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COMPLEMENTARY CURRENCIES: A SYSTEMS THEORY APPROACH TO MONETARY MACROECONOMICS

by

NEIL SMITH

A thesis submitted to the University of Plymouth in partial fulfilment for the degree of

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July 2019
Author’s Declaration

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the Doctoral College Quality Sub-Committee.

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Abstract

Complementary Currencies: A Systems Theory Approach to Monetary Macroeconomics

Neil Smith

It was commonplace in history for several types of currencies to circulate side-by-side within a country, often by design, and the notion that this may enable improved socioeconomic outcomes has been proposed in narratives across various disciplines. However, orthodox macroeconomic theory presupposes that national economies operate optimally when a single monetary unit is employed: general equilibrium optimisation modelling is applied where coordination is assumed and a single money acts only as numéraire. This thesis adopts a broader Political Economy perspective to develop a general theory macroeconomic model to elucidate the arguments for monetary plurality in a regional context. Cross-disciplinary literature is used to develop a conceptual ordering of themes to inform the modelling. A review of extant economic methodology reveals that its Formalist, Positivist perspective is not well-suited to addressing key issues, thus the research question is ineluctably connected to questions of methodology. An alternative methodology is argued to be more consistent with a necessary Critical Realist perspective and algorithmic reasoning. A modelling framework is developed combining insights from early Mercantilist economists and Classical Behavioural Economics into System Dynamics post-Keynesian Stock-Flow Consistent models. A lexicographic consumption model is developed to enable a core monetary model. This model is augmented with secondary monetary circuits, using three types of complementary currencies: Convertible Local Currency; Mutual Credit Clearing; and Local Government Currency. The models are developed and simulated using stylised facts, demonstrating "Cantillon Effects". The models demonstrate that complementary currencies may be regarded as useful coordinating mechanisms in regions where universal money is lacking. However, the introduction of secondary monies is highly context-dependent: consideration must be given to various institutionally-determined factors. The necessity of appropriate institutional structures justifies a role for government in enabling and promoting complementary currency schemes.
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<td>Agent-based Computational Economics</td>
</tr>
<tr>
<td>B2B</td>
<td>Business-to-Business</td>
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<tr>
<td>B2E</td>
<td>Business-to-Employee</td>
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<tr>
<td>CBE</td>
<td>Classical Behavioural Economics</td>
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<td>CC</td>
<td>Community/Complementary Currency</td>
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<td>CiA</td>
<td>Cash in Advance models</td>
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<td>CHF</td>
<td>Swiss Francs</td>
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<td>CLC</td>
<td>Convertible Local Currency</td>
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<td>CLD</td>
<td>Causal Loop Diagram</td>
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<td>DE</td>
<td>Discretionary External (expenditure)</td>
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<tr>
<td>DL</td>
<td>Discretionary Local (expenditure)</td>
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<tr>
<td>DSGE</td>
<td>Dynamic Stochastic General Equilibrium</td>
</tr>
<tr>
<td>G&amp;L</td>
<td>Godley &amp; Lavoie</td>
</tr>
<tr>
<td>GBP</td>
<td>British pounds</td>
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<tr>
<td>GE</td>
<td>General Equilibrium</td>
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<td>GST</td>
<td>General Systems Theory</td>
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<td>GVC</td>
<td>Global Value Chain</td>
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<td>IMF</td>
<td>International Monetary Fund</td>
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<td>PK</td>
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<td>NDE</td>
<td>Non-Discretionary External (expenditure)</td>
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<td>NDL</td>
<td>Non-Discretionary Local (expenditure)</td>
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<td>OCA</td>
<td>Optimal Currency Area</td>
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<td>OLG</td>
<td>Overlapping Generations models</td>
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<tr>
<td>P2P</td>
<td>Person-to-Person / Peer-to-Peer</td>
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<tr>
<td>PK</td>
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<td>SD</td>
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<td>SDG</td>
<td>Sustainable Development Goal</td>
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<td>SDR</td>
<td>Special Drawing Rights (of the IMF)</td>
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<td>SFC</td>
<td>Stock-Flow Consistent</td>
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<td>SME</td>
<td>Small-to-Medium-sized Enterprise</td>
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<tr>
<td>UN</td>
<td>United Nations</td>
</tr>
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<td>UNCTAD</td>
<td>United Nations Conference on Trade and Development</td>
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<td>WIR</td>
<td>Swiss <em>Wirtschaftsring</em> (Economic Circle), now WIR Bank</td>
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Chapter 1 Introduction

1.1 Introduction

This thesis is about the oft-ignored role of money in coordinating economic activity. It is an enquiry into the role of secondary money (complementary currency, CC) systems which may be designed to deliver desired socioeconomic outcomes. The research question is: can a parsimonious theoretical macroeconomic model be created to demonstrate the argued benefit of secondary money systems in addressing the economic problem? The question implies the need for both qualitative and quantitative approaches. Addressing the philosophical presuppositions of orthodox macroeconomic modelling is argued to be necessary in understanding the research gap — the current lack of an appropriate complementary currency model. The literature reveals such a model must be based on significantly different methodological presuppositions. When moving beyond the standard approach to macroeconomics, alternative methodological presuppositions must be justified. The nature of the topic also demands a cross-disciplinary approach, and as such the thesis may be regarded as a work of Political Economy. It is argued that the failure of orthodox macroeconomics to undertake this methodological approach has created a significant research gap.

The thesis is developed through a narrative centred around four interrelated problems in economics: "the Economic Problem" is acknowledged as the key consideration of economic science; "the Money Problem" has been offered by many figures in history (albeit rarely by professional economists) as explaining the economic problem; "the Coordination Problem" is understood as a particular
concern in economics, related to information, of which money is one part; and what is originally termed here "the Mode of Thought Problem" suggests the reason the economic problem has not been solved is largely due to a lack of appropriate ontological and epistemological reasoning, creating presuppositions which assume away the problem in the agenda of macroeconomics (and consequently the direction of government policy).

It is argued in this thesis that each problem implies a need to understand the adjacent problem in the hierarchy of abstraction, with solutions at higher levels feeding back into solutions to lower levels:

![Figure 1. Four interrelated problems of secondary money research](image)

Unless we approach the research from such a framework, it becomes extremely difficult to properly locate the nature of the research question and seek appropriate solutions in terms of both model development and policy.

1.1.1 "The economic problem"

The concept of the economic problem has been recognised for millennia, — víz. the fundamental problem of organising the production and allocation of scarce resources; yet, across the world today, unemployment, underemployment, extreme inequality, poverty, regional underdevelopment and regional hysteresis
remain evident. Keynes (1936 [2013], p.30) echoed Marx when he referred to "the paradox of poverty in the midst of plenty". Despite huge advances in global well-being and reductions in extreme poverty in the last century (Roser & Ortiz-Ospine, 2017) our existing economic system appears to allow the paradox to perpetuate. In posing "The Money Problem" Kitson (1903, p.4-5) asks why poverty amidst plenty is "as hideous as in the days of Caesar and Agricola", noting that more than half a century had passed since Proudhon had asked the same question. Over a century has now passed since Kitson's Proudhon-inspired book, and we still ask the same question.

In an age of "hyperglobalisation" (Rodrik, 2012), increasing regional disparities have appeared within developed nations, factors which have driven the rise of populism. The UK has a particularly notable disparity in terms of a fragmenting economy between London (and its hinterlands) and the rest of the UK. The orthodox government intervention for regional disparities is to allocate more money/resources to the regions, but this is costly and if not done in an appropriate manner, questions arise over secondary impacts (possibly de-potentialising the region in terms of self-sufficiency and resilience). Such intervention has been referred to as "Transactions of Decline" (Jacobs, 1984) being a symptomatic rather than a fundamental solution to the problem. From a systems perspective, the decline of regions may be recognised as an archetype of behaviour known as "success to the successful" (Senge, 1993): reinforcing feedback effect represents the heterodox economic notion of circular cumulative causation (Kaldor, 1970 [2013]; Myrdal, 1978). The typical symptomatic solution — transactions of decline — may be seen as either financial transfers or half-hearted attempts to re-connect a region with GVCs. This is also a systems
archetype known as "shifting the burden" (Senge, 1993). Despite 90 years of regional policy (attempting to shift the burden) the UK continues to be dogged by regional inequalities which have existed since at least the middle of the 19th century (Martin et al., 2016). The economists' "rule of specificity" implies the need for alternative, more directed intervention, to provide a fundamental, internal solution.

Problems of regional hysteresis are combined with an economic system that encourages unsustainable overconsumption from wealthy consumers in richer regions (Daly, 1996; Hickel, 2018; Jackson, 2009; Raworth, 2018; Victor, 2014).

The United Nations's Sustainable Development Goals (SDGs) (NEF, 2014; Sachs, 2015; United Nations, 1987; 1992; 2012a; 2012b; UNSDSN, 2014) provide a useful framework for addressing the economic problem today. Sustainable Development is often misinterpreted as relating purely to environmental concerns, whereas in fact several of the SDGs (United Nations, 2015) relate directly to the notion of the economic problem in a developed nation such as the UK, for instance:

- **Goal № 1, "No Poverty":** "End poverty in all its forms everywhere."
- **Goal № 8, "Decent Work and Economic Growth":** "Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all."
- **Goal № 10, "Reduced Inequalities":** "Reduce income inequality within and among countries."
- **Goal № 11, "Sustainable Cities and Communities":** "Make cities and human settlements inclusive, safe, resilient and sustainable."

The benefit of using the SDG framework to relate to the economic problem is that it has become a central pillar for delivering government policy (UK Cabinet Office, 2018). The fundamental solution of sustainable development is to
instigate internal solutions which address fundamental problems, encouraging resilience and totipotentiality of regions. This thesis argues that one fundamental solution at a local level represents a particular form of what has for generations been known as "the scarcity of money problem" (Wennerlind, 2011), "the money question" or "the money problem" (Johnson, 1923; Kitson, 1895; 1903; Soddy, 1931),

1.1.2 "The money problem"
"The money problem is one of the oldest and most difficult of the questions that have perplexed the human race" (Johnson, 1923). Such unresolved debates about "the nature and role of money" will define the historical chronicle of capitalism (Ingham, Coutts & Konzelmann, 2016). Money plays a crucial role in directing economic activity. Its absence or maldistribution undermines the ability of an economy to attain an optimum equilibrium. The money problem has long encouraged many from outside the discipline of economics to propose ideas and perceived solutions involving various forms of money. Early contributors include Owen (1821), Proudhon (1849 [1969]), Kitson (1895), Gesell (1918 [1958]), Douglas (1921; 1924 [1937]), and Fisher (1933). Professional economists have often disparaged them as "monetary cranks" (Clark, 2017; Dimand, 1991; Ingham, Coutts & Konzelmann, 2016; Mises, 1953; Robertson, 1928). Some of these characters were praised as the "brave army of heretics" by Keynes (1936 [2013], p.317), who "following their intuitions, have preferred to see the truth obscurely and imperfectly rather than to maintain error" (ibid.). Their ideas are not stated in the language of economics, thus they open themselves up to disparaging labels and have their ideas essentially ignored
(Clark, 2017; Dimand, 1991; Nersisyan & Wray, 2017). This criticism may still be applied to contemporary narratives of secondary monies, underlying the importance of developing a formal framework of analysis admissible within the economics community. While many ideas of a return to complementary currencies have been well conceptualised (for example Kennedy, Lietaer & Rogers, 2012; Lietaer & Dunne, 2013), "theory is way behind practice in this domain (Lietaer in Foreword to Douthwaite, 1999). This has changed somewhat in the ensuing 20 years, with some approaches better formalised (Groppa, 2013; Lucarelli & Gobbi, 2016; Stodder, 1998; 2009), yet there is still no universally applicable, theoretical economic model which may justify some of the claims made in the narrative and conceptual literature. It is a problem still not addressed in orthodox theory.

In contrast to the monetary pluralism espoused by some heterodox thinkers, the axiom of a single money unit in orthodox macroeconomic analysis remains universal but tacit. Optimal Currency Area theory (McKinnon, 1963; Mundell, 1961) has been adopted axiomatically, and in orthodox macroeconomic models, money is merely a neutral numéraire (Galí & Gertler, 2007). It has been claimed that conventional economic theory is essentially incompatible with understanding and modelling CC systems and a more pluralist approach is essential (Fare & Ahmed, 2017). Orthodox literature tends to regard the money system as a veil, or at best a problem of "financial frictions" (Vines & Wills, 2018); it is argued here that that the money problem is actually a specific form of "the coordination problem".
1.1.3 "The coordination problem"

While the problem of societal coordination was recognised as far back as the mercantilist writers, as society transitioned from a feudal system to a mercantile/commercial system, the formal concept of coordination in economics has its roots in Adam Smith (1776 [2005]). In the modern era it has most commonly been associated with the work of the Austrian School (Hayek, 1937; 1945; Klein, 2008; O'Driscoll Jr, 1977). Coordination failures are prevalent throughout economic systems and may be the economic problem that remains to be explained by economic theory (Klein & Orsborn, 2009; Leijonhufvud, 1998). What the mercantilist writers intuited was that macroeconomic coordination failure is a problem of a monetary economy; Polanyi (1944) suggests that the social bonds of spontaneous trust and reciprocation — imperatives for coordination of economic activity in the pre-monetary world — were broken in "The Great Transformation" to capitalism. Spontaneous social bonds have been replaced by formal institutional and legal constructs. It may be posited that the failure of monetary coordination was at least partly brought about by the historical imposition of a monetary monoculture (Cohen, 1998; Helleiner, 2003; 2017). If this is true, the most targeted approach to alleviate the coordination problem is the re-introduction of a more varied monetary ecosystem (Douthwaite, 1999). However, we do not have macroeconomic models which are capable of dealing with this problem as not only do the models assume money away, macroeconomics assumes coordinated outcomes (Weintraub, 1979). If the economic problem is to be ameliorated by the re-engineering of our monetary monoculture, a pluralist monetary system necessitates a re-thinking of our monetary analysis (Dodd, 2014), yet this is
constrained by a deeper issue of what may be called "the mode of thought problem" of macroeconomic modelling.

1.1.4 "The mode of thought problem"
Orthodox economics assumes coordinated equilibrium. This led to Keynes' accusation that "it cannot solve the economic problems of the actual world" (Keynes, 1936 [2013], p.378). There remains little link between the problem of monetary coordination and macroeconomics: this may be argued to be a direct result of the way macroeconomists have been trained to think. Mode of thought may be defined as "the way in which arguments (or theories) are constructed and presented, how we attempt to convince others of the validity or truth of our arguments" (Dow, 1985, p.11). If research problems do not represent "puzzles" both "interesting" and addressable within the existing paradigm they drift from the research agenda: "normal science" has no place for them (Kuhn, 1962 [1996]). Training in a particular method leads to a Law of the Instrument: a form of "trained incapacity" or inability to deal with problems which do not utilise an existing skill-set (Kaplan, 1964). What is termed here the mode of thought problem ultimately has deep roots in the ancient debate between substance philosophy and process philosophy (see Rescher, 2000): monetary analysis necessitates a process philosophy, whereas orthodox macroeconomics implicitly rests on a substance philosophy. The monetary coordination problem in orthodox macroeconomics is — as an axiom — assumed-away either by ignoring money, assuming it fulfils its functions perfectly, or making ad hoc additions to justify its role or create "financial frictions" (Backhouse & Laidler, 2004; Clower, 1967; Clower & Leijonhufvud, 1975; Colander et al., 2008; De

Kregel & Eichner (1975, p.1309), echoing Kornai (1971 [1991]), contrast the purpose of "Neoclassical [orthodox] theory", to "demonstrate the social optimality if the real world were to resemble the model", against the post-Keynesian paradigm which is to "explain the real world as observed empirically". The perceived argument for monetary monocultures may be seen as a result of the performative notion that real-world economies need to be made more like the orthodox model: pluralist money systems must be removed along with other so-called "frictions". This "Washington Consensus" type policy approach emerges from an artefact of methodology, whereas other forms of methodology — such as those variously adopted by Structuralist Economics and Institutional Economics — regard institutional structure as indispensable when understanding societal outcomes (Myrdal, 1978; Taylor, 2004b). Such structure is a function of government intervention. The orthodox macroeconomic approach for analysing monetary systems has not provided evidence for policy-driven solutions, often regarding such areas as too normative or qualitative for the quantitative "scientific" understanding deemed appropriate within the Positivist orthodox paradigm. It is perhaps ironic that a former Governor of the Bank of England suggested, "there is an old joke to the effect that economists spend their time trying to work out how something that works in practice can work in theory. The role of money in the economy offers an excellent example."

(King, 2002, p.168). The joke becomes more germane when it is understood that monetary plurality was the norm for hundreds of years prior to the political

Since the financial crisis the orthodoxy has recognised the need for change in modelling practice, although neo-Walrasian general equilibrium models seem set to remain dominant (see for example Vines & Wills, 2018). However, Rogers (1989; 2018), referencing the Hahn Problem (Hahn, 1965), claims that the addition of various financial frictions to neo-Walrasian general equilibrium models cannot overcome the fundamental perfect-barter nature inherent within the framework. Others recognise that a suite of economic models is needed to understand the complex nature of society (du Plessis, 2010; Haldane & Turrell, 2018; Rodrik, 2015; Vines & Wills, 2018). "One type is not better than the others. They are all needed, and indeed they should all interact" (Blanchard, 2018, p.44).

1.2 Research question, aims and objectives

The research question is: can a parsimonious theoretical macroeconomic model be created to demonstrate the argued benefit of secondary money systems in addressing the economic problem?

Aim 1: interpret arguments for secondary monies from across several disciplines to develop key themes and concepts relating to the economic problem.

- Objective 1.1: Review literature on history and theory of secondary monies, noting purported benefits of secondary monies and gaps in research.
**Aim 2**: establish how the issue of secondary monies is accommodated within the extant macroeconomic framework and the reason for the gap in research.

- **Objective 2.1**: Review literature on macroeconomic and monetary theory; interpret ontological & epistemological positions to help inform research design.
- **Objective 2.2**: Synthesize literature, noting limitations/deficiencies in the approaches and potential alternatives.

**Aim 3**: create universal general theory macroeconomic models of secondary money systems of various types (based on the analysis of Aims 1 & 2) to more formally elucidate existing narratives.

- **Objective 3.1**: develop an alternative framework, consciously positioned in relation existing literature and methodology.
- **Objective 3.2**: create a theoretically and empirically informed core [stock-flow consistent system dynamics] model based on stylised facts for parameterisation and simulation.
- **Objective 3.3**: build and simulate stylised models based on the institutional framework of three key types of secondary money systems to promote learning and insight.
Chapter 2 Background literature

2.1 Introduction

Aspects of the economic problem are not further elaborated here. The money problem and the coordination problem are the key aspects of the nature of money as ameliorating the economic problem. The mode of thought problem is presented as the nature of economics as a discipline failing to address these interconnected problems. They key gap in literature — the lack of a conceptual general theory model of secondary money systems in economic theory — is argued in this thesis to be a direct result of these interrelated issues. The background to the research question and the nature of research gap is explored in this chapter.

2.2 Complementary currencies

2.2.1 Motives for and research in CCs

Communities and regions suffering from unemployment, deprivation and inequality, may often regard the rise of hyperglobalisation (Rodrik, 2012) as an existential threat. These concerns may be exacerbated by more abstract concerns of Sustainable Development around peak-oil and climate change (North, 2010a). A common grass-roots response is the development of some kind of Complementary (or Community) Currency (CC), both as a form of micro-resistance but with objectives of economic and/or social rejuvenation (North, 2007), seeking to overturn a perceived imbalance in the current economic system. However, the praxis of CCs is not consistent with presuppositions of orthodox economic theory, leaving no link established between the CC
movement and economics (as an essential discipline which drives government policy).

