data and aggregate it to the categories chosen in FALSTAFF.*

[10] *Annex 2 includes numerical balance sheets taken from the first and final year of FALSTAFF's "base run" output.*

income, or a more sophisticated consumption function of the form favoured by post-Keynesian SFC theorists, in which household consumption C is given by a function of the form:

$$C = \alpha_1 Y_{disp} + \alpha_2 NW_h \qquad 2)$$

where Y_{disp} is the disposable income of households and NW_h is their net worth. This more sophisticated form of consumption function thus incorporates both propensities to consume from disposable income and also propensities to consume from household wealth. In the long run this dependency of consumption on household wealth provides a link between behaviour in the real economy and the health of the financial economy (Godley and Lavoie, 2007), although it should be noted that these feedbacks are much slower than those provided via stock-market signals on consumer confidence, for instance. Values for α_1 and α_2 were estimated using quarterly national accounts data between 1991 and 2013, published by Statistics Canada.[11]

Housing investment in FALSTAFF is driven partly by population growth,[12] and partly by an exogenously defined housing growth parameter to reflect changes in household size and composition.

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 rate of return on equities rises (or is expected to rise), households tend 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.

There are several distinct ways of representing this kind of allocation process. For example, one can proceed (see Godley and Lavoie, 2007) by determining for each asset A_i a target proportion of household net worth, a_i^T, occupied by that asset, given by:

$$a_i^T = \lambda_{0i} + \sum_j \lambda_{ij} r_j + \lambda_{iY_d} \frac{Y_d}{NW} \qquad 3)$$

where the 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.[13]

In this version of FALSTAFF, we estimate these target proportions using data for seven distinct asset/liability classes: deposits, bonds, equities, housing wealth, mortgages, loans and pensions.

When we estimated these relationships using the econometric software Eviews and quarterly financial accounts data for Canada and the UK from 1991 to 2013, we found a high degree of dependency on $a_i^T(-1)$, the first lag of a_i^T. In other words, it seems as though households' portfolio allocations are relatively "sticky" on aggregate. To improve the estimation we made two changes to equation 3). The

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[11] *The StatCan database (http://www5.statcan.gc.ca/cansim/) is one of the most user-friendly national accounts databases of any country in the world and one of the reasons we decided to calibrate FALSTAFF first against Canadian data.*

[12] *We assume an exogenously variable 0.5% annual growth rate for population.*

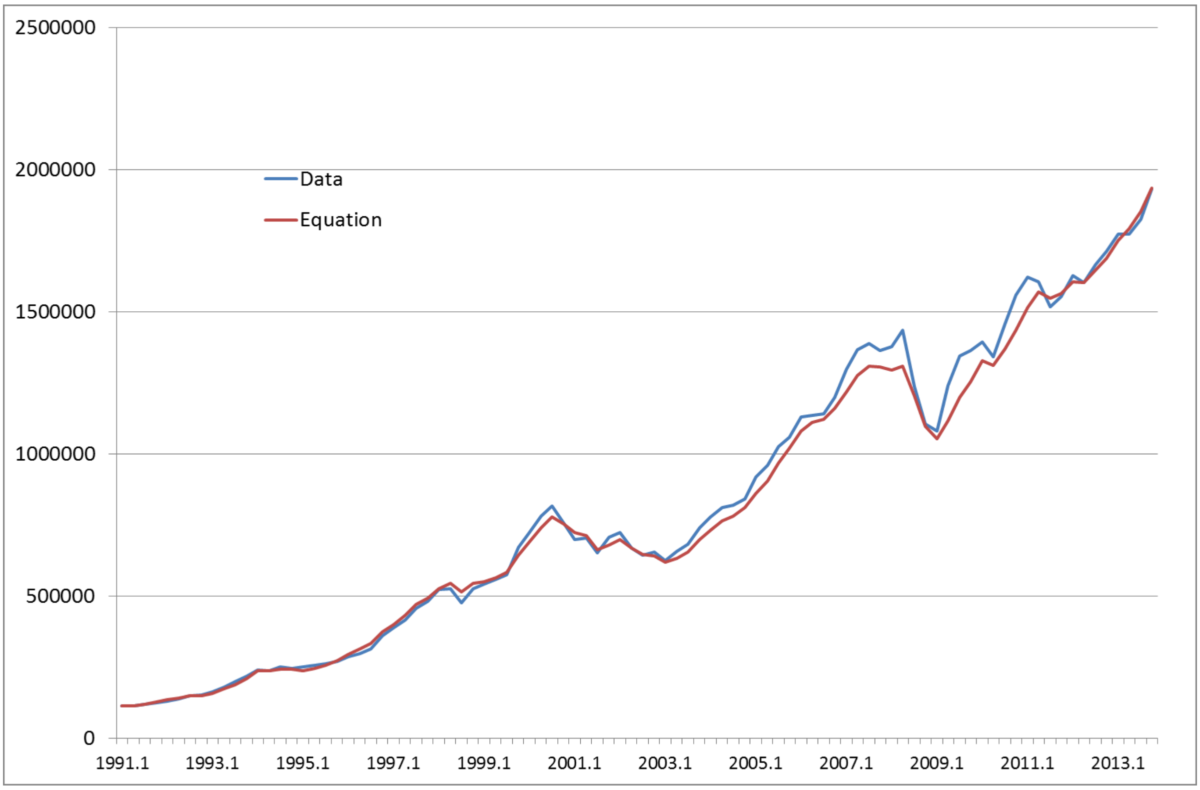
[13] *In order for this procedure to work correctly, it should be noted that liabilities (mortgages and loans) must be counted in a negative sense within the framework.*

first was to use Y_d directly rather than the ratio Y_d/NW as a dependent variable on the right hand side of the equation. The second was to include the lagged variable $a_i(-1)$ – the actual value of asset A_i as a proportion of net worth in the previous period – as an additional dependent variable on the right hand side of the equation.[14] The econometric estimation of the target proportion for each asset and liability in FALSTAFF is therefore given by:

$$a_i^T = \lambda_{0i} + \sum_j \lambda_{ij} r_j + \lambda_{iY_d} Y_d + \lambda_{iA_i} a_i(-1) \qquad 4)$$

The model in this form was reasonably successful in replicating historical trends in the holdings of different asset types. Figure 2 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.

Figure 2: Estimated and actual holdings of equities by Canadian households, 1991-2013



Source: output from the Portfolio Allocation Module in FALSTAFF.

2.2 Firms

The firms sector in FALSTAFF simulates the production of all goods and services in the economy, including those accounted for by public spending.[15] Nominal demand in the economy represents firms' income. The labour employment *LE* required to meet this demand is calculated using a time-varying

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[14] *This is similar but a little less constrained than estimating the differenced variable* Δa_i^T *on the left hand side of 9).*

[15] *Though something of a simplification of the structure of a real economy, this is also the way in which public spending is accounted for in the national accounts.*

labour productivity function *LP* which varies over time according to an econometrically estimated real labour productivity growth rate, *lpg* according to:

$$LP = LP_0(1 + lpg)^{t-2012} \qquad 5a)$$

$$LE = \frac{GDP_{nom}}{p.LP} \qquad 5b)$$

where *p* is price and GDP_{nom} is the nominal demand. It should be clear that nominal demand cannot always be met by domestic production, particularly given that labour is constrained by the available labour force which therefore determines a supply constraint on the domestic economy.

Firms' costs include taxes on production and on products (determined in the government sector), interest payments on loans, and wages. The wage bill is calculated via a time-varying wage rate *WR* which also determines price in the model. Two factors are deemed to change the wage rate in the model. Initially we assume that labour productivity improvements are passed on to workers, so that the unadjusted wage rate *WR* is given by:

$$WR = WR_0(1 + lpg)^{t-2012} \qquad 6)$$

An inflation adjusted wage rate *WR'* is then estimated by using a simplified Phillips curve that inflates the wage rate when unemployment is low and deflates it when unemployment is high.[16] The price of domestically produced goods in the model is then determined by the ratio of the inflation adjusted wage rate *WR'* to the unadjusted wage rate *WR*.

Firms have to make three other kinds of decisions in FALSTAFF: how much of their net profits *F* to distribute as dividends; how much to invest in production; and how to finance this investment. The dividend distribution F_D can be decided either via an exogenously determined "retained earnings ratio" or else through an equation of the form:

$$F_D = F_D(-1) + \eta F(-1) \qquad 7)$$

where *F(-1)* denotes profits in the previous period (i.e. the first lag of profits) and η is an econometrically estimated coefficient.