Since the financial crisis, an extensive literature on CCs has further blossomed, giving comprehensive coverage of this niche area. CCs have their own dedicated journal, the *International Journal of Community Currency Research*, and databases of research (CC-litterature.org, 2018; CCIA, 2018b; DeMeulenaere, 2018; Monneta.org, 2018; Schumacher Centre for New Economics, 2018). A review of 30 years of literature in the aftermath of the crisis indicates it is "at the crossroads of a number of disciplines", including "development studies, local development, market exchange, Third sector or social economy, sustainable development, monetary uses, monetary spaces, sovereignty, new spaces of transaction and sociability, social movements claiming for economic transformations, social cohesion, community dynamics, women’s economic initiatives etc." (Blanc, 2012). The concept remains "difficult to grasp" within the discipline of economics (Fare & Ahmed, 2017).

Swann's (1984) Schumacher inspired essay regarding "an economy of permanence" calls for regional development using CCs as "rural areas have become colonies of the central financial system." Swann cites both Galbraith (2017) and Jacobs (1984) as highlighting the centralising nature of national currency and centralised banking. Influential books emerged in the 1990s (see: Douthwaite, 1996; 1999; Greco Jr., 1990; 1994; 2001; Kennedy, 1995; Lietaer, 2001) seeking to explain and justify the concepts, coincident with an already established practice of emerging subaltern CC systems. Douthwaite (1996) offers a wide-ranging history of the development of the movement, from the
1930s experiments of Silvio Gesell inspired systems to the development of modern CCs such as LETS (Local Exchange Trading Systems).

The first North American LETS, "Green Dollars" (Linton & Soutar, 1994), developed from interaction in a local exchange system in Vancouver in the 1970s, inspired by the "Guernsey Experiment" (Grubiak & Grubiak, 1960; McConnachie, 2003) and an Irving Fisher inspired exchange in Reston, Virginia (still operating today Reston USE, 2018). The two key instigators, David Weston and Michael Linton, had differing philosophies over the best approach to use (McConnachie, 2003); these differences over the questions of book-keeping versus scrip and the choice of numéraire (illustrated in Table 1), are highly consequential issues.

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<thead>
<tr>
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<th>Unit of account</th>
<th>Nature of money</th>
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<tr>
<td>Weston</td>
<td>Labour hours</td>
<td>Physical notes</td>
</tr>
<tr>
<td>Linton</td>
<td>&quot;Green Dollar&quot; (equivalent to Canadian Dollar)</td>
<td>Book-keeping accounting system</td>
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Table 1. Differing philosophies behind original Vancouver LETS

Weston gives a coherent critique of the established monetary arrangements in relation to the problems of flows of money around the system with a national currency, and demonstrates that the schemes developed as a modern representation of Robert Owen's (1821) labour notes (Ekins, 1986; Weston, 1985). The subsequent Ithaca Hours labour-notes currency in New York (Glover, 1986) has been one of the most high-profile CCs.

Kennedy (1995) seeks an evolution of the wider money system with local and regional experiments merely steps on the road to total system reform; the three
key approaches are: LETS; commercial mutual credit clearing (e.g., the Swiss WIR); and interest-free banking (e.g., the Danish/Swedish JAK Bank). Kennedy "channels" Silvio Gesell in a modern context, seeking zero-interest money; the problem of compound interest and exponential growth of debt is deemed central. Money is just one issue, but "it seems to be a fairly central piece of the puzzle" (Kennedy, 1995, p.42).

Lietaer argues that "four megatrends" the world faces in the 21st century can be approached with a monetary solution: "Climate change and loss of biodiversity; an unprecedented growth in the number of elderly (the 'Age Wave'); Monetary Instability; and an Information Revolution." (Lietaer, 2001). Lietaer gives the definitive definition of complementary currency as "an agreement within a community to accept a non-national currency as a means of payment [...] their intent is not to replace the conventional national currency but to perform social functions that the official currency was not designed to fulfil" (Lietaer, 2001, p.160). Lietaer also argues for the important distinction between fiat money systems, and mutual credit systems: fiat being "a currency which is created out of nothing by an authority", whereas "mutual credit currencies are created by the participants themselves in a transaction as a simultaneous debit and credit" (Lietaer, 2001, p.160) [bold in original]. This distinction between fiat money (a form of exogenous money), and mutual credit (a form of endogenous money), is why monetary systems usually have at least one type of each (and are thus inherently dual currency systems): a fiat currency establishes a numéraire by which private credit contracts can be measured.
Douthwaite's model is narrative but arguably comes closest to a full-scale conceptual model of what he terms a global monetary ecosystem involving several layers of money (Douthwaite, 1999). More recent research has broadened the market in ideas, with more examples of emerging systems in the post crisis environment (see: Boyle, 2009; Greco Jr., 2010; Kennedy & Ehrenschwender, 2012; Kennedy, Lietaer & Rogers, 2012; Lietaer & Dunne, 2013; North, 2010b; Robertson, 2012; Robertson & Huber, 2000; Rogers, 2013). All of the approaches in these books remain conceptual/narrative with no formal economic models offered.

Participants in CC systems see the benefits taking various forms, which for simplification may be broken down into the three pillars of sustainability: economic; social; and environmental (Michel & Hudon, 2015; Seyfang & Longhurst, 2013a). A fundamental argument is that where a form of recessionary or under-development hysteresis has taken hold in a particular region or locality, where market failure has limited the possibility of mutually beneficial exchange, secondary money systems of various forms may be regarded as niche coordinating mechanisms, introducing "unused resources to unmet needs" (Lietaer & Dunne, 2013). This is the nature of how private CCs (corporate scrip reward schemes) emerged, acting as information systems (Boyle, 2009, p.189). While a short review cannot do justice to the volume of literature, a broadly consistent message emerges relating to potential benefits relative to the three pillar objectives:

Economic:
- removal of the alleged growth/inflation imperative dictated by debt-based-money systems;
• potential to create an endogenous supply-side response with the increased provision of underutilised resources (in particular human capital, i.e., "full employment");
• reduced inequality;
• amelioration of regional hysteresis;
• improved national macroeconomic stability;

Environmental:
• Encouragement and increased possibilities for sustainable consumption
• re-localisation of certain aspects of trade and production which are less resource intensive;
• Reduced ecological footprints.

Social:
• reduced alienation and anomie (better mental health);
• increased socioeconomic resiliency of local communities;
• increased democratic participation;
• increased community cohesion.

The objective of removing the growth imperative (allegedly) dictated by debt-based-money systems is a broader issue within sustainable finance, and is a message which the modern CC literature has taken on-board (for example, see Mellor, 2010; 2016; Rowbotham, 2012). It has been questioned if CCs are capable of addressing this specific issue without broader reform (Dittmer, 2013) while others have queried the accuracy of the charge at all (Jackson & Victor, 2015b). This thesis does not seek to address this issue, rather being concerned with the specific regional macroeconomic implications for CCs.

Seyfang & Longhurst (2013a) divide CCs into four major types: service credits (time banks) and mutual credit exchange — which between them make-up over 90% of the total — and the less common convertible local currencies and barter markets. While books on the subject tend to be supportive of CC systems, some authors otherwise highly supportive of monetary reform are sceptical of
what can be achieved through focusing on CCs, believing a much broader reform is needed (Hutchinson, Mellor & Olsen, 2002). Evidence has been presented which questions the tangible benefits of the schemes in practice (Dittmer, 2013; Marshall & O'Neill, 2018). Seyfang & Longhurst (2013a) note the potential benefits, but recognise a fundamental clash between ideology and practical needs and the ongoing need for more research and funding to establish best practices and quantify potential benefits. Michel & Hudon's (2015) systematic review of the CC literature investigates the impacts on sustainable development, finding that the three pillars are variously served; with regard to economic impact they conclude that there is evidence of benefits on local informal employment, but there is little evidence of a significant impact on economic activity: half of the studies indicated an insignificant impact in macroeconomic terms (Michel & Hudon, 2015). However, it should be noted that all but 2 of the 48 schemes assessed were time-banks, Convertible Local Currencies (CLC), barter-systems or LETS. Arguably, none of these are designed to have significant economic impacts.

Alternatively, orthodox economics in general may be regarded as sceptical of the notion of local currencies (in economic literature the term "cranks" is deliberately used as an *ad hominem* pejorative). Such scepticism is not generally presented in formal academic papers as Optimal Currency Area (OCA) theory or money as purely a numéraire is axiomatic. The Economist (2017) claims that CCs face three hurdles: they are "a form of self-imposed economic sanction", thus narrowing choice; they have a "trust deficit" as they are not backed by government; and "having to deal with two parallel currencies imposes transaction costs" ("frictions" in formal language). What the Economist
article inadvertently highlights is that money is inherently a socio-political construct: the "trust deficit" needs to be closed if CCs are to be more widely adopted. More broadly stated, critiques may be categorised under the headings that they are: naïvely utopian; not based on economic motives; a form of protectionism; "unsustainable" (in a corporate sense); potentially inflationary; pointless; a tool for middle-class virtue-signalling. Selgin (2017) ridicules the "folly" of local money for its restrictiveness, although he concedes that "despite its inconvenience local money is of course better than no money at all".

### 2.2.2 Convertible Local Currencies

Several high-profile Convertible Local Currencies (CLCs) have been adopted in the UK. These are simply token currencies fixed at parity with — and backed by — British pounds (GBP). The CLC movement in the UK was innovated in Totnes, Devon, by the Transition Movement (Transition Network, 2018), driven more by an eco-localisation philosophy than by monetary theory (North, 2010b). The first UK CLCs were in: Totnes; Lewes; Stroud; Brixton; Exeter; Bristol; Kingston-Upon-Thames. These are often more philosophically-driven microresistance (North, 2010c). The tokens were inspired by Lietaer and examples of Berkshares and Salt Spring Dollars were taken to create a local token that could engage businesses better than the existing local LETS scheme (Longhurst cited in North, 2010c, p.147ff.). However, CLCs cannot create purchasing power (Greco Jr., 2018). Scepticism appears to be confirmed by a recent case study of the Bristol Pound (Marshall & O'Neill, 2018), ostensibly the most successful UK CLC which is supported by the local credit union and Bristol City Council. Interview-based research concluded that the scheme has failed in
its primary objective of encouraging localisation and that "those pursuing localisation should engage in a more active agenda that aims to change government policy and institutions to support an equitable, sustainable economy". The instigators wished to reinvigorate localism; it has proven to be good marketing, but the jury is out on its actual monetary economic impact.¹ There are currently no formal economic models of CLC systems, although the relative failure of CLC schemes is not surprising given a more detailed account of monetary theory explored in this thesis.

2.2.3 Mutual Exchanges
At the top of the "ladder of civilization" (Withers, 1909), book-keeping credit clearing is the predominant form of money in most countries today. However, this is not well understood because in its most refined form it is called commercial banking. Credit clearing can vary on a continuum from being small and informal Person-to-Person (P2P) schemes, to supra-national highly professional Business-to-Business (B2B) schemes. The key purpose of Mutual Credit Clearing (MCC) as a CC is to create endogenous purchasing power through flexible short-term credit creation in order to meet business needs. Such credit clearing is argued to be the future of money (Greco Jr., 2010). Greco (1990) attributes key insights about such systems to E.C. Riegel (1978): "money is an accounting system"; "money is but a medium of evidencing barter balances"; "The pure monetary medium...will be...intrinsically valueless"; "money springs from mutual interest and cooperative action among traders, and

¹ Personal conversations with the organising committee of the Totnes Pound bears this out. A similar story is told in Exeter. As of June 2019, both the Totnes Pound and Exeter Pound have ceased.
not from authority" (Greco Jr., 1990, p.39-40). The solution is a "mutual credit" or "community credit" monetary system (Greco Jr., 1990, p.40; also see Greco Jr., 2001; 2010; 2015; 2018).

Whereas a banking system creates loans in the national currency, charges interest, and often creates investment loans with long terms to maturity, an MCC system primarily creates credit in its own numéraire, against the underlying value of current trade: effectively a form of trade credit. Although it is down to the actions of members to decide when to create or redeem credits, the underlying purpose of credits implies they are supposed to clear with a degree of regularity; they are not intended as a long-term supplier of investment funds, or savings funds. Although there is ambiguity in the overlap, the smaller kind of MCC are still generally referred to as Local Exchange Trading Systems (LETS). These were the first kind of schemes to develop in the UK in the modern era and have been a widespread feature of many towns across the UK for some years. North has undertaken numerous studies of LETS schemes across the world (North, 2003; 2005; 2007; 2013; 2018). Usually the unit of account is the national currency, although this often relates to an hour's worth of labour, agreed by members. Schraven (2000) and Pacione (1997) give a historical and theoretical account of LETS; due to their small size, LETS cannot be seen as hugely relevant for the economy in turnover terms, although arguable participants to not want them to be (Peacock, 2006). Schraven suggests the economic motivations of LETS may be the business connectivity of the system, or an ability to avoid tax; the increased potential to exchange externally-non-tradeable goods is a significant reason for adoption. LETS give a low hurdle to a form of casual self-employment. However, although utopian in objectives, most
schemes suffer from lack of size, formality and long-term commitment (North, 2007). Few schemes have even survived, let alone thrived. LETS are inevitably small and informal as the underlying motivation is not pecuniary gain (Peacock, 2006). While acknowledging the LETS approach, and the earlier inspiration from the work of Josiah Warren, (a contemporary American follower of Owen and Proudhon), Greco is sceptical of a "Labour Standard of Value": a more concrete form of value is required. Greco also regards Gesell's concept of *demurrage* (built-in depreciation) as unnecessary because separating the store of value from medium of exchange function is what an efficient credit clearing system should do (Greco Jr., 1990, p.57).

Whereas LETS systems are small, focused on individuals (P2P), administered by volunteers, and are as much about social bonding as they are about trade, more commercially oriented B2B approaches are those more normally referred to as mutual credit clearing systems (or exchanges/circles). MCCs target the self-employed and small and medium sized enterprises (SMEs). Legally-enforceable contracts stop bad-debts building-up with fees to allow professional administration. The Swiss *Wirtschaftsring* ("Economic Circle") or WIR (WIR Bank, 2018) is the oldest and largest example, now covering 60,000 users across the nation and turning over more than 1bn CHF (equivalent) per year, responsible for approximately 1% of Swiss GDP (CCIA, 2018a; Studer, 1998). The WIR has inspired similar systems such as the RES in Belgium (RES, 2018), SoNantes in France (SoNantes, 2018), and SARDEX in Sardinia (Sardex, 2018), all of which are relatively early in their lifecycles. As of writing, there are no MCC operations in the UK. Econometric research into the Swiss WIR has concluded it provides a useful, primarily countercyclical stabilising
mechanism to the Swiss economy (Stodder, 1998; 2009). Stodder & Lietaer (2016) conclude that despite the relatively small size of outstanding balances, the WIR gives a disproportionate countercyclical boost to the Swiss economy, primarily through SMEs, and helps to "optimise a trade-off between efficiency and resiliency, mimicking a stable ecosystem" (Stodder & Lietaer, 2016, p.34). Sardinia’s Sardex, has been modelled in a Stock-Flow Consistent post-Keynesian model (Lucarelli & Gobbi, 2016), similarly supporting the notion that clearing systems foster stabilisation despite their small size.

2.2.4 Local Government Currencies

While absent from the modern academic CC literature, a form of local government currency is implicit in most forms of monetary reform. It is unfortunate the importance of local/regional fiscal control is absent from the modern literature, as this appears to be a fruitful path (Peacock, 2014). There have been historic examples, for example, the German inter-war Wära currency, particularly in Schwanenkirchen, and Wörgl in Austria. Arguments for such a system have clearly inspired the more limited contemporary local currency schemes (Douthwaite, 1996; Kennedy, 1995). An earlier example than the Gesellian inspired Wära and Wörgl was the original Guernsey Pound which helped coordinate the building of St Peter Port Market House in the aftermath of the Napoleonic Wars (Douthwaite, 1996; Grubiak & Grubiak, 1960; Harris, 1911). Similar to Schwanenkirchen and Wörgl, the scheme was closed down by the authorities after lobbying from two local banks (Grubiak & Grubiak, 1960, p.10) and has thus moved into secondary money folklore. Similar to Scottish and Northern Irish banks which are licensed to issue sterling banknotes,
governments of the Channel Islands (and the Isle of Man) still issue their own GBP-backed currencies which are legal tender within their domains. These are a restricted form of local government money; the backing and convertibility into GBP is guaranteed by law (although not in the Isle of Man). However, these currencies are not used actively as a tool of fiscal policy. There remains a potential for local government money to be used in an active manner, although questions over viability must be asked (Douthwaite, 1996, Ch.3). Introducing an LGC is clearly beyond the realms of grass-roots activism as it requires explicit (quite revolutionary) government intervention, potentially with new laws which both enable local governments to issue currency, and which make them legal tender in payments within a region: in our institutionally imposed monetary monoculture we have laws that seek to preclude such government intervention. In recent years the potential for a large scale experiment in the Eurozone or other troubled nations have been suggested, including a ‘Geuro’ as a secondary “fiscal currency” in Greece (Andresen, 2016; Andresen & Parenteau, 2015; Papadimitriou, Nikiforos & Zezza, 2016; Zezza, 2016).

2.3 Money: Theory & History

2.3.1 Heterodox monetary theory
Confusion reigns in economics over the nature and meaning of money (Davidson, 1972b). Paradoxically, money as a problem — a Kuhnian "puzzle" — may even be regarded as outside the domain of orthodox economics. Because CC system practitioners and promoters have little recourse to orthodox macroeconomic theory when advocating the schemes, an understanding has to be had as to where the theoretical underpinnings
ultimately lie. The CC movement has become increasingly complex and largely self-propelled, innovating and adapting schemes as people see fit (Seyfang & Longhurst, 2013b). However, the vast majority of contemporary efforts to introduce some kind of local monetary system ultimately stem from ideas which have their roots in the work of a handful of key pioneers pejoratively referred to in economic literature as "monetary cranks" (Clark, 2017; Dimand, 1991; Douthwaite, 1996, Ch.3); their ideas are increasingly supported, at least implicitly, in heterodox economic theory.

Schumpeter and Keynes (and the post-Keynesians) are perhaps the most highly-regarded proponents of not just the idea of money having real economic impacts, not least through the channel of effective demand, but also (crucially) the differential impact of different types of money and credit (Bezemer, 2012). However, this distinction is often either implicit or left undeveloped, leaving a trail to be sought back to the original sources. A key distinction lies between monetary theory in orthodoxy and more heterodox ideas relating to both the functions and origins of money, arguably defined by differing philosophical presuppositions. The relative importance of the three textbook functions of money is key — viz., unit of account, medium of exchange, and store of value.

Figure 2. Competing conceptualisations of the functions of money
A naïve approach may claim money must serve all three functions equally. Alternatively, these may be seen in a hierarchy: the core function is a unit of account; followed by medium of exchange. The issue of store of value is more nuanced. Some money may possess a long-term store of value as a property, but this is not a required function of money, merely a latent, inessential property (Ali et al., 2014). More specifically, the function of being a "temporary abode of purchasing power to be used for buying still other goods and services" (Friedman, 1994, p.6) is essential, but a long-term store of value is not just inessential but may conflict with the crucial medium of exchange role. The fundamental underconsumptionist critique of Say's Law is that money introduces a particular de-stabilising influence specifically because it is capable of being freely (and cheaply) hoarded rather than spent. In times of deflation, the shortage of money means that money-hoarding is subsidised by increased real interest rates.

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<th>Theme</th>
<th>Researcher associated with theory</th>
<th>Theory</th>
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<tr>
<td>Barter</td>
<td>Menger</td>
<td>Metalism</td>
</tr>
<tr>
<td>Tribute</td>
<td>Laum</td>
<td>Chartalism</td>
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<tr>
<td>Quantification</td>
<td>Simmel</td>
<td>Cultural Alienation</td>
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<td>Mana</td>
<td>Mauss</td>
<td>Human Economy</td>
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<tr>
<td>Language</td>
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<td>Digital Money</td>
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<tr>
<td>Violence</td>
<td>Aglietta &amp; Orléan</td>
<td>Social Power</td>
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Table 2. Origin Myths of Money, adapted from Dodd (2014, p. 47)

Dodd (2014) gives an interdisciplinary perspective of the key broad "Origin Myths" of money (Table 2). While useful in the broader context of sociology and anthropology, Goodhart (1998) draws attention to the importance of the two principal origin myths dividing much economic thought: Chartalist (or Cartalist)
is C-Team/C-Theory; the Metalist / Mengerian is the M-Team/M-Theory. Mises (1953) refers to these as the acatallactic and catallactic theories of money, respectively (catallactics being a preferred Austrian School term for the science of exchange). Similarly, Bridel (2014) distinguishes between trust and authority. Goodhart argues the C team "does far better in explaining and predicting historical reality than the M team" (Goodhart, 1998), concluding that focus on M-theory is driven by methodology and ideology rather than empirics (Goodhart, 1998). Keynes stated that "To-day all civilised money is, beyond the possibility of dispute, chartalist." (Keynes, 1930 [2011], p.5). Menger (1892 [2009]) defines money as emerging from a market search process, hence Mises (1953) regards catallactic theories as the only correct approach to money: the acatallactic theories of money are not merely inferior but simply wrong. It becomes clearer why the money problem "has been the great social riddle for centuries" (Kitson, 1903, p.xxi).

M-theory regards money as neutral (at least in the long-run) and recognises both the numéraire function of money and the store-of-value property as of key importance. In contrast, heterodoxy adopts C-theory, regards money as never being neutral and alongside the function of numéraire, regards the medium of exchange role as essential: the (long-term) store of value antagonises this role. The various hypotheses which emerge from heterodoxy represent a qualitatively different issue to the principal questions considered in orthodoxy.

Heterodox economists regard money as a remarkably amorphous social concept: an abstract unit of social accounting which can be readily applied to some form of reproducible, transferable and excludable tokens (or book-keeping entries) (Keynes, 1930 [2011]; Schumpeter & Swedberg, 1991). Money
can only be understood in relation to its broader socio-political and historical context (Foley, 2016; Schumpeter & Swedberg, 1991). Keynes (1930 [2011]) gives, arguably, the definitive statement of heterodox monetary theory:

1) A **Money-of-Account** (numéraire) is the "primary concept of the theory of money"

2) Money-of-account comes into existence alongside **Debts** and **Price-Lists**

3) Debts (expressed in the money-of-account) can be recorded verbally, by book-entry, baked bricks or paper documents

4) **Money-Proper** is a means of discharging debts and can only exist in relation to the money-of-account

5) Money-proper is also a store of **General Purchasing Power**

6) A medium of exchange not related to the money-of-account may "approach to being Money, inasmuch as it may represent a means of holding General Purchasing Power", but "if this is all, we have scarcely emerged from the stage of Barter".

7) "Money-of-account is the description or title and the money is the thing which answers to the description."

8) By introducing debt contracts, **Law** is introduced, thus the **State or Community**

9) The state or community enforces delivery, but also decide what must be delivered on a contract concluded in terms of the money-of-account
   - "This right is claimed by all modern States and has been so claimed for some four thousand years at least."
   - This is **Chartalism**.

Money emerges in a wholly **acatallactic** process, viz., the abstract measure of value/unit of account is institutionally constructed and usually enforced — "for some four thousand years at least" (Keynes, 1930 [2011], p.4) — by the State.

Simply put: someone in power (authority) creates a debt-obligation on its citizens, then tells them what to pay that debt with — this becomes money,
enhanced by the network effect of exchange. Heterodox theories follow this logic and recognise that money primarily "emerges" not from a search process, but by socio-political design (Ingham, 1996; 2000; 2004). It represents the imposition of a decision by authorities which is initially imposed by legal means (primarily the function of taxation), but which subsequently becomes a social norm abstracted from the legal imposition. The heterodox position is given overwhelming historical evidence by Zarlenga (2002) and Hudson (2004). Society shapes money, and money shapes society (Dodd, 1995; 2014). However, "the Myth of Barter cannot go away because it is central to the entire discourse of economics" (Graeber, 2012, p.43); orthodox economic theory of all stripes still suffers a barter hangover (Smithin, 2003). Anthropologists have long studied money and comport with more heterodox approaches in economics (Crump, 1981; Graeber, 2012; Grierson, 1977; Quiggin, 1949). Although barter certainly did exist in some form, it primarily took place as a particular socio-cultural phenomenon, under external conditions of trade either when social institutions and trust broke down, or when trade was carried out beyond the boundaries of social institutions and trust in times of war and foreign expeditions (Graeber, 2012). A recent collection of essays (Bandelj, Wherry & Zelizer, 2017) inspired by the work of Zelizer (2017) demonstrates the cross-disciplinary perspectives on money that have flourished since the financial crisis, with a broadly psychological-sociological and anthropological perspective.

2.3.2 "Monetary cranks"
The theorists who have proposed alternative monetary schemes throughout history are often pejoratively referred to as "monetary cranks" in economic
literature (Clark, 2017; Dimand, 1991; Fontana & Sawyer, 2016; Ingham, Coutts & Konzelmann, 2016; Nersisyan & Wray, 2017; Vernengo, 2012). Fontana & Sawyer (2016) echo a distinction Dimand (1991) attributes to Keynes distinguishing between heretics, who "advance their arguments by using alternative theories, policies and methodologies to mainstream economists", whereas cranks "base their arguments on analytical errors." However, it is not clear such an obvious distinction exists. These theorists initially arose alongside early economics in the time of the "Pamphleteers" (Schumpeter, 1954, p.146), but the ideas spread particularly during the latter part of the 19th century and the inter-war period of the 20th century. An exhaustive list would be extensive, but for purposes here they may include: John Law; Robert Owen; Pierre-Joseph Proudhon; Arthur Kitson; Silvio Gesell; Clifford H. Douglas; and Frederick Soddy. There are clear links in thinking between this group and economists' heterodox monetary theory, with a genealogy of ideas which repeat through history.

John Law (1705) was the original formaliser of the non-neutrality of money concept, that, following Blaug (1999, p.20), may be referred to as Law's Doctrine (also see Aschheim & Tavlas, 2004). Law was "the best exponent of the doctrine that 'money stimulates trade'" (Blaug, 1999, p.20-21). What precedes Law (in Niehans' terminology) is "commonplace economics: 'the zero point of economic progress.'" (Clower, 1998a, p.398) [emphasis in original]. Law's position was extended by his colleague Richard Cantillon, arguing that money can have real impacts on economic activity according to the source of the money and how it flows through the economy (Cantillon, 1755). Such
impacts of changes in the quantity of money in the real economy are now referred to as Cantillon Effects (Blaug, 1999, p.21).

Frederick Soddy regarded Kitson as "the doyen of British Monetary Reformers" (Soddy, 1934, p.222); both Kitson and Gesell were directly inspired by Proudhon (1849 [1969]) who in turn was inspired by Owen's Labour-Theory-of-Value-derived notion of using labour notes in exchange (Owen, 1821). Owen rejected gold and "paper" [fiat money] as standards of value, although realisation of Owen's scheme necessitated a much wider application of utopian socialist ideas which floundered in practice. Owen in turn was inspired by the earlier work of John Bellers (1696), a Quaker reformer whose utopian idea of building a work and education-based community had at its heart a plan of using labour-notes to facilitate internal exchange within the community (Douthwaite, 1996). Douglas's Social Credit (Douglas, 1921; 1924 [1937]) was initially an English movement which inspired legions of followers in the 1930s with close affiliations to Guild Socialism (Hutchinson, 1998; 2002) and the "Green Shirts" Social Credit Party (Green Shirt Movement for Social Credit, c.1935). There are "striking similarities between the Social Credit ideas of Major C.H. Douglas and the 'petit-bourgeois radicalism' of Proudhon." (Edwards & Fraser, 1970, p.35). Douglas is most well-known for his "A + B theorem" which is essentially a critique of Say's Law, where profit is accumulated and not paid out and recirculated into consumption. This concern has been echoed today by both Solow (2008) and Hawking (2016), especially applicable as automation increases. Douglas's theory was attacked for not being well formulated (Keynes, 1936 [2013], Ch.23).
Soddy wanted whole system reform, directly impacting the early Chicago School, including Frank Knight and Henry Simons (Ballinger, 2013), later to influence Irving Fisher (Fisher, 1936) in calling for full-reserve banking. Gesell had a profound impact on Keynes' thinking and is perhaps the most regularly cited as having a direct impact on the CC movement, specifically because of the semi-mythical status of the "Wörgl Experiment" which he inspired (Schwarz, 2011). His *demurrage* ("rusting" or "stamped") money was argued to be key to rob money of its store of value function, thus forcing its primary role as a medium of exchange and helping re-establish Say's Law in a monetary economy. Wära stamped-currency were used to restore employment to the Bavarian coal-mining town of Schwanenkirchen in 1931 before the scheme was closed by the German authorities (a scheme referenced by The Economist as a potential response to the financial crisis (Economist, 2009)). The "miracle of Schwanenkirchen" influenced the town of Wörgl, which put into practice a municipally-run CC system. This appeared to perform miracles in the few short months it was allowed to exist, yet the scheme was closed down by the Austrian authorities (Blanc, 1998; Douthwaite, 1996; Kennedy, 1995; Schwarz, 2011).

Keynes argued (as had Soddy before him Soddy, 1934, p.182) that Gesell's idea of demurrage money is sound but logically limited: "The idea behind stamped money is sound. It is, indeed, possible that means might be found to apply it in practice on a modest scale." (Keynes, 1936 [2013], p.357). This was the acid test of the theory, that a modest scale — *i.e.*, a secondary currency — was implied, because faced with guaranteed depreciation, people would avoid the currency and seek-out other stores of value. Gesell was not only aware of this issue, he was inspired by the experience of early Medieval coinage
(bracteates) (Douthwaite, 1996). However, Gesell's depreciating money could only thrive when other forms of money were in locally short supply and a second-rate money (a limited medium of exchange minus the long-term store of value) was needed. His theory influenced Irving Fisher to introduce schemes into the US during the depression (Fisher, 1933) copying the earlier schemes in Germany and Austria. Recent debates on the problem of the "Zero Lower Bound" of interest rates in monetary policy are inadvertently reviving Gesell's call for negative interest rates on a wider scale, rediscovering earlier arguments for dual national currencies in the process, albeit not currently modelled (Meaning et al., 2018; Rogoff, 2017).

Gaitskell reviews much of the heretics' work and concludes that "the ideas of monetary heretics are frequently vague or complicated and not as a rule expressed in the clearest possible manner [...making] the task of criticism tedious and difficult." (Gaitskell, 1933, p.412). Mises agrees that "so long as they remain nebulous, they offer nothing for criticism to seize upon." (1953, p.93). Keynes argued that because of this they open themselves up to disparaging labels and have their ideas essentially ignored (Bezemer, 2016). Keynes believed supporters of monetary reform "must expound their arguments more fully, more clearly, and more simply, before they can overwhelm the forces of old custom and general ignorance" (Keynes, 2010, p.193). While the reformers may have been right, they made no impression on orthodoxy because they lacked a method (ibid.).
2.3.3 The Law-Proudhon-Gesell-Keynes Doctrine

The essential message that carries from *Law's Doctrine* to Keynes and the modern-day post-Keynesians is that money matters. While not an original observation, what is perhaps less well understood is that it is both the quantity and form of money that matters. There are noted links between the economics of Law and Keynes which give insight into the broader context of macroeconomics (Hanke, 2009; Hayek, 1976; Murphy, 1997; Wilson, 1948). Keynes' long "ode" to Gesell (1936 [2013], p.353ff.) gives remarkable insight into Keynes' thinking and development of his ideas central to this thesis. *The General Theory* was more influenced by Gesell than is commonly acknowledged. Preparata (2002) argues that Keynes essentially plagiarised Gesell's ideas, but reshaped them into a less radical agenda. Gesell's ambition was ultimately the same as Keynes, viz. to attack rentier capitalism; Keynes was therefore also indirectly influenced by Proudhon (Dillard, 1942). Keynes may equally have said that the future will learn more from the spirit of Proudhon than Marx, as that is explicitly the framing Gesell gave it, citing Proudhon: "Money, you imagine, is the key that opens the gates of the market (by which term is meant the exchange of products), that is not true — money is the bolt that bars them." (Proudhon quoted in Gesell, 1918 [1958], Introduction).

Proudhon's contribution to economics was essentially recognising the triangular nature of trade that overcame barter (Proudhon, 2002): the need for a form of socialisation of exchange (rather than production), abolishing interest and "money" (in the form of precious metals), replacing this with a mutual credit bank (Lu, 1922, p.98-101). Whereas the success of Owen's "National Equitable Labour Exchange" was undermined by its utopian insistence on valuing labour
equally regardless of effort (Boyle, 2000) (a similar limitation applies to modern LETS), Proudhon's bank took a more pragmatic approach and issued notes backed by market goods and services (Proudhon, 2002). The short-lived "Bank of the People" was closed down when Proudhon was imprisoned for sedition (Dana, 1896).

Wilson (1948) draws a favourable comparison between Law and Keynes. Law was similarly animated by an anti-rentier philosophy (Buchan, 1997). Proudhon, Gesell and Keynes regarded the claims for there not being enough money as being merely to protect the rentier class. Gesell's Crusoe parable illustrates how the store of value function of money (with positive interest rates) is at the root of the economic problem (Gesell, 1918 [1958], Part V). This had a profound impact on Keynes (Preparata, 2002). Much earlier, Francis Bacon had noted that "money is like muck, not good except it be spread" (Bacon, 1908, p.67). Dillard (1948, p.298) argues that Keynes was also influenced in his monetary heterodoxy by "the Ricardian socialists, the mercantilists, and even of the canonists".

Jevons (1875 [1898]) had appreciated the validity of the concept of book credit banking: anyone can set-up a book-credit system, yet the problem is getting anyone to accept the IOUs that are issued. This has been perhaps best recognised as Minsky's dictum that the workings of the economy determine what is money in a hierarchy of money, with different monies for different purposes: "everyone can create money; the problem is to get it accepted" (Minsky, 1986 [2008], p.255). The different varieties of mutual credit clearing relate to a hierarchy of simple social book-keeping that extends from P2P LETS
all the way up to the trans-national universal banks. The primary differences relate to the numéraire, regulations, collateral, and ability to issue loans. Getting people to accept this money should be understood from the perspective of heterodox theory as a function of the socio-political institutional framework imposed on society by choice, not as a result of a market process.

2.3.4 Money and space: Optimal Currency Areas vs secondary money
Rather than the single money postulated (often only implicitly) in orthodox theory, it is clear that several types of money may exist side-by-side in an economy at any one time. Optimal Currency Area (OCA) theory (McKinnon, 1963; Mundell, 1961) regards an OCA as a geographic region "defined in terms of internal factor mobility and external factor immobility" (Mundell, 1961, p.661). McKinnon (1963) defines the objectives as full employment with a stable internal price level and external balance. The posited advantages are clear yet difficult to quantify (Krugman, 2012): reduced transactions costs; elimination of currency risks; transparency; and (possibly) greater competition. The primary disadvantage a loss of flexibility of what may be called "stabilisation" policies (resilience) (ibid.). While resilience implies a need for more currencies, efficiency implies a need for a single world currency, something JS Mill argued for (Mundell, 1961, p.662). Mundell was conscious that "the classics" regarded a need for stabilisation policies as irrelevant, hence "multiplying the number of currencies entailed only a cost" (Cesarano, 2006b, p.713). As many currencies are needed as relates to the relative degree of mobility/immobility of factors (especially labour) (Mundell, 1961, p.664), thus, regional inequalities are likely to remain in regions without appropriate mobility: a point Lerner (1944, p.375)
had earlier noted. Lerner suggested towns and sub-national regions could have their own currency (Lerner, 1944), although he never followed-up this research, regarding simple factor mobility and fiscal redistribution as the key issues (Scitovsky, 1984). Lerner had ideas as radical as individual industries introducing their own currencies but, again, did not follow-up these ideas in his research (Cesarano, 2006b).

In common with orthodox macroeconomic theory, reference to "currencies" in OCA theory relates to the unit of account (numéraire) function: it is inefficient to have multiple units of account. The medium of exchange function is not considered. Goodhart (1998) critiques OCA theory suggesting that subscription to M-theory as natural if the origins of money are purely seen in terms of minimising transactions costs (which is implied if only a numéraire is considered). However, C-theory recognises that "spatial determination of separate currencies has almost nothing to do with such economic cost minimisation and almost everything to do with considerations of political sovereignty" (Goodhart, 1998, p.409). This is more fully argued in International Political Economy (for instance Cohen, 1998; 2004; 2015; Helleiner, 2003) and tacitly accepted by the OCA literature (Broz, 2005). The monetary monoculture existing in most nations today is a deliberately engineered outcome undertaken largely during the nineteenth century for political reasons (Cohen, 1998; Helleiner, 2003; 2017). Nation-states developed alongside, and as a corollary of, national fiat currency; specie-coinage of international repute circulated as a means of facilitating trade as a more efficient replacement of international barter. The development of money and credit had a defining role in underpinning Britain’s rise to global power (Wennerlind, 2011). The chartalist
approach to create a national credit system was literally an extension of alchemical reasoning, driven by the Hartlib Circle (an early "think-tank"), and was crucial to the monetary revolution which took place in Britain during the early industrial revolution (ibid.).

There remains a question as to whether or not Britain itself represents an OCA (see for example Deutsche Bank, 2013). With high labour mobility and a centralised tax system enabling fiscal transfers, Deutsche Bank (similar to Lerner(1944)) concludes that separate regional currencies are ultimately not necessary as the benefits still outweigh the costs for the UK to issue separate currencies; Deutsche Bank, however, concur with the perspective that "currency unions are a function of politics and not economics" (ibid.). The notion of separate primary regional currencies should be recognised as a related but distinct research question. Jacobs and others have argued that city regions would make better currency zones (Griffith, 2016; Jacobs, 1984), or at least that cities could support their own secondary currency (Boyle, 2000). Bordo & James (2006) argue that the "Newtonian" concept of OCA needs to be replaced with an "Einsteinian" money system, more capable of accommodating shocks.

In contrast to monetary monocultures and OCA theory, multiple money systems co-existed in history, and were primarily determined by deliberate actions of the state to serve the purpose of flexibility (Amato, Doria & Fantacci, 2003; Amato & Fantacci, 2012; Fantacci, 2005; 2008; Kuroda, 2008; Zarlenga, 2002). Graeber (2012) has highlighted that various forms of formal and informal credit relationships have existed for thousands of years. The use of multiple media of exchange was common in the US until the 1930s (Craig & Waller, 2000).
Zarlenga (2002) attributes plurality to political choice: the most successful systems in history were those which involved a powerful State combining internal and external (often precious metal) monies. Yet modern society is largely unmoved by arguments over multiple monies, perhaps because of our long-established laws and institutions. Government fiat money — cash notes and coins — is a different money to the liabilities emitted by commercial banks (bank deposits) which, for most people, act as our every-day money (Mitchell Innes, 1913; 1914; Ryan-Collins et al., 2012). The fact that these two monies are deemed fungible, and exchangeable — without question — at equal value, is not an inherent property of a dual money system, but an indication of how our customs, institutions and regulations have normalised this system. This system is clearly underpinned by regulations, including deposit insurance and the *quid pro quo* privileges of regulated banks.