The investment decision is determined in two parts. One of our intentions in the model is to be able to understand the implications of green investment on the performance of the economy. We therefore separate firms' investment into a conventional component, predicted econometrically in the model and a green component which is determined exogenously. For the conventional component, we use an investment function proposed by Lavoie and Godley (2001). Firms' investment *I* is estimated with a capital accumulation rate g which is deemed to be dependent on the rate of cash flow r_{cf} (calculated from the ratio of retained earnings to capital), the rate of interest r_{Lf} on firms loans (moderated by a leverage ratio, l), Tobin's q ratio[17] and the rate r_{CU} of capacity utilisation:

$$g = \gamma_1 r_{cf} + \gamma_2 r_{Lf} l + \gamma_3 q + \gamma_4 r_{CU} \qquad 8)$$

Broadly speaking, this function means that conventional investment is expected to increase with increasing cash flow, to decline with increasing interest rates, to rise as Tobin's q rises (because the value

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[16] *Our Phillips curve is similar to the one used by Keen (2011) with a flat section around normal employment rates, a rising adjustment for low unemployment, a declining (but flatter) line for medium unemployment and a flat downwards adjustment of the wage for high unemployment.*

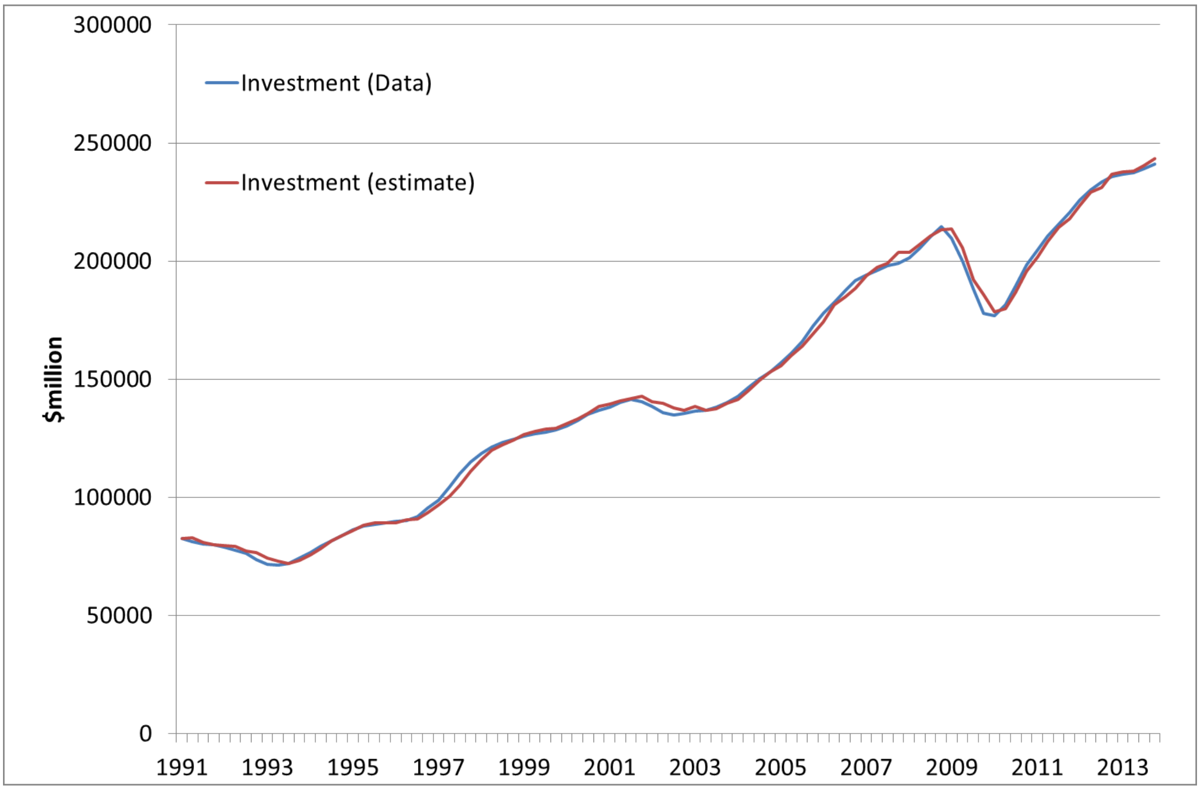
[17] *Tobin's q (first proposed by Nobel Laureate James Tobin) is a parameter that measures the ratio of the value of equity to the value of the capital stock.*

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. Conventional investment is then given by:

$$I = gK_f(-1) \qquad 9)$$

Where $K_f(-1)$ is the lag of firms' productive capital stock K_f. Equations 8) and 9) were reasonably successful in replicating the business investment behaviour of the Canadian economy during the period 1991 to 2013, as illustrated in Figure 3.

Figure 3: Actual and estimated historical values for firms' investment expenditure in Canada



Green investment in FALSTAFF is exogenously determined. It is assumed first that over the course of the run, a rising proportion of GDP (starting from zero) will be allocated to green investment. The user decides on the final target proportion and also selects the sectors in which this investment is made (firms, housing, government). The model then calculates the green investment in each sector over each year of the run assuming the same proportions of green investment in each sector as predicted for conventional investment. The impact on the economy of this green investment depends on two further parameters. The first is the extent to which it is deemed to be additional to or simply to substitute for predicted investment. The second is the extent to which both additional and nonadditional green investments are productive – in the sense that they add to the productive stock of the economy.[18] Both of these parameters can be selected by the user. The default position assumes that green investments will preferably be non-additional, or that there will be a gradual shift away from "brown investment" towards green investment within the same investment architecture predicted by the model. It should be

[18] *We use the term "productive" here in the rather conventional sense that an increase in the productive capital stock increases the immediate capacity of the economy to produce goods and services. Clearly, this does not always coincide with the long-term sustainability of that production, which might be better protected by the so-called "non-productive" investments designed to protect environmental resources.*

noted that productive additional investment adds to the productive capacity of the economy, whereas non-productive, non-additional investments subtract from the productive capacity of the economy. Non-productive, additional investments add to nominal demand in the economy, but do not change the productive capital stock. The model accounts separately for non-productive capital stocks. The importance of this distinction concerns the supply constraints on domestic production of goods and services. Just as supply is sometimes constrained by available labour, it may also be constrained by available capital. We assume here a constant capital output ratio (calibrated against historical data) to determine a further limit on maximum real (and hence nominal) demand supplied by the domestic economy. The overall limit on GDP is then the minimum of the maxima determined through labour and through capital constraints.

Table 3 below provides an illustrative overview of the kinds of green investment that might in practice fall into each of these categories, drawn from a variety of existing assessments and reports. For example, we have included all the climate change abatement and mitigation technologies (except nuclear energy) identified by McKinsey (2010), listed in the table from most to least profitable.[19]

Table 3: Illustrative examples of "productive" and "non-productive" green investment types

Positive Financial Return (high to low)	Negative Financial Return (low to high)
Improved lighting	Reduced slash and burn agriculture
Residential appliance efficiencies	Reduce pasture land conversion
Motor systems efficiency	Grassland management
Constructed wetland	Organic soils restoration
Wastewater treatment systems	Storm-water management systems
Bio fuels	Degraded land restoration
Hybrid cars	Urban forests
Retrofit residential HVAC	Public Spaces
Cropland nutrient management	Pastureland afforestation
Tillage and residue management	Green Roofs/Walls
Building efficiency (new)	Low penetration wind
Landfill gas electricity generation	Solar PV
Efficiency improvements in other industry	High penetration wind
Waste recycling	Energy Storage
Small hydro	Reduced intensive agriculture conversion
Rice management	Protected areas
Urban agriculture	Conventional pollution control systems
Geothermal	Solar CSP
	Coal CCS retrofit
	Coal CCS new build
	Iron and steel CCS new build
	Gas plant retrofit

The final decision to be made by firms is how to finance the overall investment needs (including both conventional and green investments). In FALSTAFF, firms investments can be funded through retained

[19] *Additional examples have been drawn from the Eco-Market (http://www.the-eco-market.com/green-mutual-funds/), from the Green Infrastructure Ontario Coalition http://www.greeninfrastructureontario.org/focus-area-sections, and from the authors' own experience.*

earnings (profits minus dividends), through issuing new equities and through taking out new bank loans. Once firms' retained earnings are exhausted we assume that additional financing needs are met through a mixture of loans and equities according to an exogenously variable debt to equity ratio, which is moderated to some (variable) degree by the rate of interest on firms' loans.[20]

2.3 Banks

The banks sector in FALSTAFF is a simplified accounting sector with two main functions. Its profit and loss account simply collates the interest payments on loans (including household mortgages) and pays out the interest due on deposits. Gross profits are the difference between these two.[21] Banks pay taxes to the government on these earnings and net profits are divided between retained earnings and dividends. Banks' dividends are calculated as a residual. Retained earnings decisions depend on the financing requirements of banks, which are in their turn depend on what is happening in the capital account. This is the second function allocated to banks in FALSTAFF and relates to the provision of capital facilities (deposits and loans) for other sectors.

There are two main capital account decisions to be made by banks. The first is how much money to hold as reserves with the central bank. For the purposes of this version of the model, this is allocated through an exogenously variable reserve ratio, with a default value in which reserves constitute 1% of deposits held with the bank. The second decision involves banks capital adequacy requirements. Basel III requires banks to hold a minimum of 8% of their risk-adjusted capital in the form of risk-free capital. We interpret this requirement to mean that the sum of banks reserves plus their holdings of sovereign bonds must be 8% of their total private sector lending.[22] This capital adequacy requirement then determines banks need for government bonds, and also (in conjunction with the changes in deposits and lending) determines their need for retained earnings. Specifically, the transaction matrix reveals that banks' undistributed profits FU_f are given by:

$$FU_f = \Delta D + \Delta P - \Delta L - \Delta M - \Delta R - \Delta B \qquad 10)$$

Where D represents deposits, P is pensions, L is loans to households and firms, M is mortgages against property purchases, R is central bank reserves and B is government bonds. In the event that this funding requirement exceeds total net profits, banks can also meet their funding requirement by taking out loans (advances) from the central bank.

2.4 Government

The government sector in FALSTAFF allows for a variety of government spending strategies and sets the tax rates on household income, firms' income and (indirectly) on products. Spending decisions by the government can be determined in three separate Modes in the model. In Mode 1, a simple exogenously varied growth rate is applied to both consumption spending and investment spending. The default value in the base run (described in more detail in the next section) is 2% per annum. In Mode 2, the government can operate a balanced budget policy in which spending is strictly constrained by tax receipts. Finally, in Mode 3, it can operate a counter-cyclical adjustment to the exogenous growth rate in which government spending rises (by up to 20%) if unemployment is high and falls (by up to the same amount) when

[20] *Currently this moderation of the debt to equity ratio is determined by a small exogenously set adjustment to the debt to equity preference. In future developments we will look for ways to endogenize the debt to equity ratio further to depend on market conditions.*

[21] *We do not, for instance, include banks wages in the banking sector. They are assumed to be accounted for via the firms sector.*

[22] *Sovereign bonds are typically rated at zero risk. The historical data support a close to 8% capital adequacy ratio in Canada. This rate can be varied in the model.*

unemployment is low. In each of these modes, it is also assumed that governments will tend to reduce deficits (or surpluses) through adjustments to both spending and the tax rates, when the debt to GDP ratio rises above (or falls below) certain levels.

Government borrowing is funded through the issuance of bonds which are conceptualised in FALSTAFF as simple loans with an endogenously varying interest rate. Three other sectors create an endogenous demand for loans. Households purchase bonds in response to their asset allocation preferences (equation 4) above). Banks hold bonds in order to meet their capital adequacy requirements. Central banks hold bonds (see below) in exchange for liquidity provided to commercial banks in the form of reserves. The gap between the supply of bonds (government borrowing) and the demand for bonds is assumed to be met by bond purchases/sales from the foreign sector.[23]

2.5 Central Bank

The central bank sets interest rates in FALSTAFF, by lowering the base rate[24] when unemployment is high and raising it when unemployment is low. Rates on other assets or liabilities (deposits, household loans, mortgages on property, firms' loans, central bank advances and reserves) are set by historically calibrated interest rate spreads around the base rate.[25] Aside from this monetary policy function, the central banks only other interactions are with the commercial bank sector, providing additional liquidity for the commercial banks by exchanging government bonds for central bank reserves and providing a lender of last resort function through advances when required.

2.6 Foreign Sector

Finally, we account for the balance of trade between the domestic economy and the rest of the world. The import sector can be configured in two different ways in FALSTAFF. In the "balanced trade" mode Canada is assumed to aim in the short term for a balanced trade position in which imports are more or less equal to exports. In the second mode, the trade position can float, allowing the overseas sector to supply the balance between nominal domestic demand and the (capital and labour constrained) capacity of the domestic economy. This supply balance includes provision for a given target unemployment rate. Once unemployment in the domestic economy meets this target, it is assumed that additional supply capacity is provided by the overseas sector. This device is somewhat simplistic but serves for the moment both to constrain the supply demand balance in the model and also to stabilise the unemployment rate.

Aside from the nominal net import balance, the current account of the foreign sector includes only interest receipts (from bonds and deposits) and interest payments (for loans). The net lending of the overseas sector is then allocated in two separate ways, through bonds purchased from or sold back to the domestic economy government, and loans taken out from or deposits paid into domestic economy banks. Bond purchases are assumed to take up the slack between the domestic demand for bonds and the borrowing requirement of the domestic government. The remaining transactions (in either loans or deposits) are determined by the accounting requirement of the transaction flows matrix. In other words, any bond purchases must be paid for either from the net lending of the foreign current account sector or from loans taking out from domestic sector banks.

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[23] *A more sophisticated endogenization of the price of bonds through capital gains/losses (ie changes in bond yields) is under development.*

[24] *The rate at which commercial banks can borrow from the central bank.*

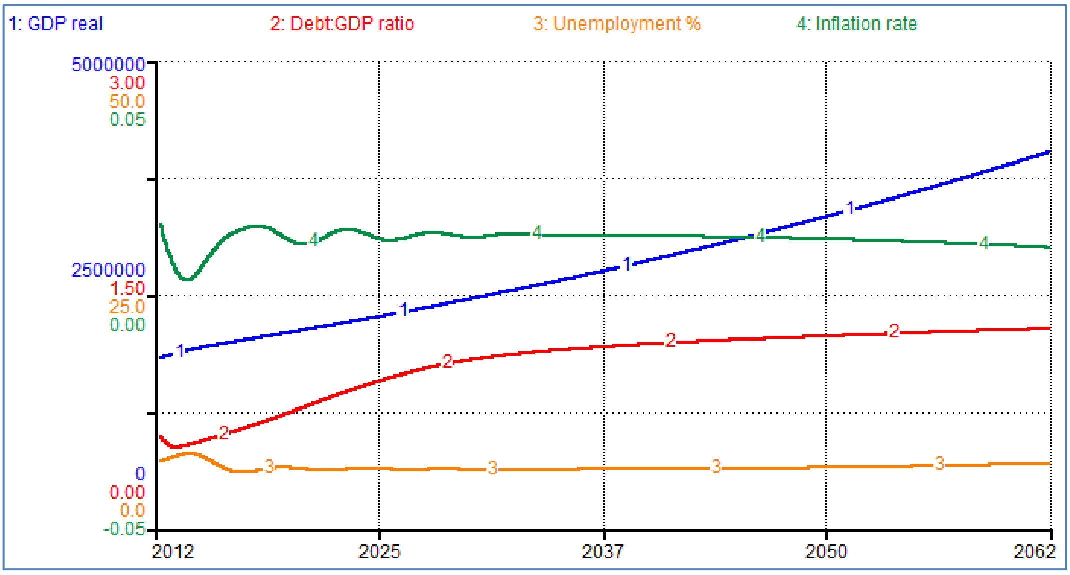
[25] *It is also possible to "turn off" the endogenously calculated interest rates in FALSTAFF. In this mode, the model simply uses the historical base year data.*

3 Illustrative Results

The work described in this paper is still in a developmental phase. By way of illustration only, we present here a hypothetical "Base Run" in which the values of key parameters are nonetheless drawn from empirical data. Having established this Base Run we then explore some variations on it, including a shift towards green investment. No firm and fast conclusions should be drawn from the specifics of these runs. The main lessons to be gleaned from this exercise concern firstly the complexity that haunts the financial implications of major shifts in investment patterns, and secondly the trade-offs that emerge between different financial aspects: one scenario might impact on household assets, another on government debt, a third on the net international position, and so on.

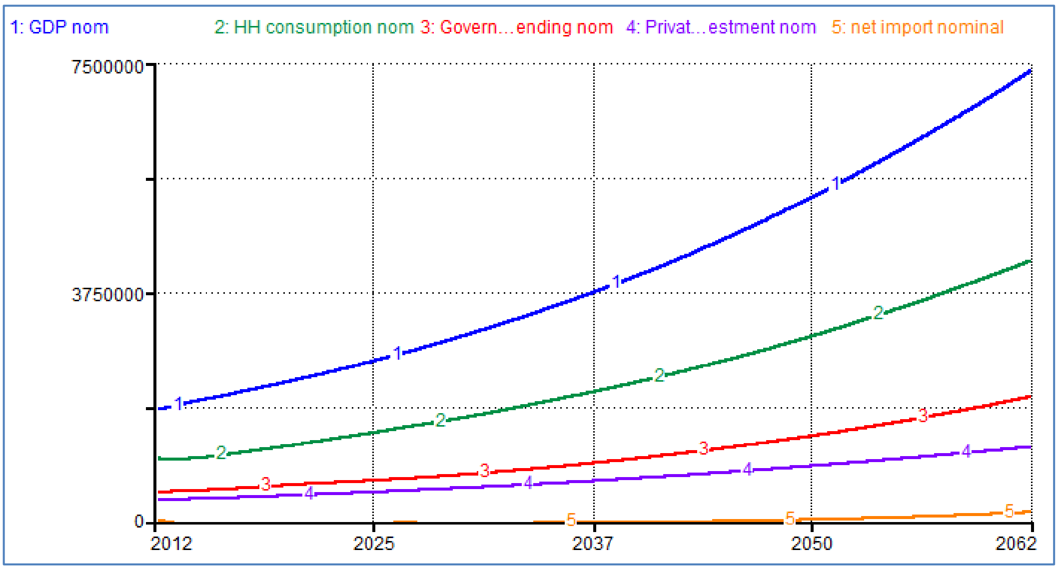
Our Base Run assumes historically calibrated levels for labour productivity growth (1%), housing growth (0.5%) and population growth (0.5%). The exogenous growth in government spending is assumed to be 2% per annum. Consumption is determined by equation 2), asset allocation by equation 4) and firms' investment by equation 8). Firms' retained earnings are allocated according to a simple retained earnings ratio calibrated at the current level (54%).[26] The base run assumes that government operates in Mode 1 (simple exogenous spending growth, moderated at high or low debt to GDP ratios). Foreign trade is not assumed to aim for a balanced trade position (i.e. overseas production is free to meet supply constraints that might arise) and there is no assumed green investment. The main real economy aggregates over the 50 years for the Base Run scenario are illustrated in Figure 4 and the structure of nominal demand is shown in Figure 5.