Renaissance Europe had its own monetary system which illustrates a deliberate dual money system where the functions of unit of account and medium of exchange were split: one money, the *libra solido denarii* (introduced across the Holy Roman Empire by Charlemagne in the 9th century, and as pounds, shillings and pence in Britain, by King Offa) was purely a numéraire, allowing the measure of trade and transactions; the second money, primarily coinage, but also book-credit, actually carried out the transactions (Fantacci, 2008). Coinage was itself hierarchical: some denominations were "black money" penny coins of no intrinsic value but which accorded to the £/s/d scale; these circulated alongside both "white money" silver shillings, and gold coins which generally accorded to pounds, but did not exactly match. For example, the gold Guinea was supposed to equate to 4 silver crowns (or £1 as a numéraire) but
did not always do so because of the varying bimetallic ratio driven by
international arbitrage. Small-denomination black money coins were used for
local transactions. Silver coins were primarily used for intra-regional (e.g.,
urban-rural) transactions and wholesale trade. Gold coins were essentially trade
coins for international transactions which had a nominal ("extrinsic") domestic
value but when used in international transaction were valued purely in terms of
their lower ("intrinsic") specie or "collateral value". In modern language,
oscillation between extrinsic and intrinsic value of money was not a bug, but a
feature of the dual currency Renaissance monetary system. Both spatial and
temporally-driven (e.g., seasonal) exchange may have necessitated multiple
monies (Kuroda, 2008). Towns or regions dependent on interregional trade
tended to use a monetary unit detached from their more "domestic" coinage
designed for internal use in the locale. The distinction between English Country
Bank and Bank of England notes in the early 19th century, though they were
fungible, they may have represented two complementary monetary circuits,
more suited to the flexibility of local demands (Kuroda, 2008). A similar system
worked this way in Sweden (Engdahl & Ögren, 2008).

comprehensive accounts of the development of money, credit and banking in
Britain and Europe from the late middle-ages through to the industrial
revolution. Other than technology, the essential business of banking has
changed very little. Bills of Exchange were essentially a mutual credit scheme
between merchants and acted as the primary medium of international trade
during the latter middle-ages up until the 19th century. This was credit given
institutionalised trust by a network of financiers. While these bills may not
necessarily be recognised as medium of exchange, Medieval trade fairs were essentially credit clearing opportunities. The numéraire was denominated in £/s/d, while the credit was akin to an early form of personal cheque. Coinage (either base metal, silver or gold) were generally not required, other than perhaps in netting-out transactions at the end of the fair. Such money forms are restricted to their particular network of exchange, and are thus wholly reliant upon it (Goodhart, 2005). Although desirable, it is not necessary that the credit relationship within a particular network (of institutionalised trust) must be capable of being transferred outside of that network (or circuit) — e.g., a tribe, village, nation State or merchant network. Where various money forms have circulated side-by-side historically, the regulations of government can either aid or hinder adoption of the potential monies. The relatively modern "Westphalian Model" of one-nation-one-currency is now breaking down (Cohen, 2004). Our current monetary monoculture has been imposed into a social system which naturally requires several differing money systems serving different purposes in order for the economy to thrive (Douthwaite, 1999). We may call the alternative pluralist vision — historically, empirically more validated — a monetary ecosystem.

Regional theory in economics maintains the orthodox neutrality of money axiom (Bieri, 2017a); such moneyless regional theorising in contemporary economics is a product of the "microfoundations-equilibrium transformation" of orthodox theory, which has created "new neoclassical urban economics (NNUE)" (ibid.). It is in geography that the spatial nature of monetary relations has received more attention. Following Harvey (1978), Leyshon & Thrift (1997) offer an analysis of the socio-spatial nature of money, although, as Martin & Pollard
(2017) argue, a return to the somewhat lost art of a study of the geography of money is crucial in understanding not just the expression of money and geography, but its constitutive nature: "spatiality is integral to money, in the forms it takes, the organisations through which it is institutionalised, the ways in which it deconstructs, reassembles and distributes assets, liabilities, risk and indeed, conceives of time and space" (Martin & Pollard, 2017, p.1). Such a return has been long in the offing (see for example Martin, 1999; Martin & Pollard review recent literature in this space, acknowledging the inexorable connection between financial-regulatory structure and (sub-national) regional development. A simple narrative monetary analogy of needing to "plug the leaks" of a regional monetary bucket has been made before by the New Economics Foundation (Ward & Lewis, 2002). The leakiness of the local economy bucket is exacerbated by the productivity-seeking, efficiency-driven tendency towards centralisation of production and ownership: non-discretionary consumer spending on basic necessities such as mortgage interest payments, rent, utility bills, food and clothing is increasingly likely to leave the area. The leakages in the bucket are monetary transmissions of value through space. Absentee landlords are the best example of contractually defined monetary leakages to the local economic system. Cantillon (1755) was the first to recognise such issues and the threats of economic leakages when monetary questions are placed in a spatial context: "all the lands in the state contribute, more or less, to maintain those who dwell in the capital." (Cantillon, 1755, p.39). He recognised that hysteresis could set in due to some exogenous shock, the example given being the royal court (big business of the day) deciding to move: "If a sovereign leader leaves a city to establish residence in another, nobles will
follow him and locate their residence with him in the new city, which will become
great and important at the expense of the first." (ibid.). Separate classes may
not participate in a local economy at all, but may have a large negative impact
on the quantity of money circulating locally if they are contractually taking one
third of the income of the local community. It was the increased adoption of
monetary exchange, landlordism and capitalism (*money-ownership* in 18th
century terminology) that allowed monetary accumulation to be spatially
separated from the area of production. Cantillon’s point has, as Harvey (1978)
demonstrates, potentially radical Marxist undertones.

Bieri (2017a; 2017b) details this more modern interpretation of what was
essentially Cantillon’s key thesis, relating the discipline to what the terms the
*Lösch-Isard synthesis* (after August Lösch and Walter Isard) "a hitherto
neglected aspect of spatial monetary thinking" (ibid., p4), combining the
heterodox notions of chartalist and hierarchical monies. Lösch recognises the
inherently hierarchical nature of money has spatial implications; Isard
recognises the linkages between stock-flow accounting analysis and input-
output analysis at a regional level; this synthesis offers an interesting new
research space going forward (Bieri, 2017a). While post-Keynesian theory is
primarily aspatial in its analysis, and orthodox theory has ignored it, Marxian
analysis (such as Harvey (1978)) provides a useful framework to address the
real-money-regional nexus (Bieri, 2014). Blanc et al. (2018) suggest that post-
Keynesians generally only have an implicit interest in monetary plurality,
although Dow (1993), echoing aspects of concern to Kaldor (1970 [2013]),
reminds that post-Keynesian economics is not blind to the spatial nature of
money, banking and finance, and recognises the need for policy intervention if
cumulative causation of the "core-periphery" problem within the nation is to be avoided. Martin et al. (2016, p.17) regard the UK's overly centralised financial system as a "consistent and deeply entrenched cause of spatial imbalance within the UK".

2.4 CC Design Principles & Conceptual Ordering of Themes

The literature on praxis and theory may allow some development of key themes for later model development. The general failure to adopt or sustain a more pluralist system in the 21st century arises from a failure of support from government. Minsky's problem highlights that indeed anyone can create money, but the problem of getting it accepted is largely a function of legal and institutional practice. The regulatory environment supports a monetary monoculture dominated by universal banks. Macroeconomic theory helps legitimise this system, with no theory to justify appropriate support of CC systems. Gomez (2018) outlines four key design principles for CCs; they are based on "empirical historical data and several theoretical considerations" (ibid., p.286):

1) An institutional framework needs to be adopted and encouraged by government actors;
2) There needs to be a public understanding and commitment as to the purpose and design of the CC which encourages adoption;
3) Any currency should respect its purpose to be used within a particular monetary circuit for a particular purpose — this is the notion of plurality and complementarity;
4) When there is no other money available (in appropriate quantities), the purpose of a secondary money needs no further justification in terms of comparing preferences or transactions costs.
Douthwaite (1999) proposes a "Who? What? When? Where? Why? and How?" approach journalists use. Initially we must ask "What is the purpose of the proposed money?" The three types of CC later modelled in this thesis are specifically for local economic resilience or recovery in times of underemployment. They are a form of money designed primarily to have an economic impact. Each is intended to serve solely as a medium of exchange for local transactions. Some conceptual ordering is required to determine the features required for a monetary system. It is this inherently institutional framing of money systems which require structures to be in place which must be treated as exogenous assumptions of the socio-political context. Some of the questions that need to be addressed when assessing such currencies are:

- Who is responsible for the monetary infrastructure?
- Do the organisers make a profit (or cover costs)?
- What power or authority do they have?
- Are the money issuers prepared to accept their issues back at face value?
- What *underlying* value does the money have or represent?
- Is the creation of money endogenous or exogenous (or both)?
- Is the money creation endogenous to the creation of underlying value, or exogenous to it?
- Is there collateral backing?
- Is the unit of account different or fixed with primary national currency?
- If the unit of account if fixed, how is this maintained/guaranteed?
- What physical form does the money take?
- Are transactions recorded — is credit monitoring required?
- Can contracts be legally enforced?
- Is the money intended to stay in circulation permanently?
- How can it be withdrawn?
These are the primary parameters to which any proposed currency should be able to conform and any analysis should consider as relevant. It is these conceptual themes which have to be interpreted in the form of structural and behavioural assumptions when building theoretical economic models. These themes will be addressed for each of CLC, MCC, and LGC in the modelling section.

2.5 Gap in Literature (part 1)

There is much narrative and qualitative research across various disciplines on the nature and role of contemporary CC systems: formal, general theory macroeconomic modelling is absent. Mental/narrative and qualitative approaches proliferate outside of economics, but the underlying theoretical justifications are not articulated within the formal language of economics. The zero-lower-bound problem of interest rates has reignited some interest in dual currencies (Meaning et al., 2018; Rogoff, 2017), but so far this discussion remains both narrowly-focused on central bank digital national currency, and purely narrative hypothetical accounts. The problem of CCs has otherwise been implicitly solved by assumption or completely ignored in orthodox economics, with a distinct lack of monetary plurality in orthodox economic theory (Blanc et al., 2018). This is a consequence of "the mode of thought problem", and is the fundamental gap in literature. There are some specific approaches within heterodox economics which may serve as a springboard for research.

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2 Legal restrictions, such as those imposed in the Treaty of Lisbon, are a complicating factor for those who seek to implement secondary currencies. The nature of such restrictions is abstracted from here not just because there are complex ambiguities in the legal status of CC providers, but because legal restrictions can (and likely should) be adapted to the underlying economic argument, rather than behave as restrictions on currency innovation.
Douthwaite has a fairly comprehensive programme of reform for a monetary ecosystem of various currencies for different needs, although this remains purely narrative and is not a formal model (Douthwaite, 1999). Some empirical evidence, such as regarding the WIR (Stodder, 2009; Stodder & Lietaer, 2016) and Argentina (Colacelli & Blackburn, 2009), has been developed in econometric models which help demonstrate that there are potentially useful gains to be had when such systems emerge. However, econometric case studies do not represent the general theoretical model sought here. A few specific models combining theory with empirics have been developed in alternative frameworks. These are reviewed at the end of the next chapter, after establishing why the broader gap exists, and how it may be closed.

2.6 Chapter Summary

This chapter has developed a background to understanding the motivations for CC systems and the nature of the underlying history and theory of money plurality. Money in history has clearly been more pluralist than it is today, and this plurality has been the result of institutional design, not a naturally emergent process of individual agency. Today’s monetary monoculture must also be understood as a product of institutional design. A clear gap in literature emerges as while there is much narrative and empirical evidence of complementary currency systems, there remains no general theory economic model. In order to address the gap, the reason why it exists, and has persisted, needs to be understood. This is the objective of the next chapter.
Chapter 3 The methodological gap

3.1 Introduction
The gap in the literature has been identified: essentially there is no theoretical formal macroeconomic model which seeks to develop a general theory to address the problems of a monetary monoculture by recreating a pluralist monetary ecosystem. There is a need to understand why this gap exists in order to inform the research design and methodology to develop the models in this thesis. This chapter looks at the theoretical and methodological issues that have created the gap in research and reviews some of the research in heterodoxy which has (implicitly at least) tried to partially fill it.

3.2 Money and coordination in theory

3.2.1 Money as a veil?
The problem of coordination in a monetary economy was of central concern to the so-called paper-money mercantilists, Law and Cantillon (Eagly, 1974) and 17th & 18th century mercantilism more generally (Grampp, 1952; Heckscher, 1935). Modern economic theory assumes away the "scarcity of money problem" which was at the core of earlier political economy (Wennerlind, 2011). While money is narratively (qualitatively) presented as overcoming the coordination failures of barter, coordination failure in a monetary economy is "habitually solved by assumption" (Backhouse & Laidler, 2004, p.48). The misrepresentation of mercantilism as suffering from a "Midas Fallacy" (primarily attributable to Smith and Say), set political economy on the wrong track for generations (Coutinho & Suprinyak, 2018). The paradox is at the heart of the
"Keynesian Revolution" money is needed to overcome the inefficiencies of barter, but "the very existence of money is likely to render Say's Law invalid." (Tarshis, 1987, p.5498). Keynes was putting money back on the agenda for understanding the macroeconomy (Kohn, 1986), yet Goodhart claims that after working 50 years in monetary macroeconomics it is "in a worse state than when I initially found it." (Goodhart, 2014, p.78).

Michael Linton may be justified in complaining that "just as fish don't see water, economists don't see money" (Linton & Soutar, 1994). Hume gave monetary theory its dichotomisation through assumption, referring to money as "the oil which renders the motion of the wheels more smooth and easy" (Hume, 1752 [1906], p.27). The concept that money is merely a veil and fundamentally unimportant (Pigou, 1950; Robertson, 1922) is perhaps the most well-known expression of the role of money in orthodox economic theory. At the beginning of the Rational Expectations Revolution Lucas declared that "money is a veil" (Lucas Jr, 1972, p.121) [emphasis in original]. Classical theory involved a qualitative understanding that money did have an effect, but a quantitative one where the economy approximated barter, and money was neutral (Samuelson, 1968). Rather than a lubricant, money is like a catalyst in a chemical reaction, and "only an iota of catalyst is needed for the process" (Samuelson, 1968, p.3). This indicates that understanding and formal theory do not always comport. Incorporating money into theory may be regarded as "naggingly untidy" or "endlessly challenging", and "is, at best, incomplete" (Friedman & Hahn, 1990). This is why, following a kind of Kuhnian path of least resistance, orthodox macroeconomic has "solved" the problem by assuming it away. Orthodox models which assume coordination tend to either ignore money, assume it
functions perfectly, or create an inessential role for money as a modelling artefact. Even the simplified IS-LM framework is moneyless: the "mutant 'Keynesian' neoclassical synthesis" (Davidson, 1978) bowdlerised the notion of the preeminent role of historical (causal) time and money in Keynes' macroeconomic analysis, thus Hicks became "dissatisfied" with the IS-LM framework he helped beget (Hicks, 1980). The approach has enabled genuine progress, but at the cost of nuance, historical appreciation and narrative approaches (Backhouse & Laidler, 2004). Such a framework is unsuitable for the kind of analysis required.

3.2.2 Orthodox monetary theory

The New Palgrave compendium on Monetary Economics (Durlauf & Blume, 2010), shows the subject has evolved towards contemporary empirical analysis and monetary policy from the original New Palgrave compendium on Money (Eatwell, Milgate & Newman, 1989) which is dedicated almost wholly to historical and theoretical analysis of money. Arestis & Mihailov (2011) demonstrate three broad categories of orthodox monetary economics: theory; policy; and public finance. Theory is defined as involving "rationalising and microfounding money itself as well as its demand by economic agents." (ibid., p.772). This particular definition of theory excludes by assumption the socio-political institutionalist approach of heterodox theory. Arestis & Mihailov's survey (2011) indicates that beyond these approaches, orthodox monetary theory has little to say about money qua money, but is primarily focused on monetary policy and public finance, primarily relating to: the natural rate of interest; the
interest rate transmission mechanism; central bank independence, rules versus
discretion etc.

The problem lies in a focus on the formalised General Equilibrium (GE)
approach, associated with Walras (McKenzie, 2008; Niehans, 1994). Now
termed neo-Walrasian GE theory (Leijonhufvud, 1976; Negishi, 1985;
Weintraub, 1974; 1979; 1985), it has become synonymous with the concept of
macroeconomics. Bridel (2014) critiques the money in GE approach: Money-in-
the-Utility-function (MiU) models (associated with the work of Patinkin, 1965);
Cash-in-Advance (CiA) models (associated with the work of Lucas & Stokey,
1987); and Over-Lapping-Generations (OLG) models (in the vein of Samuelson,
1958) are the key approaches. Such approaches are made because money's
fundamental purpose — viz., to address the coordination problem of exchange
— is intractable: assuming away the primary purpose, the method leaves
models with "no real role for money to play" (Graziani, 1996; Smithin, 2003,
p.20-21). Neo-Walrasian GE models are ultimately based on a perfect barter
economy (Rogers, 1989; 2018). The problem of the coordinating role of money
production and distribution of resources between various economic actors has
been removed by axiom (Clower & Leijonhufvud, 1975). In GE models, money
"is clearly an inessential veil covering the real allocation" (Ostroy & Starr, 1990,
p.52).

Schumpeter distinguishes macroeconomic models between Real Analysis and
Monetary Analysis (Schumpeter, 1954, p.264ff) which Blaug (1999) defines
concisely:
"[Real analysis is] analysis that explains economic activity solely in terms of decisions about goods and services and the relations between them; money is a veil because a well-functioning monetary system permits analysis of trade as if it were barter." Blaug (1999, p.22-23)

"[Monetary analysis is] any analysis that introduces the element of money at the outset of the argument and denies that the essential features of economic life can be represented by a barter model." (ibid.)

The dichotomy indicates a fundamental disjoint in presuppositions between supporters of monetary reform and orthodox economics. Kohn (1986) argues that the "as if" barter analysis is legitimate most of the time, primarily because it is tractable, but "real analysis is special and simple", whereas monetary analysis is necessarily "general and complicated" (Kohn, 1986, p.1195). Even in contemporary New Keynesian GE policy models "money per se plays no role other than to provide a unit of account" (Galí & Gertler, 2007, p.29), yet the idea of a numéraire good, as per Clower (1967) does not overcome the objection that in a monetary economy "goods cannot buy goods". A "technically convenient clearing-markets assumption" effectively incorrectly re-instated Say's Law (Laidler, 2008, p.8): "The discipline's very comprehension that a monetary economy might suffer coordination failures, let alone of Keynes's specific analysis of these issues, already weakened by IS–LM, was threatened" (ibid.).

Clower (1965) and Hahn (1965) were the first to formally attack neo-Walrasian theory as an ineluctably moneyless concept, in response to Patinkin's (1965) attempt to rescue money and value theories from the "inappropriate dichotomy". Patinkin at least recognises that neoclassical "monetary economists had better intuitions than they were able to articulate" (Samuelson, 1968, p.14). Clower argues that the "Post-Keynesian Dilemma" is "either Walras' Law is
Methodological gap

incompatible with Keynesian economics, or Keynes had nothing fundamentally new to add to orthodox economic theory" (Clower, 1965, p.110-111) [emphasis in original]. Clower's "Dual-Decision Hypothesis" notes consumers are potentially money-income constrained if they cannot sell labour services: notional demand may not always be translated into actual demand. Essentially a barter economy is "one in which all commodities are money commodities." (Clower, 1967, p.4). While a money economy may overcome the problem of double coincidence of wants, coordination cannot be assumed: an equilibrium market in the Walrasian sense only applies to hypothetical notional demands. Walras' period-zero tâtonnement process cannot be sustained: "contemporary general equilibrium theories can be maintained intact only if we are willing to barter Keynes for orthodoxy" (Clower, 1965, p.124).

Money "test the limits" of GE theory (Gale, 2016). Gale confirms Ostroy's earlier concern (Ostroy, 1987) that GE theory is focused on "as if" conceptions of centralisation which excludes a role for money by assumption (Gale, 2016). GE analysis began as a moneyless concept, and it remains a moneyless concept (Koo, 2009; 2011). It is clear that the monetary coordination problem in neo-Walrasian theory is axiomatically assumed-away, either by ignoring money or assuming it fulfils its functions perfectly, delivering a perfectly functioning pseudo-barter economy (Backhouse & Laidler, 2004; Buiter, 2009; Clower, 1967; Clower & Leijonhufvud, 1975; Colander et al., 2008; Davidson, 1972a; De Antoni, 2006; Godley, 1996; Hahn, 1989; Hayek, 1937; Howitt, 2002; Koo, 2009; Kornai, 1971 [1991]; Leijonhufvud, 1967; 1968; 1981; Mises, 1949 [1996]; Negishi, 1985; Snowdon, 2004; Snowdon & Vane, 2005).
While moneyless GE theory has dominated macroeconomics, search-and-matching theory has dominated monetary microeconomics. John Law (1705, p.4-14) first espoused what has become the orthodox search approach to money as merchants assign a particular commodity a role as a medium of exchange to ease the problem of barter, later used as a convenient narrative by Smith (1776 [2005]) and Say (1821 [2001]). Money is alluded to overcome the "double coincidence of wants" famously espoused by Jevons (1875 [1898], Ch.1). The canonical expression is by Menger (1892 [2009]) and subsequently Mises (1953). Menger's narrative model has been formalised and made rigorous in the micro-founded search-and-matching literature (Kiyotaki & Wright, 1989; 1993; Ostroy, 1973; Wright, 2016). While it may be concluded that introducing fiat money into an abstract economic model can improve welfare (Wallace, 2017), formal search models generally rely on abstract, model-consistent — i.e., "rational" — expectations (Lavoie, 2015). An exogenous deus ex machina is required to impose a probability on the likelihood of a money-good being generally accepted, hence money remains ineluctably a social convention (Bridel, 2014): the full knowledge required for money emerging in a market process implies a circularity of reasoning. It is not clear, despite what Wright (2018) argues, that such search-theoretic microfoundations are essential to macroeconomic modelling. Search theoretic models are not relevant for CC systems (such as the WIR) which have a form of centralised exchange (Stodder, 2009). "Societies engineer money rather than discover it" (Desan, 2017, p.112). "Money and credit are system properties. They cannot be defined independently of the structure of exchange and production in which they operate." (Shubik, 1985, p.128). "Money was invented as a social, and
governmental, phenomenon, not as a means of reducing transactions costs in markets” (Goodhart, 2009, p.828). Societies engineer money for specific socio-politico purposes (Helleiner, 2017) — to abstract from this clearly undermines any remaining concept of "positive economics", despite the discipline's attraction to formalist modelling.

3.2.3 Money, information & coordination in theory
The philosophical perspective of social ontology comports with the heterodox economists that money is a social institution at the very heart of the coordination problem in society: it cannot be a veil (Lawson, 2016). The root of the problem is orthodox macro theory is methodologically incompatible with monetary economics as it assumes market clearance and coordination (Clower, 1965): Keynes was primarily concerned with lack of coordination, hence disequilibrium (ibid.). Say's Law had assumed away the monetary coordination problem in Classical economic theory; the "Walrasian auctioneer" is the deus ex machina which serves the same purpose in neo-Walrasian theory (Clower, 1967; Clower & Leijonhufvud, 1975; Leijonhufvud, 1967). Leijonhufvud cites the cyberneticist Wiener, drawing the analogy between the Walrasian Auctioneer and Maxwell's Demon in physics: information is not free, and cannot be assumed (Leijonhufvud, 1967, p.410). As neo-Walrasian theory considers coordinated outcomes, a non-coordinated macroeconomics is a specific genre of research which should be considered outside the neo-Walrasian approach (Weintraub, 1979). In orthodox macroeconomics some coordination failure models exist (recognised formally as models with multiple potential Pareto efficient equilibria), yet these arise as a result of rigidities (Romer, 2006,
not the absence of money *qua* money. Macroeconomists have a qualitative understanding that money has a crucial role in coordinating activity, yet while coordination failures are a central component of modern microeconomics and evolutionary game theory (Bowles, 2004), they are difficult to integrate into the neo-Walrasian paradigm of orthodox macroeconomic theory.

Weintraub (1985) regards the assumptions of full relevant knowledge and coordination as two of the neo-Walrasian program's "Hard-Core" axioms: a formulation of the "veil of money" and "neutrality of money" axioms (Patinkin & Steiger, 1989). Similarly, Snowdon & Vane (2005, p.461) describe money neutrality as a "fundamental axiom of neoclassical theory". The fundamental building block of a barter economy has been maintained as an often-tacit assumption deemed as desirable (for example, see Lucas, 1980). Clower later criticised the "Smithian Diversion" of an invisible hand which rather than being an "ingenious modelling expedient" as its promoters claimed, should be treated as "an explanatory evasion which opened a yawning gap in economic analysis that requires closing." (Clower, 1998b, p.401).

Addressing the issue of how monetary transactions coordinated an economy is why Keynes regarded his theory as General, as opposed to the coordinated special case of Classical theory (Kohn, 1986). Keynes (1979, p.76-79) distinguishes between a "cooperative [barter] economy" and an "entrepreneur economy" where the monetary coordination problem is prevalent. Between these two is a "neutral entrepreneur economy": a special limiting case of the entrepreneur economy, being a hypothetical construct of the kind orthodox
macroeconomics models. Keynes used Marx's *Circulation of Commodities* (Marx, 1887, Ch. 3) to highlight the issue: a double-coincidence of wants in a barter, or C—C, economy has been replaced by dis-coordination in an entrepreneur economy, where the process of production and consumption is broken up into various uncoordinated chains of C—M—C' and M—C—M'. This is a dynamic process through time: money mediates the process of exchanging commodities (or effort) across time allowing a break with no guarantee of coordination (Keynes, 1979, p.76-79).

Information is the key difference between a monetised economy and a Walrasian economy (Koo, 2009 p. 261). Hayek became concerned with how a general equilibrium in the economy could be brought about given the imperfect information available to agents (Hayek, 1937; 1945). Concerns over the macroeconomic implications of the coordination problem, raised by both Clower and Leijonhufvud are associated with a more Keynesian approach (Clower & Leijonhufvud, 1975; Leijonhufvud, 1967; 1968; 1981). Money represents information and its use is an implication of optimising behaviour (Brunner & Meltzer, 1971). Meltzer has acknowledged that "Del Mar's (1896) emphasis on the informational role of money anticipated the contributions of Brunner and Meltzer (1971)" (cited in Aschheim and Tavlas (2004)). In experimental economics, Camera *et al.* (2013) concur with the conclusion that money coordinates, concluding that "the experiment finds evidence consistent with [Hayek's notion of] 'the indispensable role money plays in making possible the extended order human cooperation' " (ibid., p.14892). Kornai (1971 [1991]) identifies the issue as a control problem, although (contrary to Hayek), price structures alone are not capable of providing the appropriate amount of
information (Kornai, 2010); a view later argued by Mirman (2017). Cochrane & Graham (1976) emphasise Leijonhufvud’s concern that the price mechanism contains both incentives and information whereas neo-Walrasian analysis just focuses on incentives. Whereas Hayek (1937; 1945) is often regarded as introducing the problem of information into economics, Howitt (2002) argues that Leijonhufvud (1967; 1968) introduced information into macroeconomic theory, yet there is little cross-fertilisation between information and money in macroeconomics; despite a history of informal concerns of information problems, GE theory "simply ignored these" (Stiglitz, 2000, p.1442). While an ephemeral concept of "information" appears central to the development of modern economies, overall the attempt to create substantive or useful theory may be seen as profoundly disappointing (Mirowski & Nik-Khah, 2016). This gives contemporary support to Hayek’s early critique that "we fall in effect back on the assumption that everybody knows everything and so evade any real solution of the problem" (Hayek, 1937). Information as coordination was central to the real Keynesian revolution, yet both Hayek and Keynes "struggled to escape the invisible hand of the Walrasian auctioneer (Goodspeed, 2012, p.10).

The early 1970s witnessed a debate between GE theorists assuming coordination, and those calling for information, cybernetics and control theory to be taken seriously in solving the empirical problem of lack of information and coordination. Leijonhufvud was an early promoter of cybernetics in macroeconomics (Aoki & Leijonhufvud, 1976; Cochrane & Graham, 1976), yet he has been criticised as a good critic, but lacking an alternative theory (Minsky, 1982). Kornai (1971 [1991]) promoted a systems approach and attacked GE theory for failing to account for information feedback. Hahn (1973) accepts
Kornai’s critique, that a cybernetic, systems theory approach is better suited to modelling the macroeconomy and that "the time has come to start from scratch" (Hahn, 1973, p.327). However, the information-centred cybernetic control approach did not gain traction in the mainstream; the information/coordination problem fell into the background (Mirowski & Nik-Khah, 2016). The incorporation of money as information in Living Systems Theory — Money Information Markers (MIMs) — (Bailey, 1990; Miller, 1978; Swanson, 1998; Swanson & Bailey, 2009; Swanson, Bailey & Miller, 1997) has not been adopted within macroeconomics, albeit in sociology the notion that money is a form of information marker is gaining traction (Peacock, 2017). This is important in the context of systems theory because one of the most profound and easiest to implement leverage-points of any system is re-engineering information distribution (Meadows, 2008). The key role of national currency as a medium of exchange is to distribute information communicating demand and supply. A shortage of national currency effectively represents a degradation of a key information channel. Attempts to modify GE theory to incorporate information problems failed (Stiglitz, 2002, p.469n). Information theory in economics ultimately focused far more on the performative task of market design (Mirowski & Nik-Khah, 2016). The fictional axiom of fully informed agents with model consistent ("rational") expectations remains a convenient epistemological fit for the still dominant neo-Walrasian programme.
3.3 Mode of thought

3.3.1 Neo-Walrasian macroeconomics

While neo-Walrasian GE theory remains dominant as the method of macroeconomics, it must be understood as being more limited in scope than the universality often propounded by its practitioners. Kuhn's warning of the danger of "normal science" paradigms serves as a pithy summary of the mode of thought problem identified here whereby macroeconomics has solved by assumption the key problem at hand, thus creating a gap in research:

one of the things a scientific community acquires with a paradigm is a criterion for choosing problems that [...] can be assumed to have solutions. To a great extent these are the only problems that the community will admit as scientific or encourage its members to undertake. Other problems, including many that had previously been standard, are rejected as metaphysical, as the concern of another discipline, or sometimes as just too problematic to be worth the time. A paradigm can, for that matter, even insulate the community from those socially important problems that are not reducible to the puzzle form, because they cannot be stated in terms of the conceptual and instrumental tools the paradigm supplies. (Kuhn, 1962 [1996], p.37)

Hypotheses used to develop economic models are driven by a combination of an individual's fundamental weltanschauung and the pre-ordained methodology adopted in a paradigm or school of thought. Presuppositions are often implicit, or not regularly restated as a paradigm adopts a set of tools which gives a preformed answer to such questions. The dominant mode of thought can allow crucial problems to go unresolved. While the mercantilists had a nuanced understanding of a monetary economy, Ricardian mathematical formalism dominated late 19th century economics (Keynes, 1936 [2013]). Conflicting approaches of the "English Methodenstreit" were somewhat reconciled (Keynes, 1904), yet abstract "Positive" economics increasingly came to
dominate. The scope of modelling narrowed, with quantification and mathematical rigour increasingly prioritised, an approach given further prestige as World-War II saw the transfer of the centre of the discipline to the US from Europe. Science more generally proceeded in a manner conducive to the US's military-scientific complex during the Cold War (Kuhn, 1962 [1996]; Mirowski, 2001). GE theory rose from obscurity pre-WWI (where it was considered "too mathematical, too abstract and too impractical") to — courtesy of Hicks, Samuelson and Lange — "the front ranks of economic theory" in the 1930s and '40s, before becoming again — in the hands of Arrow, Debreu and Hahn — regarded as "a purely formal representation of the determination of economic equilibrium [...] having no practical value whatsoever" Blaug (1999, p.550).

Economics has arguably placed far more weight on this particular type of theory than Walras ever intended: he regarded it as a hypothetical model, of a type which we today call "false" (Bürgenmeier, 1994).

Various styles and schools of thought emerged within orthodoxy.

Macroeconometric models (aka Cowles Commission models or Structural Econometric Models) were the primary modelling tools during the 1950s and '60s, and although still used, they have been marginalised. Bourbaki-inspired (Weintraub & Mirowski, 2008) Arrow-Debreu-Mackenzie (neo-Walrasian) GE models were often confined to academic debate, deemed as being too complex and esoteric for policy advice. However, the prestige of aggregative macroeconometrics was undermined by the Lucas Critique (Lucas, 1976) and the Rational Expectations Revolution (Lucas Jr, 1972); macroeconomics increasingly became applied microeconomics with the hegemonic (neo-Walrasian) micro-foundations revolution becoming de rigeur (Fair, 2012; Wren-
Lewis, 2018). Real Business Cycle models became the basis for later New Keynesian models, morphing into Dynamic Stochastic General Equilibrium (DSGE) models which are now the staple of central banks, despite there being no place for money, *qua* money (Rogers, 2018). Fictional (usually implicit) axioms about coordination and availability of information remain.

The formalist *Bourbaki* turn in economics took place as computing was (slowly) developing (Velupillai, 1996). Von Neumann was the first to develop the systematic use of theorems and structures of formalist pure mathematics in economics of which there is no "dialectical relationship between theory and experimentation" (Dore, 1993, p.30ff.). Economics was "merely a convenient vehicle for his essentially mathematical exercise" (ibid., p.34). While Von Neumann later became contemptful of "neoclassical" orthodoxy (Mirowski, 2001); neo-Walrasian GE theorists "sunk into excessive mental aestheticism" (Morishima, 1991). The abstract, formalist neo-Walrasian macroeconomics remains at the heart of orthodox GE modelling. The epistemology of these models may be considered (as per Eichner & Kregel, 1975) to explain social optimality "as if" the real world resembled the model. Although the neo-Walrasian project achieves a useful framework of argumentation (Crespo & Tohmé, 2017; Dow, 2003; Rosser Jr, 2003; Weintraub, 1985; Weintraub & Mirowski, 2008), the formalist mathematical turn in economics was highly destructive (Boylan & O'Gorman, 2018; Velupillai, 2012). The weakness of this "neo-Walrasian diversion" is "common knowledge in the profession" (Costa, 2009, p.51). Today, the New Consensus Macro (NCM) is a limited discipline focused on studying exogenous shocks to a given long-run equilibrium solution: its weakness must be noted (Fine & Dimakou, 2016).
Partly because of the acknowledged weakness of neo-Walrasian models, model pluralism is increasingly encouraged. The Bank of England recognises a legitimate place for a suite of macroeconomic models aiming to understand different aspects of reality or tell different stories (Fair, 2012; Haldane & Turrell, 2018; Wren-Lewis, 1999). The Bank's key model genres are: (1) macroeconometric models; (2) small-scale macro models; (3) Phillips Curve models; (4) optimising (GE) models (Bank of England, 1999). A suite of models is considered to reconcile a trade-off between theory and empirics (Haldane & Turrell, 2018; Wren-Lewis, 2018). More recently, a movement has begun to "Rebuild" macroeconomics (NIESR, 2018), focusing on critiques of DSGE modelling (Vines & Wills, 2018). Broad conclusions are that DSGE modelling can survive, but key changes must be adopted: financial "frictions" should be added (although money, qua money, still is not expected to play a role); "rational expectations" must be at least relaxed, if not dropped; for example, the consumer's inter-temporal, utility optimising Euler equation is recognised as deeply problematic, implying unrealistic foresight and knowledge of households. (Vines & Wills, 2018). The demand for microfoundations must be dropped (Wren-Lewis, 2018), with alternative approaches and "short-cuts" being re-legitimised (Blanchard, 2018). Blaug regards neo-Walrasian theory as an intellectual "cul-de-sac" with the concept of regarding market equilibrium as a set of simultaneous equations "an utterly sterile innovation" (Blaug, 1999, p.570). Even Schumpeter, often unreasonably positive about Walras' innovation (Blaug, 1999; Niehans, 1994; Perlman, 2006), ultimately regarded the future of macro theory as needing to be dynamic, thus fundamentally challenging to the
Walrasian framework (Schumpeter, 1954). Leijonhufvud's demon (1968, p.397) has yet to be exorcised. Clower's critique remains fresh:

it is neo-Walrasian theory that is nonsense when interpreted as having anything to say about the coordination problems of a monetary economy. What is needed is not just a radical reconstruction of monetary and finance theory but a revision of the foundations of contemporary economic analysis that emphasizes the institutional features of money and markets (Clower, 1999, p.410)

None of this suggests that GE theory should be ejected from economics. As Weintraub (1979) argues, the meaning of the term "equilibrium" has become a "Wittgensteinian language game […] dependent on the players of the game and the rules that they decide to play by at a particular moment in the history of economic thought" (Weintraub, 1991, p.108). The semantic tangle of what GE means misses the point that any form of macroeconomics must be both general and relate to some concept of equilibrium: all macroeconomics therefore must be "general equilibrium".

3.3.2 Alternative visions of monetary macro
Where macroeconomists should deal with reality, their preconceived methods actually distort understanding (Leijonhufvud, 2011). A formal macroeconomics where "money matters" has long been an ambition of more heterodox thinkers about money (Davidson, 1978), yet whether a particular paradigm has chosen to focus on real or monetary analysis is largely a product of the times. "Topsy-turvy economics" is needed for an "upside-down economy" suffering unemployed resources where money is the scarce resource (Lerner, 1951, p.147). In an upside-down economy "money is more important than goods." (p.150). Keynes was explicit that the "machinery of thought" used for Real-
Exchange Economics" is fundamentally unsuited to the task of analysing a Monetary Economy (Keynes, 1933 [1963], p.8-9) [emphasis in original]: a "developed theory of Monetary Economics" is essential (ibid.). The Classical Dichotomy is a "false division" as "the importance of money essentially flows from its being a link between the present and the [uncertain] future" (Keynes, 1936 [2013], Ch.21) [emphasis in original]. The implied uncertainty is in the sense that Davidson regards as non-ergodic (Davidson, 1991), or what may more correctly be called non-stochastically random (Carrión Álvarez & Ehnts, 2016). The maximisation (or optimisation) problem ubiquitous to most formal economic models does not apply to dynamic frameworks (Samuelson, 1972). The money-production economy is an inherently dynamic system, linking the now with the future, hence the optimisation approach is a "snare and a delusion" (Leijonhufvud, 1993, p.11).

Frisch (1933) was the first to make a micro/macro distinction in economics distinguishing between the inherently static "micro-dynamics" of the emerging neo-Walrasian general equilibrium models and necessarily aggregated macro-dynamic analysis of business cycles (the Stockholm School types of analysis which were coalescing into the later "Keynesian" approach (Laidler, 1999)): the Keynesian/Stockholm approach developed monetary-macro in contrast to Walrasian real-micro analysis. The concept of monetary effective demand "remains the valid approach to macroeconomics" (Taylor, 2004a, p.172) [emphasis in original]. This is a key underpinning of Structuralist Macroeconomics, defined by Taylor as being "based on social relations among broad groups of actors" whose fundamental assumption "is that an economy's institutions and distributional relationships across its productive sectors and
social groups play essential roles in determining its macro behaviour." (Taylor, 2004a, p.1). This is achieved by developing Social Accounting Matrices (SAMs). The Structuralist methodology has been identified as commensurable with the approach of Heilbroner's "Worldly Philosophers" (Heilbroner, 1953 [2000]): Smith, Ricardo, Malthus, Mill, Marx, Marshall, Veblen, Keynes and Schumpeter (Baghirathan, Rada & Taylor, 2004). Mainstream analysis "omits structure and structural change." (Taylor, 2009, p.2) [emphasis in original]. Structuralism "tries to ground theory in everyday reality" (Taylor, 2004b, p.104). "Structuralism emphasizes system-wide analysis, aimed at generating proposals for improving economic performance" (Baghirathan, Rada & Taylor, 2004, p.306). Structuralism may well be regarded as a GE modelling framework for non-Walrasians, including include empirically-driven Input-Output (IO) and Computable General Equilibrium (CGE) models which trace their ancestry primarily to Leontief, national income accounting and work by Leif Johansen in the 1960s. While various governmental institutions rely heavily on some form of CGE model (see for example HMRC, 2013; Mitra-Kahn, 2008; PwC, 2014), paradoxically these "computable" GE models are not strictly "computable" in the algorithmic sense (Mirowski, 2001), but ostensibly remain reliant on neo-Walrasian axioms. Leontief remained wary of such models which were constructed on "quite arbitrary, purely theoretical assumptions" (Leontief, 2017, p.6). However, the approach is feasible without commitment to neo-Walrasianism at all (Mitra-Kahn, 2008; Velupillai, 2006).