Figure 4: FALSTAFF's "Base Run" showing main real economy aggregates



[26] *Econometrically estimated coefficients for equation 2 are given by: α_1 = 0.83 and α_2=0.02; and for equation 8 by: γ_1 = 0.27; γ_2 = -0.035 ; γ_3 = 0.002; γ_4=0.003. Coefficients for the λ in equation 4 are given in Annex 3.*

Figure 5: FALSTAFF's "Base Run" showing composition of aggregate final demand



It is of interest to note that the real growth rate in the Base Run declines very slightly from around 1.7% at the beginning of the period to 1.5% per annum at the end. But real GDP rises from $1.84 trillion to a little over $4 trillion in 2062. We note here that the relative stability of the macroeconomic aggregates is a function of two feature of this exercise. Firstly, key parameters have been calibrated against relatively stable past trends. Perhaps more importantly, we have not at this point introduced behavioural assumptions relating to market confidence or government policy that might create greater instability. For instance, it is to be noted from Figure 4 that both inflation and unemployment are constrained within relatively stable corridors.[27] But the debt-to-GDP ratio certainly rises to levels that might not be considered acceptable under contemporary political sensitivities. This rise in sovereign debt could conceivable invoke sharper reactions in terms of spending and taxation than envisaged in our Base Run which may create greater instability than we envisage here.

Looking a little deeper into the financial implications of the Base Run, Figure 6 illustrates the net lending positions of different financial sectors of the economy. These positions are a key concern for a stock-flow consistent model. In line with the transaction flows matrix illustrated in Table 1) the condition of stock-flow consistency requires that the net lending of all sectors must add up to zero, a condition which is met in Figure 6. Figure 6 is therefore an important first indication that the model is running correctly, confirming that stock-flow consistency holds throughout the course of the run. The same point is underlined by the transaction flow matrices and Balance Sheet printouts attached in Annexes 1 and 2.

Equally important however, is what can be gleaned from Figure 6 about the long-term financial sustainability of the economy under our base run. Though the relative positions of different sectors remain fairly stable over the first half of the run, some worrying divergences begin to arise in the later years. In particular, the net lending position of the foreign and corporate sectors improves significantly at the expense of increased net borrowing in the households and government sectors. This can be expected to have potentially destabilising impacts over the longer term. We can gain further insight into the implications of this trend by examining the net financial and non-financial worth of households.

[27] *This is a result of the way in which trade stabilises employment at a target level (Section 2.6).*

Figure 6: Net lending positions in FALSTAFF's "Base Run"

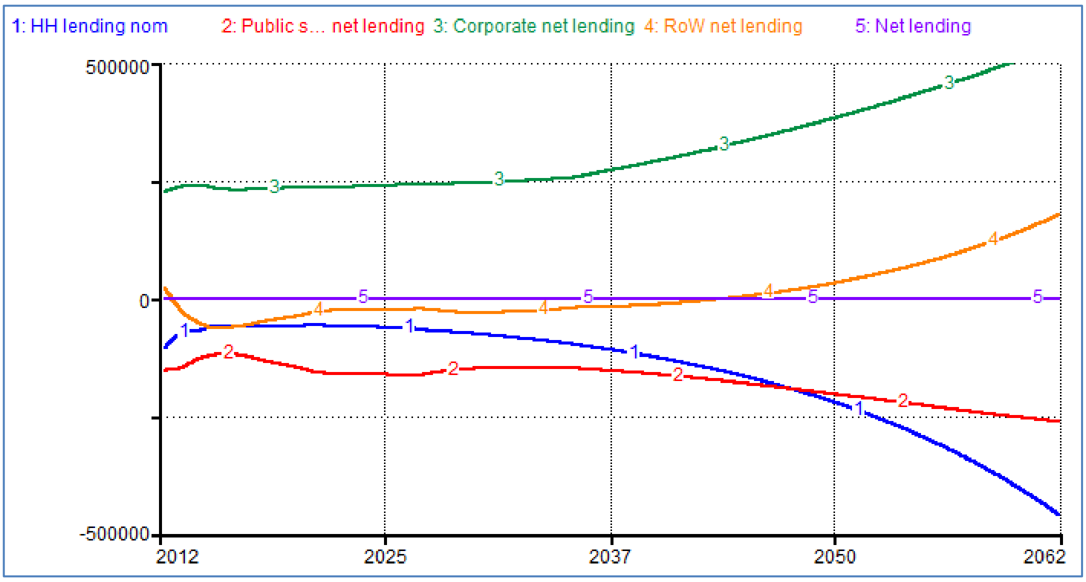


Figure 7 reveals that net financial worth in the household sector is beginning to decline by the end of the run, although perhaps less than expected from the consistently negative net lending position of households. Overall net worth (which is equal here to net financial worth plus the value of housing) is still on the increase. The explanation for this is to be found in Figure 8 which shows the value of selected household assets and liabilities. Essentially, an extended housing bubble, supported by an expansion of mortgage debt is allowing household net worth to continue to rise, even as other indicators of financial health decline. For instance, in this run, the pension wealth held by households is reduced to zero, a situation which would have enormous ramifications for social inequality and the quality of life of an aging population. By the end of the run, the value of firms' equity is also clearly on the decline.

Figure 7: Household net worth and net financial worth in FALSTAFF's "Base Run"

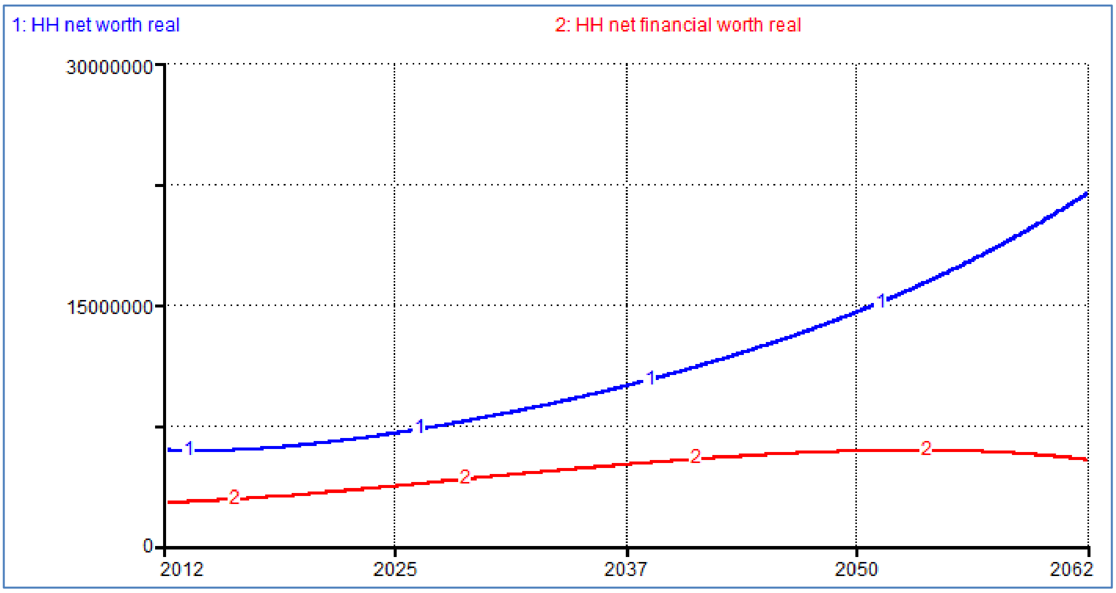
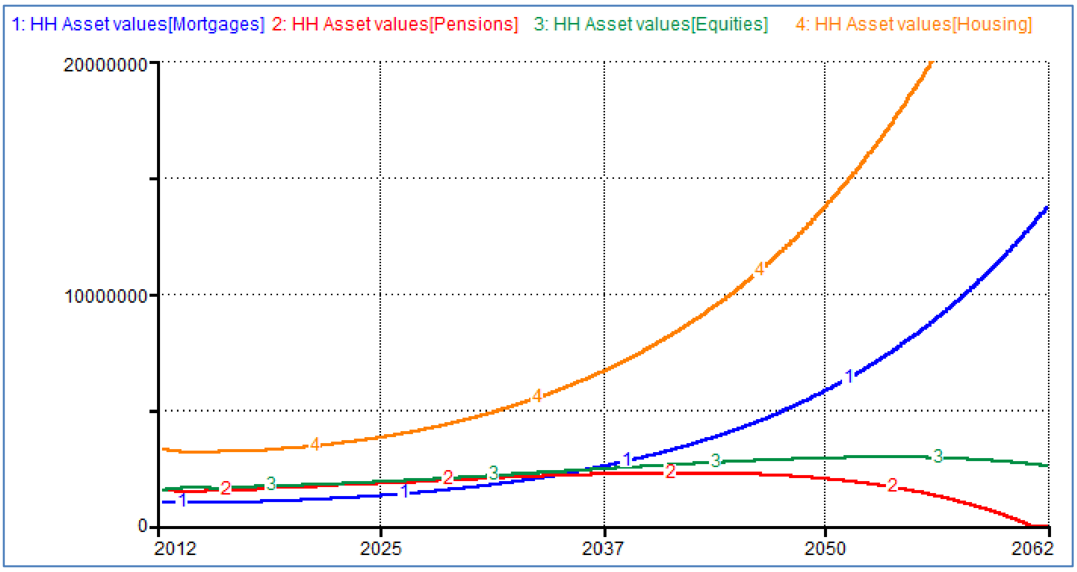
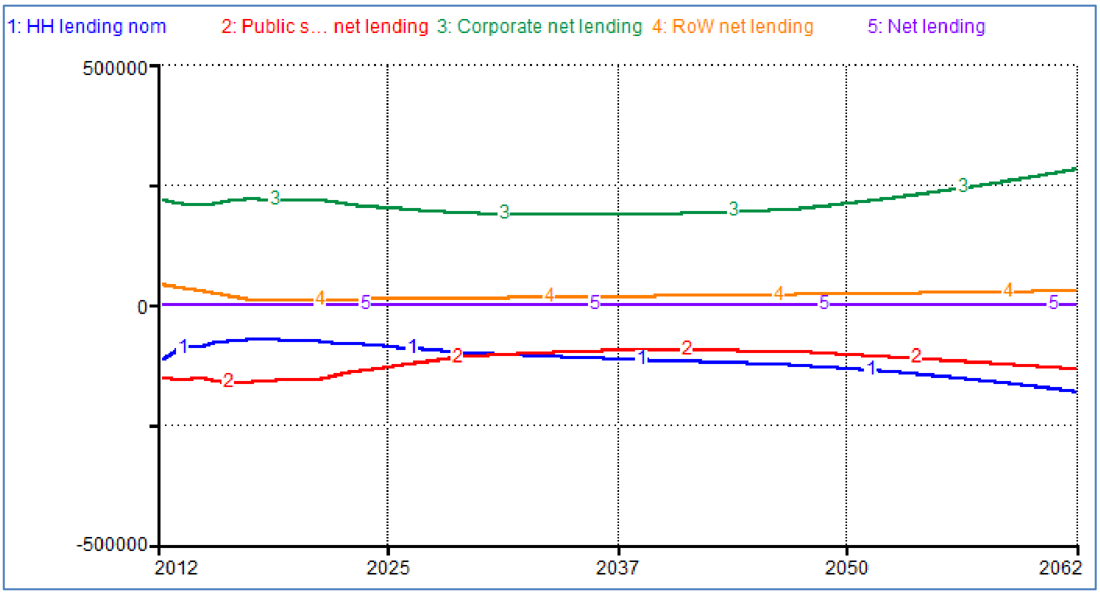


Figure 8: Selected household assets and liabilities in FALSTAFF's "Base Run"



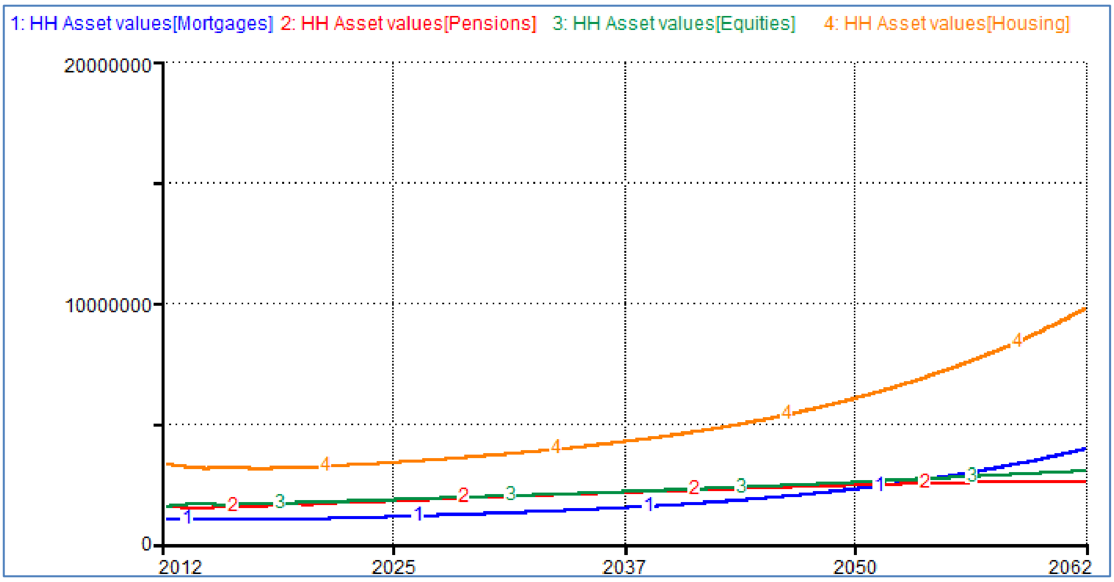
A simple innovation does much to stabilise these imbalances. By aiming for a balanced trade position in which the import gap declines to zero and stays there, the net lending positions are substantially changed over the longer term (Figure 9). The relative positions are now much more stable over the course of the run. Perhaps more surprisingly, this has the impact of dramatically reducing the size of the housing bubble and reversing the flight out of pension wealth (Figure 10).[28] Broadly speaking, this reflects the fact that more income remains within the domestic economy, to the benefit of households' savings position.

Figure 9: Net lending positions with "balanced trade" in FALSTAFF's "Base Run"



[28] *It should be noted that in spite of the "balanced trade" assumption, net lending remains slightly positive over the run for the foreign sector. This is a result of the net positive interest payments arising from bond ownership overseas.*

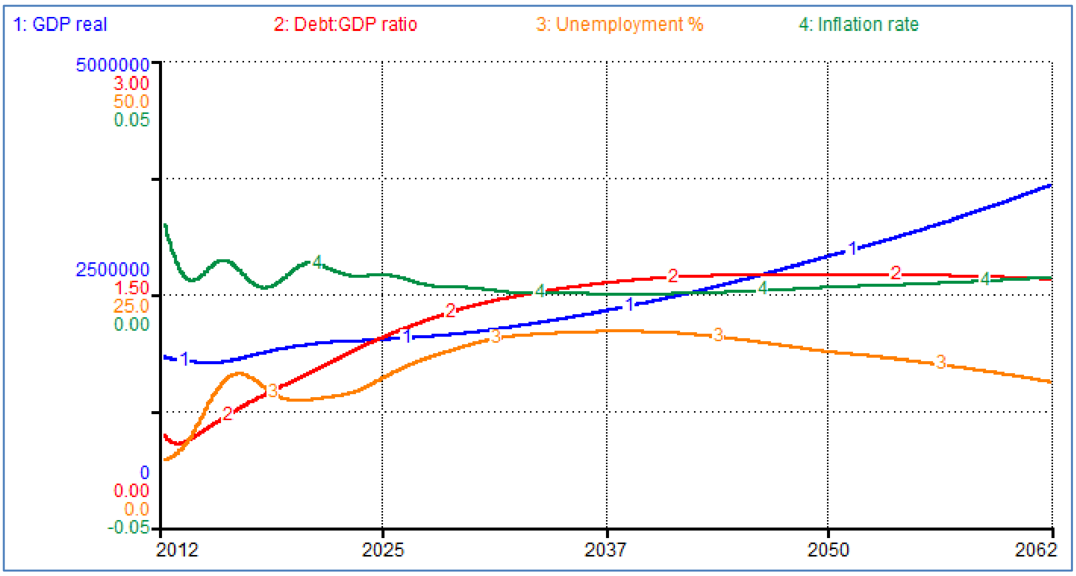
Figure 10: Revised asset position of households with "balanced trade"



These gains in terms of financial stability come at some cost however. Figure 11 illustrates the main real economy aggregates in the revised base run, and it can be seen (in comparison with Figure 4) that the real GDP is somewhat lower at around $3.7 trillion than in the unconstrained case, and though inflation is well under control, both unemployment and the debt-to-GDP ratio have risen considerably. The level of unemployment exceeds 20% over the middle years of the run, giving rise to a potential deepening of social inequalities and the risk of escalating societal tensions.

There are potentially a number of ways of mitigating the risk of these impacts. Some of them – such as a countercyclical spending strategy by government, a shortening of the working week, or a decline in the rate of growth of labour productivity – already lie within the capability of FALSTAFF to explore further. Others – such as a progressive tax position or a different approach to public sector employment – are amongst the planned innovations to the modelling framework in the future. In the interests of space, we illustrate just one more scenario in this paper aimed at exploring some of the financial implications of a long-term green investment strategy.