CGE and IO models remain primarily driven by real rather than monetary phenomenon, but structuralist models have the ability to commensurate the complex social phenomena of money into a formal framework that allows

This implicit concept of a micro-meso-macro framework arguably traces its origins to Schumpeter where "meso constitutes a structure component of a 'deep' invisible macro structure" as well as "a process component of a visible 'surface' structure" (Dopfer, 2012, p.133). It is implicitly fundamental to Institutionalist and Evolutionary economics (Dopfer, Foster & Potts, 2004), and consistent with a realist ontology. The Franco-Italian Circuit School (Circuitists) were earlier users of a structural approach to gain a better understanding of the monetary circuit (Lavoie, 2009), whereas the Stockholm School innovated the use of accounting procedures in economics (Hicks, 1956). In these approaches, money is a key restriction in achieving end-states. Before rejecting his IS-LM framework, Hicks already declared that "In all its main forms, modern economic dynamics is an accounting theory. It borrows its leading concepts from the work which had previously been done by accountants (with singularly little help from economists); and it is in accordance with this that social
accounting should be its main practical instrument of application. (Hicks, 1956, p. 221)” (quoted in Velupillai, 2005, p.866). Any "equilibrium" both in piece of time, and any end-state must — at a minimum — comport with limitations defined by monetary accounting identities. The problem to be solved is the notion of "Where does money come from and where does it go?" (Caverzasi & Godin, 2014). This specific approach is now referred to as Stock-Flow Consistent (SFC) modelling.

SFC models are structuralist SAM models, with the primary focus on monetary accounting (Taylor, 2004a; 2008). The approach has become standard in post-Keynesian macroeconomics. Post-Keynesian economics (forthwith, PK) rejects the neo-Walrasian framework, and follows a real-world problem-solving approach to macroeconomics (Eichner & Kregel, 1975). Money is key in a world of fundamental (radical) uncertainty and the notion of sequential-causative processes taking place in historical time. SFC modelling has evolved primarily from the work of Copeland (1947; 1949), Tobin’s group at Yale (Backus et al., 1980) and Godley at Cambridge (see Caverzasi & Godin, 2014; Dos Santos, 2006; Godley & Lavoie, 2007; Nikiforos & Zezza, 2017). The approach gives closure to the flow of money around the economic system, including stocks of money and contingent liabilities: "everything comes from somewhere and everything goes somewhere" (Godley & Lavoie, 2007, p.xxxiv). Such social accounting for money is the only way to "rid this subject of quackery and misconceptions" (Copeland, 1949, p.255).
3.3.3 Contra-Whig Economics
PK-SFC theory is essentially reconstructing long-understood ideas which were difficult to make tractable and hence fell off the research agenda for economists during the formalist revolution: Johnson warned of the dangers of formalist monetary analysis where "elaborate technologies" encourage a focus on solving trivial, second rate pseudo-problems rather than useful problems (Johnson, 1974, p.213). Much of the methodological critique and manifesto for developing an appropriate framework for evaluating secondary monies is best accommodated by going back to basics, rejecting the so-called Whig interpretation of economics whereby it is assumed "that good ideas from the past are embodied in the common scientific wisdom" (Boettke, Coyne & Leeson, 2014, p.531). We cannot assume that economic science progresses cumulatively; history itself has a role to play in economic methodology, and knowledge is constructed in a social context (Cesarano, 1983; 2006a; Negishi, 1985; Weintraub, 1991). Contra-Whig economists thus reject the notion that theoretical (and methodological) progress is smooth; flawed ideas may dominate, and better new theories may be created by developing ideas of the past (Boettke, Coyne & Leeson, 2014). In particular, older dynamic systems represent "a magnificent cast" (Baumol, 1970, p.13-14 quoted in Forrester (2003, p.28)).

What we today call monetary macroeconomics was virtually the sole concern of 17th and 18th century economists (Murphy, 2008) and arguably until the marginalist revolution of the 1870s. The era of economic pragmatists pre-dating the Humean Classical dichotomy enables modern economists to put their methodology into a broader context. Integrating monetary and real analysis was
precisely what mercantilist writers tried to do (Grampp, 1952, p.499). Marx was
the most explicit of early economists in looking at the economy in terms of
accounting and monetary circuits (Bezemer, 2010). John Law, however,
epitomises Laws' Doctrine and the late-mercantilist zeitgeist that money and
credit were essential to trade and growth. Law offers, arguably, the world's first
abstract theoretical economic model and provides the basic work-horse for this
thesis, although it has never before been formally constructed and simulated.
The only elucidation of his model is narrative, both by Law himself and later
Murphy (1993; 1997), who demonstrates that Law, rather than Cantillon or
Quesnay, was the "originator of the circular flow of income and expenditure"
(1993, p.62), although this "has gone unnoticed" (ibid, p.47). Law's primitive
circular-flow model comes pre-packaged with a germane socio-historical
narrative, is parsimonious and familiar in terms of simple macroeconomic
models. His model was specifically seeking to elucidate the real economic
impacts of introducing what may be called a secondary/complementary money
system. Murphy summarises Law's argument in that an insufficient supply of
silver in Scotland had caused unemployment, hence "A method had to be found
of supplementing, if not supplanting, the monetary system based on silver"
(Murphy, 1997, p.94).

Law proposed introducing intrinsically worthless tokens, backed by the value of
land, into an abstract island economy suffering a shortage of silver money. The
landlord ("proprietor"), essentially acting as a government, would "coin pieces of
paper" (Law, 1705, p.184) and spend these tokens into circulation for
goods/services, giving these pieces of paper value by accepting them in
payment of rent on his land. The tokens would circulate on the island and return
to him in lieu of rent paid in silver money. They are essentially promissory notes redeemable against rental obligations; such anticipation "notes" (tally sticks being an example in England) formed the basis of modern taxation and banking and contemporary language may refer to them as Revenue Anticipation Notes (RANs) (Desan, 2015). In Law's island the landlord is the "government" and "tax" is rent. This reflects a fundamental observation of Neo-Chartalism or Modern Money Theory (MMT): "Under a fiat monetary system, money is an accepted medium of exchange only because the government requires it for tax payments." (Mosler, 1995, p.9).

Law's story was intended to portray (in abstract) the economy of Scotland in 1705, still suffering a lingering economic depression related to the drain of silver associated with the disastrous Darien Scheme (see for example MacLean, 1900 [2008], Ch.4) and the subsequent collapse of the precious-metal-backed Scottish banking system. Law's model was later adopted and adapted by both Cantillon and Quesnay for their own purposes although, in contrast to Cantillon and Quesnay, "to Law money was of paramount importance […] Law aimed to show both at the theoretical and at the policy levels the importance of money." (Murphy, 1997, p. 78). Law was concerned with curing unemployment through an increase in the money supply, and hence appropriating the social gains from substituting paper money for precious metal (ibid.).

Cantillon adds several dimensions of richness to Law's model, including notions of differential effects of how money enters the system: so-called Cantillon Effects (Blaug, 1999, p.21). Cantillon maintained Law's abstraction of an isolated "large estate" (1755, p.79ff.) but while Law's model focused specifically
on the context of introducing secondary money as a policy option, Cantillon
developed Law's model into a more complex economy: the concept of the *three
rents*\(^3\) demonstrates "the mainspring of circulation in the state" (Cantillon, 1755, p.124). He presented theories of how towns and cities emerge, and the
relevance this has for economic activity, conveying the essence of the
inherently spatial nature of what became known as the capitalist mode of
production. It is this spatial nature of production where money serves the
specific purpose of coordinating movements of value through time and space;
this is not possible in a barter economy, and perhaps helps illustrate the
fundamental importance of money in the development of capitalism:
geographical dispersion and de-personalisation negates barter and
necessitates money. Cantillon's urban and rural economies have their own
particular dynamics and circuit flows of money. *Rentiers* were not necessarily
located in the regions where they procured their income: the great estates paid
rents which accumulated in big cities, being spent on luxuries, hence a
geographic schism develops in the circular flow between income and spending.
Entrepreneurs and manufacturers gained economies of scale (and
transportation cost savings) by locating near the bigger cities. Workers migrated
and agricultural produce was transported to feed growing cities.

This approach naturally lends itself to a recognition of differential economic
impacts according to the origination and circulation of money. Cantillon Effects
of a sort found their way into Keynes' understanding of differing monetary

\(^3\) In terms of agricultural production, wage labour receives \(1/3\) of output, the farmer receives \(1/3\) as income, and the final third either goes to the landlord as rent (or the bank as interest), or the entrepreneur farmer as profit.
circuits in his *Treatise* (Keynes, 1930 [2011]), although in this context we may think of an industrial-financial split rather than urban-rural (Blaug, 1999, p.21). This distinction between rural and urban is why Cantillon sought to use interventionist policy to ensure geographic balance between the two as he understood that rural decay was essentially inevitable under the emerging system (Berdell, 2009). Murphy (2008, p.85) illustrates the concept of Cantillon effects in a table:

![Figure 3. Mapping Cantillon effects (adapted from (Murphy, 2008, p.85))](image)

Reading left to right: it is apparent that the arrow of time is key in determining the output on the right-hand-side. These are processual, causal, path dependent relationships in historical time, determined by both explicit and implicit decisions within the system. In terms of developing a model in this context, this may be termed a *Cantillon Logic Gate*, enabling a model which generates Cantillon effects through the differentiated introduction of money into the model economy.
Cantillon’s *Essai* demonstrates that early economic theory was inherently dynamic but intractable given the methods available. In terms of its implicit methodological notions, the *Essai* has compelling theoretical content and remains fertile ground for exploration. Cantillon's work was the basis of macroeconomics, implicitly arguing the need for social accounting through sequential period analysis for proper macroeconomic analysis (Hicks, 1990). Cantillon is a key theorist, being “one of the shining stars of the classical galaxy” (Niehans, 1994, p.24). It is Law's island model, augmented by the theories of Cantillon, which is the primary inspiration for the nature of the modelling in this thesis.¹

### 3.4 Gap in literature (part 2)

The key gap identified in chapter 2 is a lack of interest or appropriate framework in the theory of money plurality in orthodox economics. Reviewing the competing heterodox approaches, various attempts at formally theorising around money plurality emerge, although none can be seen as attempting a general theory model which is the primary objective of this thesis. A wide range of financial assets may be included in SFC modelling, but as of 2014 no-one had added what may be regarded as secondary money systems to this schedule (Caverzasi & Godin, 2014). However, Sardinia's Sardex — a form of MCC system — has now been modelled in an SFC model (Lucarelli & Gobbi, 2016), based on Zezza's (2012) model outlining Graziani’s *Theory of the Monetary Circuit* (TMC). The model is briefly outlined in matrix form with a

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¹ While being the principal inspiration for the models in this thesis, the explication of Law's model is outlined in the Appendix.
selection of equations (although excluding key behavioural equations), and the conclusion supports the notion that clearing systems support stabilisation despite their small size. This model does however add extraneous detail related to the specific example of the Sardex (for example adding a form of demurrage to the currency and charitable payments) as well as a banking system: neither is required for a general theory model, and the framework becomes unnecessarily complicated (a typical critique of SFC models) for the task at hand. No simulations of the model are offered.

Groppa (2013) presents a model of a type of MMC, with empirical reference to the *Punto Transacciones* scheme in El Salvador. Two small models are presented as systems of equations, illustrated with flow charts: one of the models is a description of a banking system. The models are referred to as a system dynamics model, although it is does not cite literature or follow accepted practice in system dynamics; unfortunately, they do not benefit from reference to specific stock-flow consistency. The modelling narrative appears to conflate MCC systems with CLC systems, as it seeks to link creation of credits to the supply of existing currency, which should not be necessary in an MCC system. The claimed benefit of the system is an increase in propensity to consume for users of the currency, which manifests itself through reduced saving of the currency itself. No simulations are offered.

There have been several suggestions for introducing parallel national currencies in either Greece or Italy (Andresen & Parenteau, 2015; Papadimitriou, Nikiforos & Zezza, 2016; Zezza, 2016). So far, these models are narrative. Andresen has outlined a technique for modelling systems adopting a
type of bond, using block-diagramming techniques (Andresen, 2016; 2018), but specific models of the proposals remain primarily as outlines.

3.5 Chapter Summary

A monetary economy is distinct from a real-exchange (barter) economy; the key distinction is that money represents a coordinating mechanism. This coordination problem is solved by assumption in orthodox monetary macroeconomics: this is argued to be as a consequence of the mode of thought problem. The critique of the existing macroeconomic approach is necessary in order to address the research question. The chapter has outlined the structuralist SFC approach as the building block of alternative framework, with insights from the cybernetic approach which briefly appeared in the 1960s. The remaining chapters are structured as follows: chapter 4 builds on these insights to understand a methodology which justifies why an alternative approach is not just appropriate but necessary in addressing the research question, as well as outlining the key characteristics the alternative must adopt; chapter 5 builds on this justification to detail the specific method and establish the core model with simulations and discussion; chapter 6 develops the core model into three separate CC models with simulations and discussion; chapter 7 concludes with a summary of contributions, policy implications, and ideas for future work. The Appendix contains the development of John Law's Island model and the full list of equations for later models.
Chapter 4 Methodology: justifying method

4.1 Introduction

Methodology is "the middle ground between discussions of method (procedures, techniques) and discussions of issues in the philosophy of social science" (Schwandt, 2011). The nature of the research problem implies a necessarily interdisciplinary approach, yet the "fallacy of exclusiveness" (Jevons, 1876) still pervades macroeconomics despite its weaknesses and the philosophical illegitimacy of methodological monism. A silo-effect in the academy appears a key reason for creating the gap in research, and invokes Kaplan's concern of the "Law of the Instrument" (Kaplan, 1964, p.28) and Kuhnian "normal science" (Kuhn, 1962 [1996]): research which does not adopt the "normal" framework for macroeconomics may simply be ignored. Economists interested in the inherently socio-political money problem require a method consistent with an appropriate meta-methodology or mode of thought. This "mode of thought problem" implies a discussion of methodology as a form of underlabouring, intrinsically necessary in correct evaluation of the research question. This chapter responds to chapter 3's critique in order to justify the proposed method. While combining system dynamics with a post-Keynesian Stock-Flow Consistent approach is emerging as an approach in monetary macroeconomics, it has been given little methodological justification in the literature, and system dynamics has not been accepted in economics as an appropriate or useful method. A key part of SD modelling is developing confidence in the usefulness of the models and transferring that confidence to others (Forrester & Senge, 1980). It may be contended that such transfer may
be context-dependent on audience, differing between the social and hard sciences, and arguably has proved a difficult task with orthodox economics (Bardi, 2013). It is argued here that in order to make the case for SD, heterodox economists must be explicit in articulating a commitment to philosophical realism — *viz.*, "the ontic presuppositions of their analysis" (Lang & Setterfield, 2006). The purpose of this chapter is to elucidate and justify the overall methodology as comporting with an appropriate realist philosophy, making it defensible in policy debates over macroeconomic issues.

4.2 Development of methodological perspective

"The essential error of modern economics" is the fundamental irreconcilability between reality and method (Lawson, 1996), yet policy is driven by theoretical models open to this critique. Economics is a model-based science, with models "endemic at every level" (Morgan, 2012, p.2). While some models, especially in Institutional Economics, remain narrative, the majority of contemporary economic models are based on formal mathematics. The presuppositions which go into formulating economics models are generally neither stated, nor questioned; this may lead to a confusion of model purpose amongst model users and even model creators if they have not sufficiently weighed the appropriateness of their axioms (Boland, 2014). Differing assumptions may drive different conclusions, but the method or the ontological underpinning of theory construction is rarely questioned. In contrast, other disciplines may be more perspicacious in establishing what the realistic goals of analysis are before building models (Simon, 1990). The issue may be illustrated in the conceptual model of Theory Construction offered by Chick (2003).
The mode of thought implies the need to unpack and confront presuppositions of modelling practice. Within a broader context of systems theory, a consilience of approaches emerges and various concepts apply. Alongside post-Keynesian Stock-Flow Consistent modelling: a Critical Realist perspective; cybernetics; Classical Behavioural Economics; macrodynamics; intuitionist and algorithmic mathematics; system dynamics and simulation.

Lawson argues for the necessity of a Critical Realist approach (Lawson, 1998; 2003). From such a perspective, concerned with social ontology, economies may be understood as open, complex social systems not subject to extrinsic closure (isolation from exogenous causality) or intrinsic event regularities; they are subject to emergence and novelty (Lawson, 1998; 2010). The macroeconomy is not just a complex adaptive system, but a social system inherently more complex than physical and biological systems (Simpson, 2000). From the perspective of epistemology, we have a limited ability to understand,
interpret and (especially) quantify the nature of such systems. Hayek's "pretence of knowledge" remains extant (Hayek, 1974). It is crucial to recognise economics as a social science subject to such epistemological limitations: qualitative understanding, or broad quantitative approximations of the overall system's structural changes and dynamics are likely the best we can hope to achieve.

A critical realist perspective is particularly important for the social/institutional structure of money which transcends individual human agency and is governed by social rules (Lawson, 1998, p.163). Any money system is dependent upon a specific point in history, a specific location, specific rules, laws and social structures; an approach which eliminates social structure can only explain by chance such aspects of money (Lawson, 2016). Thus, appropriate monetary macroeconomics is not merely analytical, it necessarily becomes a dialectical process (Lawson, 2009), implicitly favouring a Structuralist approach. This supports McCloskey's regard for economics as an inherently rhetorical discipline, with storytelling and metaphor essential for its task of persuasion (1983; 1986; 1990; 1994). This approach is akin to embracing "Economic Sociology" (Wirtschaftssoziologie) (Schumpeter, 1954 [2006]), utilising the various social sciences (Swedberg, 1990; Swedberg, 1995), and comports with a Systems Theory approach. While there has been little connection in literature between critical realism and systems theory, Mingers (2016) argues that there is a powerful philosophical complementarity between the two, and the methodology implied by critical realism very much maps onto approach developed in systems sciences. One such philosophical presupposition relates to the need for understanding and explanation through the recognition and
creation of mechanisms which demonstrate generative causality (Mingers, 2016). Combining a critical realist approach with systems theory is a potentially fruitful way of addressing many key problems the world faces (Mingers, 2016). The graphical representations often favoured by systems theorists also comports with recent research by Pearl in causal inference (2000); an approach requiring a language of mathematics that involves graphical representation (Pearl & Mackenzie, 2018, p.26-27).

General Systems Theory (GST) is primarily associated with Boulding (1956) and Von Bertalanffy (1968), and includes a more narrative socioeconomics (Boulding, 1948). "The Skeleton of Science" creates a framework, yet in a general system "exact prediction is impossible", yet not formless: "something can be said about its assumptions and the consequences of these assumptions" (Boulding, 1955, p.203). Institutional Economics is the most appropriate home of the systems approach to economics (Boulding, 1957). GST is an overall encompassing scientific framework — "a doctrine of principles" — across various disciplines (Bertalanffy, 1968, p.xix). Kornai called his approach economic systems theory, recognising that the approach economists had taken could only ever be a simplistic starting point (Kornai, 1971 [1991]). Similarly, Weintraub regards GST as a broad conception whereby neo-Walrasian general equilibrium theory "is but a specification to certain economic problems" (Weintraub, 1979, p.71). Weintraub notes how "control mechanisms and control points, information networks, message flows, decision rules, hierarchical organisation, of the entire system […] all would necessarily appear in a complete systems view of an economy" (Weintraub, 1974, p.57). Indeed, a
crucial concept in systems theory is the nature of information and how it is conveyed around the system (Meadows, 2008).

4.2.1 Cybernetics
Cybernetics (from the Greek *kybernētēs*: a pilot or governor) "is a theory of control systems based on communication (transfer of information) between system and environment and within the system, and control (feedback) of the system's function in regard to the environment" (Bertalanffy, 1968).