Figure 11: Revised real economy aggregates under "balanced trade"

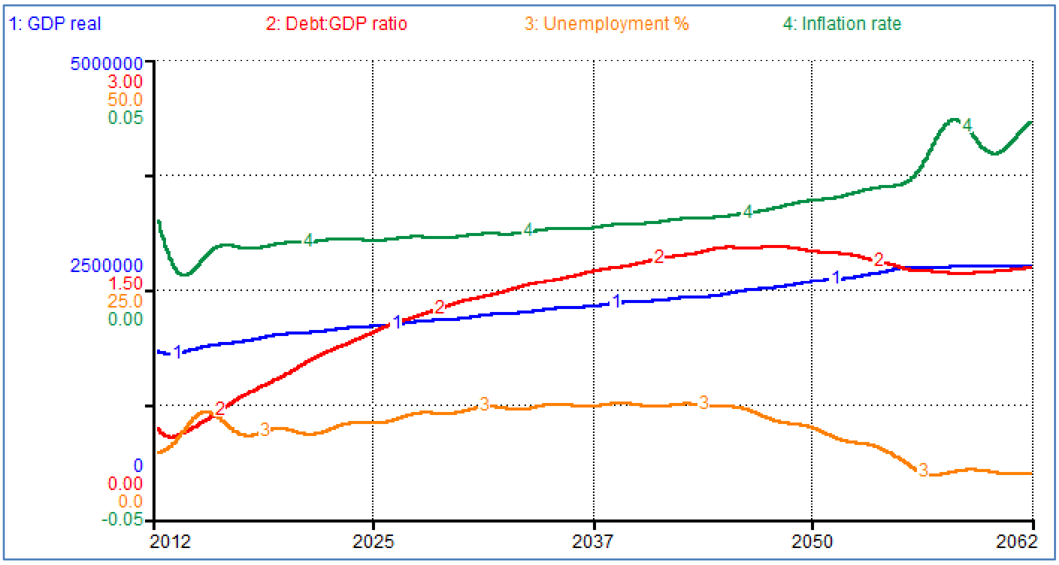


Our "Green Transformation" scenario sets up an economy in which over the course of 50 years, the investment portfolio in Canada has been transformed along the lines discussed in Section 2 and illustrated in Table 3. We imagine an endpoint in which around 12% of GDP is given over to green investment.[29] For the purposes of this paper we will assume that this investment transformation is undertaken solely by the corporate sector and that as much as possible of the investment is non-additional, or that the total investment still lies within the range of investment predicted by our econometric investment function in equation 8).

In the event that the predicted non-additional green investment exceeds the predicted conventional investment, however, the scenario assumes that the green investment target will still be met, with the excess being designated as additional to the investment predicted by the model. We also make an assumption here that half of the green investment (both additional and non-additional) can be counted as productive investment in the sense discussed in Section 2.2. The rest of the investment contributes to final demand, and all of it must be financed through firms financing mechanisms (retained earnings, loans from banks and the issue of equities). But the non-productive component of investment does not add to the supply capacity of the economy.

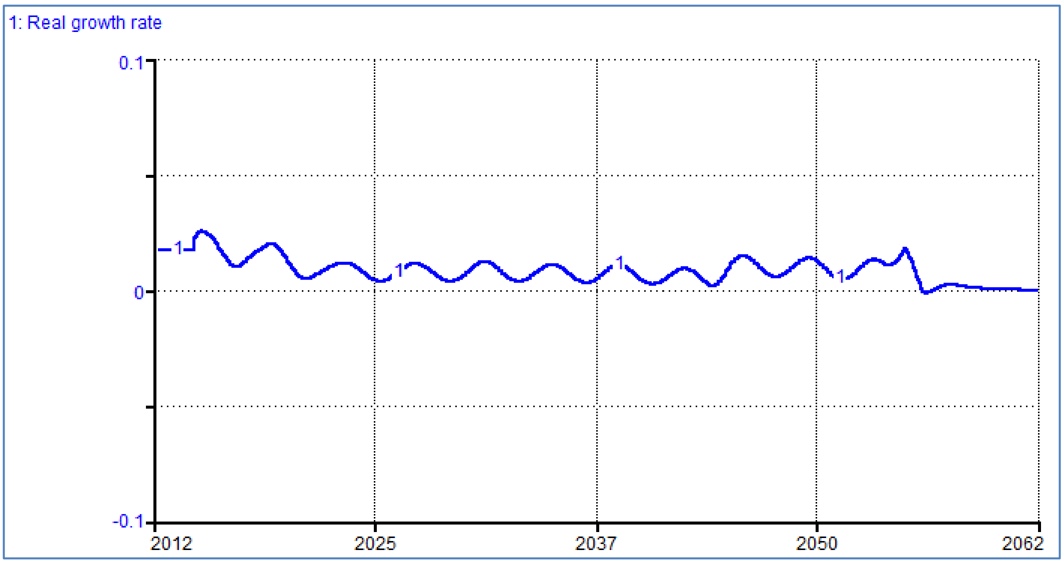
This shift in investment structure – alongside a potential shift to a more service-oriented economy (Jackson and Victor, 2011) and perhaps also an element of "secular stagnation" (Gordon, 2012) – is deemed to lead over time to a progressive decline in the rate of growth of labour productivity.[30] In fact, by the end of the run, we assume that labour productivity growth, having started out at a little over 1% per year has become slightly negative at -0.5% per year. This increase in the employment intensity of economic growth tends to reduce the productive capacity of the economy. But by the same token it also serves to maintain employment levels. For the purposes of this run, we retain the "balanced trade" assumption adopted in the revised base run and in order to increase the chances for government to mitigate potential impacts on employment from these changes, we adopt the countercyclical spending assumption discussed in Section 2.4.

Figure 12: Main real economy aggregates in FALSTAFF's "Green Transformation" run



[29] By comparison, 12% of GDP represents around half of the conventional investment expenditure in the current economy.
[30] In later versions of FALSTAFF we aim to endogenize the relationship between investment and labour productivity growth.

Figure 13: Real growth rate in FALSTAFF's "Green Transformation" run



The results of FALSTAFF's "Green Transformation" run in terms of the main real economy aggregates are illustrated in Figure 12. By comparison with the base run (Figure 4), it is to be observed that the real GDP is just over $2.75 trillion by 2062, considerably lower than under the Base Run. Furthermore, it transpires that, by the end of the run, the growth rate has declined almost to zero (Figure 13). Nonetheless, the debt-to-GDP ratio is no worse at the end of the run than in Figure 11, and although inflation is rising slightly, unemployment has been more successfully restrained, peaking at 12.5% in the middle years but declining to around 5% by the end of the run. The net lending positions (Figure 14) again show some cause for concern, particularly the sharp increase in public sector net borrowing towards the end of the run. But there is some comfort that, in spite of evidence of house price inflation, household asset positions rise more slowly than in the Base Run (Figure 15).

Figure 14: Net lending positions in FALSTAFF's "Green Transformation" run

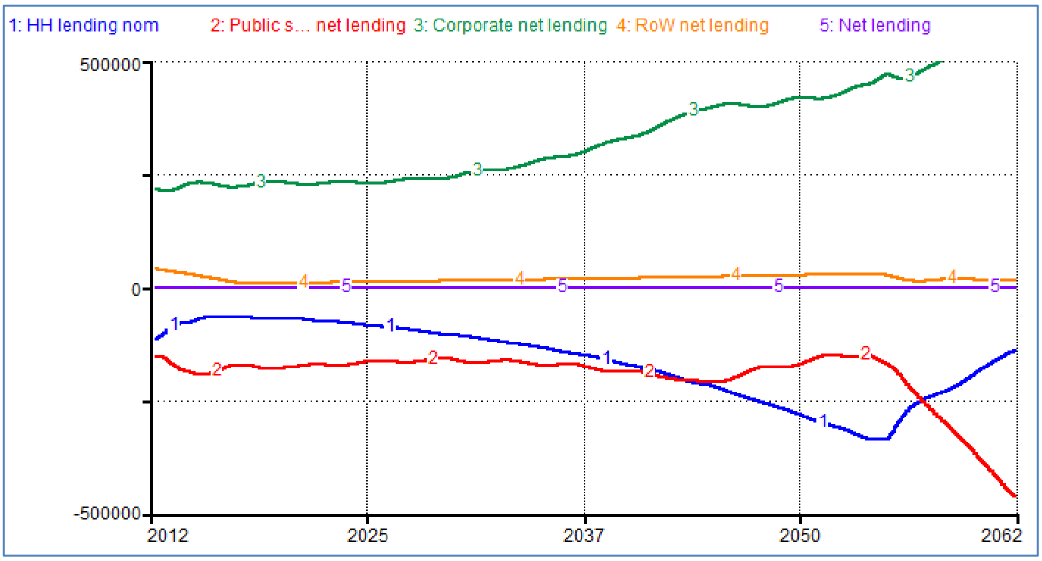
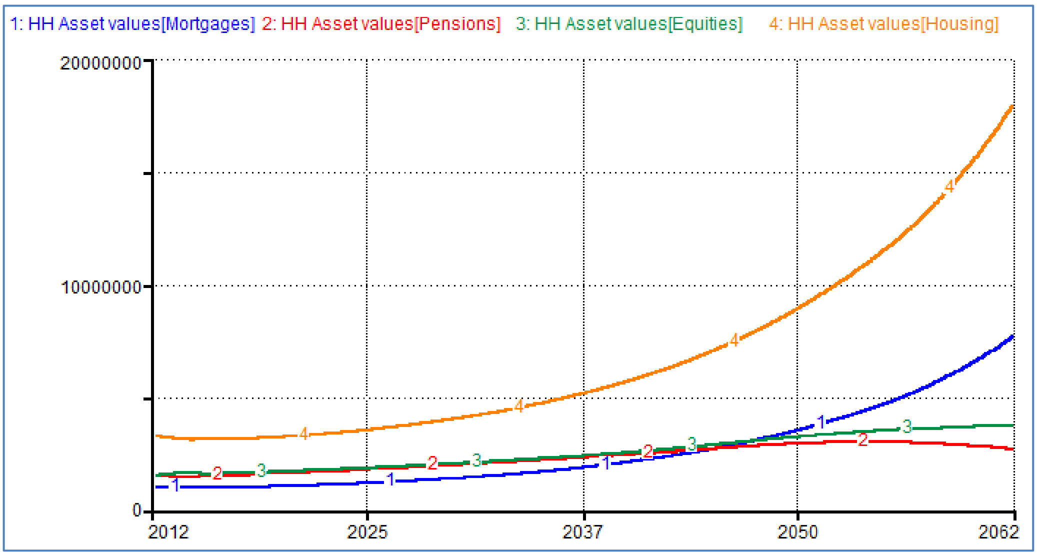