Leijonhufvud contended that while "almost *nothing* can be learned about dynamic systems from the study of 'clockworks'" (such as neo-Walrasian analysis), the cybernetic approach offered an appropriate way forward for the dynamic, monetary economics of Keynes (Leijonhufvud, 1968, p.230) [emphasis in original]. This cybernetic concept of information feedback and control is central to the broader concept of systems thinking dating as far back as Hume and Smith in classical political economy (Mayr, 1970; 1971b; 1971a; Richardson, 1991). However, economic method matured at the end of the 19th century in two particular mathematical styles, reflecting differing mathematical epistemologies: postulation and proof, versus hypothetical modelling (Morgan, 2012, p.18). Leijonhufvud's insight was that Keynes consciously tried to reorient economic methodology away from the increasingly dominant (but inappropriate) postulation and proof approach in order to understand a monetary production economy. "*The Economics of Keynes*" is primarily about the information and coordination problem in a cybernetic sense: "the Keynesian Revolution which did not come off" (Leijonhufvud, 1968, p.396-397). In contrast, the "Keynesian Revolution" of "Keynesian Economics" ignored the methodological critique of
Keynes and built on the neo-Walrasian foundations which Keynes had rejected (Davidson, 2015).

It was engineers who were essentially formalising Hume and Smith's concepts, applying feedback in control system engineering to economics; researchers included Tustin (1951; 1953), Phillips (1950; 1954; 1957), and Allen (1955; 1956; 1960). Hayes (2009) gives a useful review of the approach. The approach made use of engineering Block Diagrams to represent the underlying models, aiding comprehension of causal structure and lags in dynamic systems (Allen, 1956; 1968). Goodwin's (1951a) essay is the seminal text in this early approach (Richardson, 1991). The "zeroing servo" process and its ubiquity in decision-making in the economic process (which can be approximated by iterative computing) was implicitly at the heart of the original Walrasian system which may better be regarded as an iterative, computable (algorithmic) solution: this is the "true representation of Walrasian tâtonnement" (Goodwin, 1951b, p.4). Indeed, Smith's "invisible hand" may be less ephemerally conceived as a monetary-servomechanism.

4.2.2 Cybernetic decision-making to Classical Behavioural Economics

Many economic decision concepts have a cybernetic control loop of a desired level and a perceived/actual level creating an "error term" which decision-makers seek to correct (Goodwin, 1951a; 1951b). Herbert Simon (1952) developed the concept of bounded rationality in applying a servomechanism approach to management decision making on a production line in an environment of limited information (see Richardson, 1991, p.143-148). The theory of decision-making emerging in operations research and management
science was based on real-world limitations of bounded information and procedural rationality (inspired by Institutional Economics). Hayek's work was fundamentally influenced by this cybernetic concept (Oliva, 2016), yet there was no room for this approach within orthodox economics, which had already created a fiction of "omniscient rationality" and abstract concepts of optimisation (Simon, 1978). Simon's approach was difficult to make tractable in larger scale models, thus his work became focused on microeconomics and artificial intelligence, for which he won a Nobel Prize (Simon, 1978). While bounded rationality has spawned an extensive literature, Simon's insights have yet to be usefully applied in macroeconomic models (Laville, 2000; Mallard, 2015; Salehnejad, 2006), and his work has been marginalised in Modern Behavioural Economics (Mallard, 2015).

Simon's Classical Behavioural Economics is distinguishable from Modern Behavioural Economics because it is computable, and its concepts of bounded rationality and satisficing are based not on optimisation but on "decision problems (in its metamathematical sense)" (Kao & Velupillai, 2015, p.238) [emphasis in original]. The "information as computation" approach has profound implications for orthodox economic theory: "certain aspects of the neoclassical model were shown to be Turing non-computable" (Mirowski & Nik-Khah, 2016, p.117-119). The cybernetic approach to information-poor, goal-seeking, procedural rationality in decisions and action remains a more realistic approach to information gathering, dissemination and decision-making than that proposed in the rational expectations' literature. This is the processual ecological rationality of homo heuristicus as distinct from the as-if approach of economists studying homo economicus (Todd & Gigerenzer, 2012).
4.2.3 The "servomechanism thread" & System Dynamics

Whereas cybernetics is primarily interested in balancing feedback for control systems to bring a process or mechanism to a desired state (analogous to the conception of equilibrium-seeking stability in orthodox macroeconomics), Keynes added a "deviation amplifying" feedback loop in addition to neoclassical economics' "deviation counteracting" feedbacks (Leijonhufvud, 2009) — i.e., there may be no assurance of a stable equilibrium point the economy is tending towards. Institutional Economists refer to these as "cumulative" and "equilibrating" feedbacks respectively (Kaldor, 1972; Myrdal, 1978). Cumulative feedback enables emergent system behaviour from confounding meso-macro constraints — paradoxes. Such paradoxes include those of: thrift; costs; debt; public deficit; tranquillity; and risk. (Lavoie, 2015, p.17).

The broader feedback approach effectively settled into two "threads": the cybernetic thread, and the servomechanism thread (Richardson, 1991), with the cybernetic thread primarily focused on psychology and decision-making and the servomechanism thread associated with economic and social systems. Attempts by implicit feedback thinkers in economics (including Frisch, 1933; Kaldor, 1940; Kalecki, 1935) to wrestle formally with the fundamental dynamics of business cycles suffered severe constraints due to the difficulty of the mathematics required to analyse the behaviours (Richardson, 1991), while Tustin, Phillips and Allen were using block diagramming techniques and attempting simulation specifically to address the Hicks/Samuelson/Kalecki accelerator-multiplier problem. Jay Forrester (1958; 1961) understood that the powerful mathematics of control-theory could not be made analytically tractable in the larger, more complex macrosociological models: simulation was the only
feasible method. Forrester essentially had no preconceptions about how economics should be done, hence *Industrial Dynamics* — later *System Dynamics* — was developed independently of the cyberneticists in economics and became the first computer simulation method for studying a variety of complex system questions, including organisation and larger socio-economic systems. The approach emerged from a combination of feedback control systems, military decision-making, and the developing discipline of management science seeking practical solutions to real-world problems (Forrester, 1956; 1958; 1961). Operations Research (OR) had developed a broad array of techniques to deal with microeconomic problems (Vertinsky, 2017) at a time when Friedman's *Instrumentalism* (Friedman, 1953) dominated economics. Forrester desired to reorient economics away from a restrictive method (Forrester, 1956), but rather than replicating models of Keynes, Hicks and Kalecki, he developed his own models from the ground up, microfoundations included.

SD allows a formalised way of thinking in terms of endogenous circular causality in social science. Similar to Simon, Forrester developed his approach to agent decision-making in applying the concept of servomechanisms to management decision making on a production line in an environment of limited information (Richardson, 1991, p.143-148) (see Forrester, 1958; 1961; Simon, 1952). System dynamics (SD) implicitly represents Simon's well-known concept of bounded rationality in its models (Morecroft, 1983). The potential to deploy well-grounded "microfoundations" is long-established in SD; they are completely independent of the underlying presuppositions of microfounded behaviour in the neo-Walrasian programme, reflecting the realism of Simon's classical
behavioural economics. Macrobehavior emerges from microstructure (Forrester, 1989a), but this is not the orthodox microstructure of maximising subjective expected utility, roundly rejected by Simon (1978).

Figure 5. Forrester's conceptualisation of basic model structure (Forrester, 1961, p.67)

Forrester conceptualised the decision framework, incorporating stocks and flows, diagrammatically. Forrester's models involved — uniquely at the time — the use of digital computer simulations of complex, dynamic, non-linear feedback systems. Thus, whereas Simon initially found tractability in larger systems difficult, Forrester used SD to diversify into broader socioeconomic and environmental issues; this is perhaps a key distinguishing feature which allowed SD to survive the rational expectations revolution and ultimately dominate the "servomechanism thread" of feedback thinking in the social sciences (Richardson, 1991). The origins of SD are recounted in numerous papers (see for example Forrester, 1989b; 2007; Radzicki, 2003a; Sterman, 2000). SD is argued as the "economic theory for the new millennium" (Forrester, 2003). It is a "dynamic, disequilibrium approach to modelling complex systems that
portrays human behaviour and micro-level decision making as it actually is" (Radzicki, 2003a, p.138). Richardson (1991, p.80) notes that "Myrdal outlined an approach to societal problems that strikingly foreshadowed the work of Forrester." Indeed, the epistemology of Institutional Economics as outlined by Myrdal (1978), in terms of feedback, endogeneity, lack of ability or need for precise quantification of non-economics factors, is strikingly similar to many aspects of that outlined by Forrester (1956).

The context of SD within the broader evolution of systems thinking is outlined by Schwaninger (2006). While SD is a simulation technique, Barlas (2016) notes the "serious error" of equating SD merely with a piece of simulation software or a diagram (the "tools") rather than the principles which are conceptual and philosophical. It is often regarded as representing a particular worldview — a Kuhnian paradigm — of systems thinking (Forrester, 2007; Meadows, 1976; Richmond, 1994; Sterman, 2007). The approach involves a particular overarching "vantage point" (Richmond, 1994) or "frame of reference" (Forrester, 2007 p.356). This broader paradigmatic approach is used for conceptualising various problems across diverse disciplines from economics, business and sociology to physics, biology and ecology (Bossel, 2007; Meadows, 2008). Richmond (1994, p.139) defines systems thinking as the "art and science of making reliable inferences about behaviour by developing an increasingly deep understanding of underlying structure", or indeed "system dynamics with an aura" (ibid., p.136). It is this approach which Mingers (2016) recognises as comporting with a critical realist philosophical perspective.

Meadows (2008) critiques the contrasting approach of economic models which are usually presented as a system of equations, thus hiding the causal structure
and the system perspective necessary for clear understanding. SD seeks transparency and has a history of presenting complex models for use by non-specialists (see for example Forrester, 1961; Lane, 2008; Morecroft, 1982). The notion of mapping of economic models was earlier demonstrated by Frisch (1933) and had an early advocate in Michael Polanyi (1936 [2013]). SD may be regarded as coming under the original conception of what "econometrics" is (Frisch, 1936). It shares similarities with macroeconometrics, but the presuppositions tend to clash, specifically with regard to SD’s desire to make broadly accurate statements about long-term system-wide behaviour (where shifting feedbacks are key), whereas econometrics is not genuinely dynamic (processual) and is focused on generating precise short-term forecasts (Meadows, 1976).

Forrester's *World Dynamics* (Forrester, 1971) (best known as the forerunner to the *Limits to Growth* model (Meadows et al., 1972)) saw the methodology tainted by demonisation as "*Models of Doom*" (Cole et al., 1973). Unhelpful political controversy delegitimised SD models in the eyes of economists (Bardi, 2013) and the approach was undermined by a scathing critique (Nordhaus, 1973) despite being rebutted (Forrester, Low & Mass, 1974); two decades later, a more restrained critique emerged (Nordhaus, 1992). SD models were regarded as outside the scope of economics (Cochrane & Graham, 1976). The CIA ambiguously regarded the approach as "nothing new" yet potentially revolutionary — the relative simplicity and inter-disciplinary communication meant they regarded Forrester as being "well along in building a methodological nuclear weapon" (CIA, 1975, p.7). Radzicki (2011) gives a comprehensive
overview of the applicability of SD to economics, and suggests SD is a key tool for PK theory (Radzicki, 2008).

4.2.4 Macrodynamics & simulation
Dynamic macroeconomics evolved narratively in the 18th century with Law and Cantillon (see Murphy (2008)), and was a well-developed theoretical discipline awaiting an appropriate method to apply it. However, a genuinely dynamic analysis is difficult: akin to "crossing the Rubicon" (Schumpeter, 1954, p.1126). Echoing Keynes, Schumpeter suggests it "cannot be accomplished simply by adding dynamic qualifications to static theory. It requires new techniques and raises fundamental problems of its own" (Schumpeter, 1954, p.1108). While macroeconomics is predicated on dynamics, "there is no generally acceptable theory of dynamics" (Quint & Shubik, 2014, p.306). The dominant neo-Walrasian research programme essentially redefined the concept of dynamics to mean stability analysis (Weintraub, 1991). This schism between statics and dynamics ultimately has roots in an age-old debate between substance philosophy and process philosophy (Rescher, 2000): "becoming is no less important than being — but rather the reverse" (Rescher, 2000, p.4)[emphasis in original].

Keynes has been accused of adopting a static methodology (Kohn, 1986), whereas Leijonhufvud suggests that Keynes' "theory was dynamic. His model was static." (Leijonhufvud, 1981, p.5). Keynes was clearly dealing with a conception of equilibrium in the General Theory which defied analytical treatment with the methods available (Hansson, 1985), and was implicitly demanding simulation technology (Chick, 2003). Keynes noted "the nature of
economic thinking" as "not to provide a machine, or method of blind manipulation, which will furnish an infallible answer, but to provide ourselves with an organised and orderly method of thinking out particular problems" (Keynes, 1936 [2013], p.297). Keynes is rejecting analytic solutions and describing a form of structured computer simulation; he also warned of the dangers of econometrics (Keynes, 1938), commensurate with Lawson's critical realist critique. The notion of simulating complex social systems as the main job of economics was implicitly argued in the work of the Institutionalists (Veblen, Commons and Clark) and in the work of Schumpeter preceding Evolutionary Economics (Radzicki, 1988; 1990).

Although Blaug argues that Walrasian GE theory is merely taxonomic (1999, p.7), the approach is generally represented as a method of mathematical postulation and proof, whereas Fisher built a hydraulic-mechanical model of Walras' scheme: a method of reasoning with a hypothetical mathematical model (Morgan, 2012). Fisher's (1892 [2006]) decision to use hydraulics to compute the dynamic process towards Walras' assumed equilibrium system is germane: Walras' auctioneer was created to justify an axiom asserting that excess demand or supply in various markets must — in theory — sum to zero, validating a proof of general equilibrium. Fisher chose to explore a different reasoning approach to the problem, avoiding the fictional axiom, seeking instead a broader understanding of the process — or various potential, path-dependent processes — by which economic systems evolved towards the potential equilibrium. As a more accomplished mathematician than Walras, Fisher may have been more cognisant that the approach used by Walras relied too heavily on what Poincaré referred to as "arbitrary hypotheses" (Boylan &
O'Gorman, 2018). Fisher's hydraulic approach was essentially a recursive simulation using a hydraulic analogue computer; the later Newlyn-Phillips Machine (Phillips, 1950) echoed this. An approach which satisfies "every desideratum specified, implicitly, explicitly, or even vaguely, from an epistemic, epistemological, or methodological point of view as economists" (Velupillai, 2018, p.10). Complexity of construction and the rigidity of physical models such as Fisher's or Phillips' inevitably meant they never flourished in economics, but the concept of recursive computation was valid.

The Stockholm School pioneered the use of [non-physical model] dynamic economic analysis in the 1930s, yet the approach was largely absent from the post-war discipline of macroeconomics (Backhouse & Laidler, 2004). Lundberg regarded the Walrasian system as wholly inappropriate for starting a dynamic analysis, and thus used sequence analysis based on causal processes; however, the reaction functions were a bit ad hoc and the results were sensitive to how expectations were formulated (Faxén, 1991). This comports with Simon's understanding that the major distinction between different schools of thought in economics is the belief in how expectations are formed (Simon, 1983, p.104-105). The conundrum Lundberg faced was having a relatively simple difference equation model (which could generate intuitive dynamics and handle non-linearities far better than formal solutions), but which was highly inefficient before computing (Baumol, 1991). The early dynamic analysis failed to spread not just because much was only published in Swedish (often in government reports) and their results were not generalisable, but because the systems were difficult to reconcile with the new-found econometric techniques (Sandelin, 2011). Frisch also developed a recursive approach to his "macro-
dynamics", conceptualising the approach with a diagrammatic representation of his *Tableau Économique* (Frisch, 1933), yet step-by-step numerical computation/simulation was an extremely intensive manual exercise, and the presence of non-linearities made solutions even of highly simplified systems of equations very difficult; it is impossible to provide an analytic solution to a system of more than a handful of non-linear equations (Bertalanffy, 1968, p.20). In any higher-order complex system numerical iteration (simulation) necessarily becomes the required approach to modelling. Despite the richness of their lessons, such recursive nonlinear models are extraordinarily complex (Velupillai, 1991). Simulation may lose the elegance of analytic solutions, but there can be no *a priori* assumption that a monetary economy has an analytical solution as an "equilibrium"; orthodox macroeconomics has essentially fudged this by pursuing linearization methods for local solutions.

While dynamic simulation models cannot provide general solutions or proofs, they "are powerful instruments of proof of what can perhaps be described as 'not necessarily' propositions or (what is close to the same thing) propositions which assert that so and so *can* happen" (Baumol, 1991, p.192) [emphasis in the original]. This should not be seen as a weakness, but as a strength of being consistent with — and essential for — the espoused ontology of complex socioeconomic systems. Outside economics, other disciplines have routinely regarded simulation as the preferred method for decades (see for example Borshchev, 2014; Law, 2007). In Regional Science, modelling has become a tool to structure debate around "what-if" scenarios rather than prediction (Batty & Torrens, 2005). Forrester developed SD based on a similar epistemology, crucial for understanding the purpose of system dynamics: complex systems
are inherently unpredictable and precise forecasts are unobtainable (Forrester, 1956; 1958; 1961). There is no prior expectation that an equilibrium solution is either desirable or possible. Forrester regards simulation as more of a broad check on mental and narrative models: simulation can "answer questions" regarding the "validity of descriptive economic theories" (Forrester, 2003). SD modelling in the social sciences entails a different epistemology from traditional economic and econometric models, but it is more consistent with the underlying social ontology (Mingers, 2016). The purpose of SD modelling is "to facilitate understanding of the relationship between the behaviour of a system over time and its underlying structure and strategies/policies/decision rules" (Wolstenholme, 1990, p.2). The simulation approach frees economics from constraints imposed by statistics and analytic solutions, being a "practical trial-and-error approach" (Forrester, 1989a, p.8): "It does not possess the elegance of more analytical methods, but it allows far greater scope for representing the actual structure of an economic system and for discovering the causes of behaviour that are observed in the real world" (ibid.). Leijonhufvud similarly argues that "the properties of more complex systems can only be investigated through computer simulations" (Leijonhufvud, 1993) [emphasis in the original].

While economics (particularly heterodox approaches) has for decades had elements of simulation, the idea of moving away from formalistic analytic-solution-based equilibrium modelling and applying pure simulation — in the philosophical sense of only accepting finite, algorithmic solutions — is less accepted in economic orthodoxy. Reiss (2011) pleas for more use of simulation in economics relative to both abstract mathematical models and experiments, arguing the approach requires fewer restrictive assumptions, and can be used
to explore various potential inferences of social system behaviour. Simulation may be regarded as an epistemic genre of a specific kind (Lehtinen & Kuorikoski, 2007): "a new epistemic technology" or a "digital workbench"; a form of experiment to creating a form of evidence (Morgan, 2004). Simulation models are incremental, scalable, and modular, naturally reflecting real system hierarchy, and are usually more communicable because of the visual nature of the approach (Borshchev, 2014). Simulation is increasingly recognised as the default approach in PK economics. Wray (2011) attributes the more modern numerical simulation approach to Tobin and regards it as the only way to treat true dynamics. Simulations allow elimination of reduced form equations and allows much greater insight into more complex, dynamics models than do analytic solutions (Lavoie & Godley, 2001). In SAM models, closure conditions are dependent on the researcher's "overall perception of the pattern of causality" at a specific time and place, emphasising the use of simulation rather than econometrics (Baghirathan, Rada & Taylor, 2004).

The value placed on (or how one interprets) the "evidence" of simulations may present problems in economics (Morgan, 2004). It may be conjectured that an economist trained in the formalist tradition may question the appropriateness of the "evidence". While it must be appreciated that the very nature of complex systems means that they cannot be predicted with precision, simulations without prior analytic solutions are arguably rejected by economists because of this perceived lack of mathematical elegance, certainty of results or analytical transparency (Reiss, 2011). Economists should be more aware that the idea of a mathematical proof being equated with "rigour" is merely a social construct, as is acceptance of mathematical postulation and proof as being necessary or
relevant for economics (Velupillai, 1996). This is at the heart of the mode of thought problem. Economists attracted to simulation look for guidance and intuitive insight into dynamics which are impossible to answer analytically. Implicitly, there is a proclivity for intuitionist rather than formalist axioms of mathematics: the element of the arrow of time, central to Brouwer's intuitionism (Boylan & O'Gorman, 2018), is a key component of post-Keynesian economics. In order to justify a greater role for pure simulation in economics, consistent with the need to understand ontology and epistemology, it is useful to get guidance from the philosophy of mathematics.