Figure 15: Household asset values in FALSTAFF's "Green Transformation" run



4 Discussion

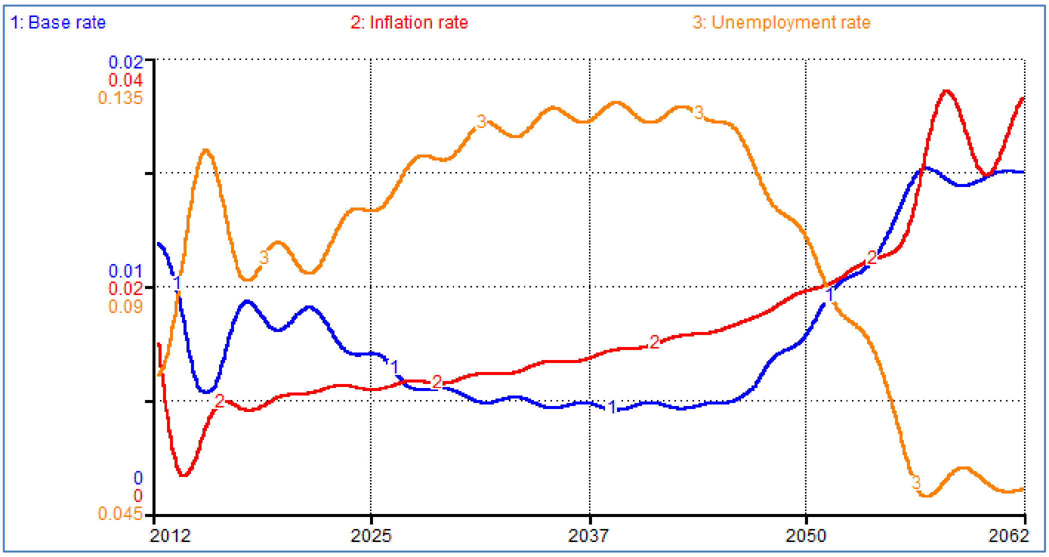
Our intention in this paper has been to highlight the important inter-relationships between the real and financial economy and to illustrate how these have to be taken into account in understanding and managing the transition towards a sustainable economy. We were concerned in particular to examine the real and financial economic implications of a large-scale transformation of investment patterns to protect ecosystems, reduce greenhouse gas emissions and build the infrastructure for a sustainable economy. Although FALSTAFF is still very much a work in progress, it is sufficiently developed to begin to give insights into these issues.

Necessarily, we have presented only a few preliminary findings here, based on particular assumptions about the nature of that change. Our primary intention in presenting these scenarios is to illustrate the need to take into account interactions between the real and financial economy, and to identify potential trade-offs between the financial positions of different sectors, arising from shifts in investment.

Any model is only as good as the assumptions that go into it and clearly we could have tested a wide range of other assumptions in this model. What if green investment is more or less productive than we have assumed here? What if crises of confidence in the house market arising perhaps from over-indebtedness of households stimulate a change in consumption patterns or shift in the savings ratio? What if shift in equity prices precipitates a flight out of equity? What if public sector debt levels lead to shift in bond yields?

These are all legitimate questions to ask of our FALSTAFF framework, and questions which in principle could be addressed through it. Equally the framework could be used to test policy innovations in the financial economy. We have barely touched on such issues in this paper. But it is worth noting for instance that Central Bank interest rate policy is one of the aspects of the model which is stabilising inflation and unemployment over the various runs. Figure 16 shows changes in the bank base rate in response to unemployment. These shifts in the base rate flow through to the interest rates charged on loans, paid on deposits and in turn to the rates of return on equities and housing.

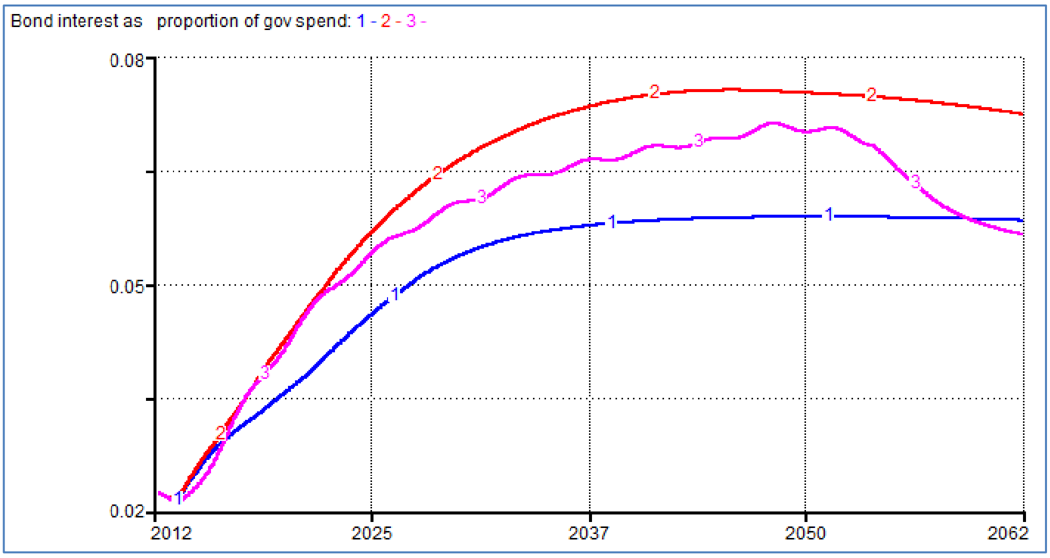
Figure 16: Base rate responses to unemployment and inflation



It is worth noting that the FALSTAFF framework could explore policies related to capital adequacy or to reserve ratios, and with some development could also look at "overt monetary financing" (Turner, 2013) or even some version of the Chicago plan (IMF, 2013). In the scenarios presented in this paper, the default reserve ratio has been adopted and the Basel III capital adequacy requirement has been maintained (see Annex 2). One of our ambitions in developing this work is to explore the implications of changes in these financial policy measures.

This ambition is relevant in particular to one of the biggest concerns relating to our illustrative scenarios: the high and rising level of sovereign debt. One reason for the rising debt-to-equity ratio faced by the government is the increasing impact of bond interest payments on government finance (Figure 17). There has been considerable recent discussion, in the aftermath of the financial crisis, about the potential for a shift in money creation away from the private creation of money by banks and towards sovereign money creation (Woolf, 2014; Jackson and Dyson, 2012). The issue was even addressed in a recent groundbreaking backbench debate in the UK Parliament. Such an initiative could dramatically ease the government's financial position and facilitate public sector-led green investment strategies of a completely different order than we have seen hitherto. Once again, however, the broader impact of such a strategy on real economy aggregates and on sector financial positions needs to be fully understood. A framework such as the one we have developed here could prove invaluable to this challenge.

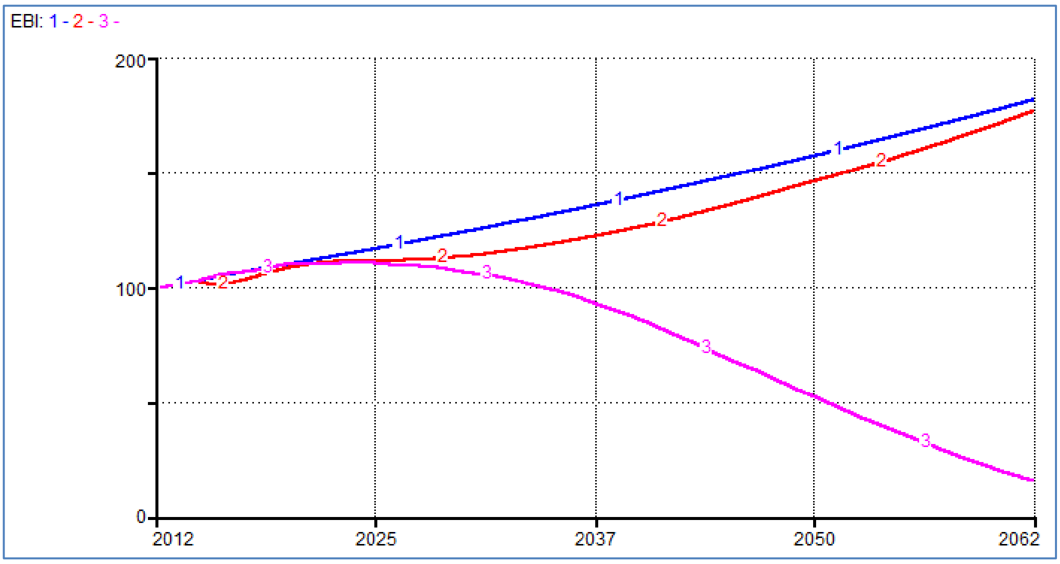
Figure 17: Government bond interest paid as proportion of spending for the three FALSTAFF scenarios



1 = Base Run; 2 = Base Run (revised); 3 = Green Transformation

An important element in any inquiry into green investment concerns the effectiveness of the investment in reducing the environmental burden of economic activity. We have largely left this question out of the paper, taking instead indicative levels of green investment as the starting point for unravelling the financial implications. It is worth commenting however that FALSTAFF currently contains a simple representative environmental burden index (EBI) (loosely calibrated on empirical data) which tracks the likely impact of different scenarios in terms of environmental impacts. Figure 18 illustrates the output from this index (as it is currently calibrated in the model) for the three scenarios presented here. Not unexpectedly, only the green transformation scenario (scenario 3 on the graph) has a positive effect on the environmental burden.

Figure 18: Illustrative "Environmental Burden" index for the three FALSTAFF scenarios



1 = Base Run; 2 = Base Run (revised); 3 = Green Transformation

Finally, it is clear that a part of the challenge of transforming investment lies in understanding its impacts on the distribution not just of incomes but of assets and liabilities. In a previous model we developed a simple two sector model of households to explore the implications of Piketty's (2014) hypothesis that slowing down growth would lead to a rise in inequality (Jackson and Victor, 2014). Our preliminary analysis indicated that this is by no means an inevitable outcome of a slower growth economy, but depends crucially on the relationship between labour and capital. It would add considerably to the analysis in this paper to extend the structure of FALSTAFF further in this direction and explore the distributional aspects of what we have presented here. This is one of the issues that we intend to address in future work.

Appendix 1: Transaction flows matrix from initial and final year in FALSTAFF's "Base Run"

Period	2012								
Net lending	2,053	87,670		141,715		-102,364	-150,920	23,900	-0
	Central bank	Banks current	Banks capital	Firms current	Firms capital	Household	Gov	Rest of world	Totals
Consumption				1,029,827		-1,029,827			0
Government spending				472,108			-472,108		0
GCFC (excl gov)				352,322	-223,678	-128,644			0
Net exports				-17,384				17,384	0
Wages		-		-923,424		923,424			0
Dividends		-94.45		-147,085		147,179			0
Mixed income				-213,059		213,059			0
Net interest paid to banks		113,152		-15,130		-98,022	-	-	0
Bond interest	194	2,939				1,189	-10,838	6,516	0
Reserve interest (net)	-98	98							0
Central bank profits	-96						96		0
Taxes		-28,425		-172,783		-130,723	331,930		0
Banks retained earnings		-87,670	87,670						0
Firms retained earnings				-365,393	365,393				0
Change in advances	-		-						0
Change in reserves	2,844		-2,844						0
Change in deposits			-23,131		-	23,131	-	-	0
Change in bonds	-2,844		-3,417			-3,813	150,920	-140,846	0
Change in equities					-	-			0
Change in mortgages			23,675			-23,675			0
Change in loans			-60,702		-141,715	85,470		116,947	0
Change in pensions			-21,251			21,251			0
Totals	0	0	0	0	0	0	0	0	0

Period	2062								
Net lending	0	-0		539,904		-459,000	-260,678	179,775	-0
	Central bank	Banks current	Banks capital	Firms current	Firms capital	Household	Gov	Rest of world	Totals
Consumption				4,280,808		-4,280,808			0
Government spending				2,042,288			-2,042,288		0
GCFC (excl gov)				1,220,274	-832,416	-387,858			0
Net exports				-152,474				152,474	0
Wages		-		-3,651,984		3,651,984			0
Dividends		-475,782.55		-560,258		1,036,040			0
Mixed income				-857,270		857,270			0
Net interest paid to banks		639,459		-22,059		-540,388	-	-77,012	0
Bond interest	2,877	19,829				-	-127,019	104,313	0
Reserve interest (net)	-1,598	1,598							0
Central bank profits	-1,279						1,279		0
Taxes		-185,103		-927,006		-795,240	1,907,350		0
Banks retained earnings		-	-						0
Firms retained earnings				-1,372,319	1,372,319				0
Change in advances	-		-						0
Change in reserves	10,229		-10,229						0
Change in deposits			941,739		-52,653	-889,086	-	-	0
Change in bonds	-10,229		-56,921			-	260,678	-193,528	0
Change in equities					-402,939	402,939			0
Change in mortgages			-945,147			945,147			0
Change in loans			70,558		-84,312	-0		13,753	0
Change in pensions			-			-			0
Totals	0	0	0	0	0	0	0	0	0

Appendix 2: Balance sheets from initial and final year in FALSTAFF's "Base Run"

		Basel III						
		7.8%						
		Reserve ratio						
Period	2012	1%						
	Central bank	Banks	Firms	Household	Gov	RoW	Totals	
Net Financial worth	**-**	**- 48,176**	**- 2,353,718**	**2,690,696**	**- 764,421**	**475,619**	0.00	
Net Assets	14,128	3,165,455	532,248	4,294,429	26,688	475,619	8,508,567	Differences
Advances	-						-	0
Reserves		14,128					14,128	0
Deposits			532,248	1,138,279	26,688	-	1,697,215	0
Bonds	14,128	214,553		86,809		475,619	791,109	0
Equities				1,552,925			1,552,925	0
Mortgages		1,022,621					1,022,621	0
Loans		1,914,153					1,914,153	0
Pensions				1,516,416			1,516,416	0
Net Liabilities	14,128	3,213,631	2,885,966	1,603,733	791,109	-	8,508,567	
Advances		-					-	
Reserves	14,128						14,128	
Deposits		1,697,215					1,697,215	
Bonds					791,109		791,109	
Equities			1,552,925				1,552,925	
Mortgages				1,022,621			1,022,621	
Loans			1,333,041	581,112		-	1,914,153	
Pensions		1,516,416					1,516,416	

		Basel III						
		7.7%						
		Reserve ratio						
Period	2062	1%						
	Central bank	Banks	Firms	Household	Gov	RoW	Totals	
Net Financial worth	**0**	**1,018,276**	**- 2,353,526**	**9,838,778**	**- 9,503,295**	**999,768**	- 0.00	
Net Assets	220,950	24,136,183	2,088,915	23,578,880	26,688	7,806,841	57,858,457	Differences
Advances	0						0	0
Reserves		220,950					220,950	0
Deposits			2,088,915	21,002,304	26,688	-	23,117,907	0
Bonds	220,950	1,502,192		-		7,806,841	9,529,983	0
Equities				2,576,576			2,576,576	0
Mortgages		13,740,103					13,740,103	0
Loans		8,672,938					8,672,938	0
Pensions				-			-	0
Net Liabilities	220,950	23,117,907	4,442,441	13,740,103	9,529,983	6,807,073	57,858,457	
Advances		0					0	
Reserves	220,950						220,950	
Deposits		23,117,907					23,117,907	
Bonds					9,529,983		9,529,983	
Equities			2,576,576				2,576,576	
Mortgages				13,740,103			13,740,103	
Loans			1,865,865	0		6,807,073	8,672,938	
Pensions		-					-	

Appendix 3: Coefficients for household portfolio allocation model in FALSTAFF

	Const	Deposits	Bonds	Equities	Housing	Mortgages	Loans	Pensions	Income	Lag
Deposits	0.00	0.08	-0.08	-0.01	-0.02	0.27	-0.05	-0.01	0.00	0.92
Bonds	0.01	0.07	0.12	0.00	-0.01	0.01	-0.11	-0.02	0.00	0.83
Equities	0.04	-0.18	0.09	0.04	-0.02	-0.49	0.19	-0.02	0.00	0.91
Housing	0.03	0.34	-0.03	-0.01	0.08	0.23	-0.18	-0.07	0.00	0.89
Mortgages	0.00	-0.10	0.08	0.01	0.00	-0.25	0.11	0.01	0.00	0.91
Loans	-0.01	-0.01	0.11	0.00	0.00	-0.11	0.02	0.01	0.00	0.90
Pensions	0.04	-0.19	-0.30	-0.03	-0.04	0.35	-0.02	0.09	0.00	0.88

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