4.2.5 Epistemology of mathematics & computation
Feynman makes a distinction between a Greek and a "Babylonian attitude" to mathematics: "even in mathematics you can start in different places" (i.e., have different axioms) (Feynman, 1965 [1992], p.46ff.) Dow (1985) cites Feynman in calling for economists to reject Cartesian dualism and adopt a more Babylonian approach to methodology: an argument echoing both JN and JM Keynes (Dow, 1990; 2012). Orthodox economists chose to assume away problems of process, dynamics, uncertainty and non-linearity, preferring to work within the constraints of the methods available in the search of analytic solutions. Boylan & O'Gorman (2018) give a history of this struggle between formalism and intuitionism in the philosophy of mathematics as it applies to economics. The schism in economics may be traced to the adoption of Hilbert's formalist approach to mathematics at the turn of the 20th century, given prestige by the Vienna Circle's Logical Positivism, attempting to demarcate "science" from "non-science" (an attempt now thoroughly discredited in the wider philosophy of science — cf. Popper,
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Kuhn, Lakatos, Feyerabend (Blaug, 1993; Caldwell, 1984; McCloskey, 1983)).

The Bourbaki school of formalist mathematics had a profound influence on orthodox macroeconomics in the 1930s. Whereas the father of modern economics, Alfred Marshall, sought intuition and realism in his method, the Bourbakist Debreu — the father of neo-Walrasianism — may be seen as the anti-Marshall, taking shelter from the fuzzy world of economics in a neat, abstract formalism, (Dardi, 2016). Rigour — as interpreted by formalists following in Debreu's footsteps — is a purely abstract, axiomatic phenomenon with no applicability to economic phenomena: the paradox is that formalist mathematical rigour is incompatible with economic rigour (Boylan & O’Gorman, 2018). Boylan & O’Gorman (2009) agree with Kaldor's (1972) PK critique of the relevance of neo-Walrasian theory, that the fundamental set-theoretic axioms of neo-Walrasian theory are logically incompatible with empirical interpretation. Similarly, Clower (1995) suggests that rather than economics neo-Walrasian theory should be regarded as "excellent set-theoretic logic". Bourbakian formalism is fundamentally unsuited for processual, or complex, dynamic systems (Agliardi, 2004). Velupillai echoes both Mill and Jevons in stating that it is "ignorant" to claim that there is only one way to formalise in economics: not only have qualitative policy proposals been made for hundreds of years, the formalist approach is deficient in empirical content (Velupillai, 1996).

Velupillai (1996) poses a counterfactual, asking why set theory came to dominate and what would have been if an alternative — recursion theory (aka computability theory) — had become the preferred mathematical logic of economics? Knowledge in economic theory is inevitably technologically constrained. Today's computer technology gives access to this branch of
mathematics that had formerly been inaccessible to economists, providing for
the epistemologically more substantiable theory of computation as the basis for
economic modelling (Velupillai & Zambelli, 2015). The generally narrative
approach of post-Keynesians has historically isolated them from an increasingly
mathematically literate orthodox community (Weintraub, 1991). PK economics
took longer to establish as a quantitative discipline because PK economists
rejected the Bourbakian undertones of the neo-Walrasian programme. It has
only been in the last few decades that advances in computing have allowed
mathematically tractable development of the ideas which represent the
essential Keynesian mode of thought. Had the "technology" (both computer and
theoretical) existed in the 1930s, economics would have taken a naturally
algorithmic or combinatorial turn: "economic concepts would have been in
recursion-theoretic terms" — viz., economics would have become a computable
science rather than a formalistic representation of set theory (Velupillai, 1996,
p.260). Computable economics is the direction Goodwin (1951b) was explicitly
pointing to in cybernetics, not just as the true Walrasian "groping" to find
equilibrium, but also as wholly commensurable with Marshall's analysis.
Electronic computing techniques developed in the 1950s and coincided with
increased wariness of abstractions in economics (Orcutt, 1957; 1960). The
"enthralment" of neoclassical economics with methods inconsistent with
empirical evidence "risks becoming sheer dogma, bereft of any relevance for
policy guidance" (Orcutt, 2016, p.2-3). Keynes had previously warned of the
"mere concoctions" of "imprecise" mathematical methods losing "the real world
in a maze of pretentious and unhelpful symbols" (Keynes, 1936 [2013], p.297).
Both Velupillai and Boylan & O'Gorman argue that an appropriate way of incorporating computable (algorithmic) mathematics into economic models is using Herbert Simon's approach. Kao & Velupillai identify the concept of heuristics more formally with the recursion theoretic concept of algorithms: "Simon’s behavioural economics is almost comprehensively demonstrated by his encapsulation of *Human Problem Solving* and agents and institutions as *Information Processing Systems*" (Kao & Velupillai, 2015, p.249) [emphasis in original]. Simon was key in understanding the role of computers as an information processing system which can present decision making, rather than just acting as a calculator (Morgan, 2004). Simon also recognised hierarchy as how nature has adapted to deal with complex systems — an essential definition of a complex system is one that has hierarchy (Simon, 1962). Computer simulations allow large models with fine detail enabled by hierarchy within the modelling environment, enabling various views of the model to maintain intuition, whilst enabling a richly specified model to be operational. Hierarchy is a way of compartmentalising and dealing with what would otherwise be information overload (ibid.). Loasby argues that neo-Walrasian GE theory is inferior and inappropriate because "Systems that work must be selectively, not universally, connected, and large systems must be complex assemblies of smaller systems" (Loasby, 2012, p.835). This may be read as suggesting that the way forward for "general equilibrium" is taking a Marshallian route of partial equilibrium system (Rogers, 1989), and one which is suitably informed by the dynamics of decision-making in an algorithmic cybernetic sense, and combining them with hierarchy into the larger model.
4.2.6 Combining System Dynamics with Stock-Flow Consistent modelling

SD has previously been espoused as a useful and naturally complementary approach for Institutional and post-Keynesian economists (Atkinson, 2004; Harvey, 2013; O'Hara, 2007; Radzicki, 1990; 2003b; 2003a; 2008; 2015; Radzicki & Sterman, 1993; Richardson & Courvisanos, 2009; Saeed & Radzicki, 1993). However, while there is now a growing body of work combining SD and SFC (with a varied emphasis of style and technique), few have noticed or formally argued for the specific synergy between PK-SFC modelling and SD. Although often expressed in slightly different terms, the concepts of: stocks and flows; feedback; and limiting factors are key commonalities between system dynamics and PK-SFC modelling.

Yamaguchi (2016) has developed his own style of accounting derived dynamic macroeconomic models he terms "Accounting System Dynamics". Keen's approach (for example Keen, 2016) while systems theory conscious, is more eclectic, with a focus on "Godley Tables" and adapting the engineering block-diagram approach used by Andresen (1998); it is less directly descended from Forrester's approach. Tymoigne's (2006) complex model of Minsky's system has SFC accounting in the background, although does not present any conscious systems approach. Campiglio's (2012) ecological macro model was inspired by Keen. Jackson & Victor (2014) champion the approach, primarily arguing for its intuitiveness and ease of communication, and have created a series of models incorporating a financial sector with the emphasis towards ecological economics (Jackson & Victor, 2015a; 2015b; 2016).
The nature of the stock-flow accounting constraint in SFC models removes many degrees of freedom from macroeconomic modelling, as the monetary accounting structure forces the "free wills" of agents to conform (Taylor, 2004a). Macroeconomic behaviour thus "emerges" (in the ontological sense of emergence) from the institutional constraints imposed; macroeconomics is largely about explaining this process of emergent behaviour (Taylor, 2004a).

Godley & Lavoie note the "stupendous difference" between PK-SFC modelling and orthodox macroeconomics:

> We have a plausible story about how money enters and leaves the system. And money is the vehicle via which people receive their income, settle their debts, pay their taxes and store their wealth, thus linking each period to the next. (Godley & Lavoie, 2007, p.91)

The notion of equilibrium in this system is not wholly teleological on the part of agents, and hence represents a qualitatively different type of "equilibrium". The role of structure determining behaviour implies a key similarity between the underlying mode of thought of SD and PK-SFC modellers. Tobin, as a father of Stock-Flow Consistent modelling, describes monetary macroeconomic models which "must be regarded as referring to a slice of time, whether thick or paper-thin, and as embedded in a dynamic process in which flows alter stocks, which in turn condition subsequent flows" (Tobin, 1981, p.31). This could be a pithy description of SD. Godley is an implicit systems thinker, regarding "model architecture" as key: it "takes priority over parameter estimation" (Godley, 2001, p.234) (see also Cripps & Lavoie, 2017; Lavoie & Zezza, 2012). Godley & Cripps (1983, p.44) note the importance of the stability of stock-flow norms with the disclaimer that changing stock-flow norms "would not render the study of systems with given structures useless; indeed, the general theory of such
systems would help to clarify the consequence of structural change." Godley and Forrester espouse remarkably similar approaches to modelling, worth recounting verbatim; Godley states that

> Our use of the model was unconventional in that we treated it, not as something which would generate accurate forecasts of what would actually happen, but as a tool that informed our minds as to a great many possible outcomes conditional on a wide range of alternative assumptions both about exogenous variables and about parameter values. (Godley, 2001, p.234)

In a similar vein, Forrester suggests that

> In using a model, we should look less for prediction of specific actions in the future and more for enhancing our understanding of the inherent characteristics of the system. [...] a model should be judged by its ability to reproduce or to predict the behaviour characteristics of the system (Forrester, 1961, p.54) [emphasis in original]

Both statements represent a systems thinking point of view. Godley & Cripps (1983, p.42) refer to "a 'system' approach." Godley & Lavoie (2007, p.9) state that "we shall always be exploring the properties of complete systems". The relative robustness to parameter variation is consistent with the PK use of "stylised facts" (Clower, 1999; Kaldor, 1961) which have to be intuitive, logical, and plausible: SD equivalently uses difficult to quantify "soft variables". Such stylised facts, or "empirical regularities" in a broad sense are essential in seeking to establish a form of "truth content" in causal social science theories (Dore, 1988). Forrester criticises economists for focusing on numerical precision while often applying obvious structural inaccuracies: the idea that extensive statistical data collection must precede modelling is not only false but "exactly the reverse is true" (Forrester, 1961, p.57). The causal inference approach
supports the notion that human intuition is grounded in causal, not statistical logic (Pearl & Mackenzie, 2018).

4.3 Chapter Summary

The Keynesian Counter-Revolution shifted onto the wrong tracks of clockwork neo-Walrasianism; the rational expectations revolution consigned the cybernetic approach to obscurity. Today however, the development of computer technology and contemporary research in ecological rationality in an uncertain world allows macroeconomics to benefit from the Simon/Forrester approach to microfoundations of decision-making; it can be placed in a system model with natural hierarchy — an essential feature of complex systems. Moving beyond neo-Walrasian analysis, we are more able to develop appropriate general systems studying dynamic phenomena of equilibria and non-equilibria situations essential for understanding a monetary economy. The approach rejects the narrow confines of positivism and mathematical formalism, and comports with a more appropriate realist, dialectical perspective. This chapter has taken the gap discovered in the context of the problem of methodological monism in economics as driving the absence of theoretical macroeconomic models in the literature. It has presented a methodological perspective which seeks to justify why an alternative research method is necessary, and has enabled an alternative research method to be identified. The method of System Dynamics, combined with Stock-Flow Consistent modelling is presented in the next chapter.
Chapter 5 Method & modelling

5.1 Introduction

This chapter outlines the specific method being used and develops the core model. The essential socio-political framework is developed using stylised facts as underlying assumptions to develop model structures. The models are developed from a broadly post-Keynesian methodological framework, based upon foundations of Godley & Lavoie's specific SFC method (2007) and system dynamics, with an emphasis on developing behavioural aspects of model from precepts of classical behavioural economics.

5.2 Method of thesis

5.2.1 Method of System Dynamics

Saeed (2014) gives a useful overview of Forrester's "operational approach to economics": an iterative modelling process attempts to map a real-world problem, simulate behaviour, develop an understanding of the dynamics, and experiment with structural changes to improve outcomes. The principal approaches to building economic models in SD are either developing a model from scratch with empirical observations of the social system (like SD modellers generally do across disciplines) or start with an existing economic model and develop the model with the tools of SD, adding insights from systems theory (Radzicki, 2011). The approach taken in this thesis is that John Law's narrative island model from his principal work Money and Trade Considered (Law, 1705) is a useful conceptual "building block" (Orcutt, 1960) to develop with insights from Cantillon (1755), later economic theory (in particular post-Keynesian and
classical behavioural economics), and systems theory. The models developed from Law are detailed in the Appendix to aid parsimony of explication in the main text.

SD conceptualises real and metaphysical resources of a system (including, for example, money, capital, workers, commodities, goods, technology, expectations, beliefs etc.) as stocks and flows. The procedure may be described as "to observe and identify problematic behaviour of a system over time and to create a valid diagrammatic representation (or model) of the system, capable of reproducing (by computer simulation) the existing system behaviour and of facilitating the design of improved system behaviour" (Wolstenholme, 1990, p.2). The initial modelling process is a transitional stage between an espoused verbal/mental model and formal mathematical structure. Modelling generally begins by creating a conceptual map to capture causal connections between stocks and flows, representing key information feedback loops within a defined model boundary (Radzicki, 2011; Sterman, 2000). The approach may begin from either a feedback loop approach or a modular/structural approach (Wolstenholme, 1990). The approach followed in this thesis is the modular/structural approach, beginning with representation of stock-flow diagrams (SFDs) more akin to Forrester's (1961) original approach.

The visual model structure represents a system of integral equations, with the rate of flow into and out of each stock controlled by (in the terminology of system dynamics) a specific "decision" which is the result of hypothesised set of behaviours defined by a "decision rule" or a "policy" process; the policy is fed by information flows from the various levels, creating numerous information
feedback loops. In contrast to the "as if" requirement of "Positive Economics" (Friedman, 1953), SD models must demonstrate plausible (yet simplified) behaviours and assumptions, having real-world meaning in the actual system under investigation (Forrester, 1961). Figure 6 illustrates the metaphor of a bath-tub representing the hydraulic mechanism of stock-flow modelling, adding for reference the difference equations normally used in PK-SFC modelling:

**Hydraulic Metaphor:**

![Hydraulic Metaphor Diagram]

**System Dynamics Stock and Flow Diagram:**

<table>
<thead>
<tr>
<th>Integral Equation:</th>
<th>( Stock(t) = \int_{t_0}^{t} [\text{Inflow} - \text{Outflow}] ds + Stock(t_0) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Differential Equation:</td>
<td>( D(\text{Stock})/dt = \text{Net Change in Stock} = \text{Inflow}(t) - \text{Outflow}(t) )</td>
</tr>
<tr>
<td>[additionally] discrete time difference equation:</td>
<td>( \Delta \text{Stock} = \text{Stock} - \text{Stock}_{t-1} = \text{Inflow} - \text{Outflow} )</td>
</tr>
</tbody>
</table>

Figure 6. Hydraulic metaphor of stock and flows, adapted from Sterman (2000, p.194)

Where appropriate, according to the dimension of the variable, these stock-and-flow variables may be connected together (e.g., labour cannot be added to capital). This creates distinct circuits (alongside the monetary circuit, capital circuits, goods circuits, labour circuits etc.) which impact upon each other through the exchange of information. Stocks and flows must be conserved unless flows are identified as emerging from "sources" or disappearing into "sinks" which are beyond the conceptual boundary of the model. The various stock accumulations (integrations) give the system memory, thus enabling path dependency to emerge as a typical characteristic. Information feedback loops are inherent in most SD model structures; they can either be balancing loops...
leading to goal-seeking behaviour, or reinforcing loops leading to exponential growth. Feedback loops usually contain various types and lengths of time-delays. Overall combinations result in a finite set of fundamental modes of dynamic system behaviour including s-shaped growth, oscillation (including damped oscillation, limit cycles and chaos), growth-with-overshoot and overshoot-and-collapse (Sterman, 2000, p.107ff.).

A key benefit of SD compared to macroeconometrics is that system behaviour is posited to be primarily determined by structure, not parameters, because stocks or flows have certain limiting factors (for example, inventories, employment, population, carbon-absorption) which ensure the presence non-linear behavioural relationships (Radzicki, 2011). Detailed parameter estimation throughout the model is thus not a necessity in taking key insights, enabling conceptual, qualitative/mental models to be usefully represented, as well as more data-driven models. Models developed in this thesis are conceptual in nature, similar to what Simon (1990) refers to as "symbolic models". They may be regarded as illustrative "insight models" or "metaphorical models" generating transferable insight (Morecroft, 2012). Consistent with the objective expressed by Forrester & Senge (1980) the models are akin to a "general theory": such models may be seen as relating to a "family of social systems" to which the universal model is deemed applicable, and hence have to be robust enough to account for the heterogeneous nature of local economies reflected in potentially large differences in parameters. The "reference mode" (Richardson & Pugh, 1981) is a stylised narrative, rather than data-driven.
While some systems researchers apply a so-called "soft-systems" approach (Higgins (2013) for example, presents a purely qualitative systems approach to explain the 2008 financial crisis), Forrester regarded formal simulation as essential. Extreme-value testing and sensitivity analysis are regarded as the most appropriate ways to gain insight into such systems (Barlas, 1996; Forrester & Senge, 1980; Sterman, 2000), yet Forrester (1961, Ch.13) and Sterman (2000, Ch.21) warn that researchers should be humble in making claims for truth: "validation and verification of models is impossible" (Sterman, 2000, p.846). Such an appreciation of the limits of knowledge is in keeping with the critical realist perspective (Lawson, 2010). Valid means simply, "well suited to a purpose and soundly constructed." (Coyle, 1995). "The questions [...] is never whether a model is true but whether it is useful." (Sterman, 2000, p.890). Establishing the suitability of such models for purpose must rely on the type of knowledge which form the source of model development, including narrative (Forrester, 1961, p.128). Model validation can thus never be entirely formal or objective, but is a process from beginning conceptualisation to the ongoing task of simulating and comparing with objectives: "a gradual process of 'confidence building', rather than a binary 'accept/reject' division" (Barlas, 1996, p.188). The process of creating models becomes a key part of problem formulation and gaining understanding of the problem at hand, as it forces the elucidation and tractability of narratives and assumptions of the social process (Morecroft, 2015; Sterman, 2000; Wolstenholme, 1990).
### 5.2.2 Method of PK-SFC modelling

The complementarity between SFC modelling and SD emerges through the financial constraints established in the PK-SFC framework which are mapped onto the SD approach, helping to define the necessary monetary structure and boundary. The approach adopted by Godley & Lavoie (2007), now becoming standard in PK-SFC modelling, is adopted in this thesis. The modelling process is presented by Godley & Lavoie (G&L): it involves defining "a series of evolutionary models, each of which describes an economy moving forward non-ergodically in historic time", "always exploring the properties of complete systems" (Godley & Lavoie, 2007, p.9). They describe the method as to "write down systems of equations and accounting identities, attribute initial values to all stocks and all flows as well as to behavioural parameters, using stylised facts [...then] shock the system with a variety of alternative assumptions about exogenous variables and parameters to explore the consequences." (ibid.) G&L argue that simulating increasingly complex models allows the development of knowledge, creating "'informed tuition' as to the way monetary economies must and do function" (ibid.).

The SFC micro-meso-macro framework is flexible; both metaphysical (information) and substantive/real constraints can be added as deemed appropriate. In order to get better empirical mapping, SFC models must incorporate specific institutional detail – the meso; discussion of such details is essential for appropriate policy-making discussions (Dos Santos, 2006). Such specific institutional detail is largely defined in narrative, and informs the model structure. The CC models in the thesis are created with this institutional narrative, informed through the conceptual ordering of themes developed from
the literature review. Various microeconomic assumptions — the micro — may be made to establish behavioural equations.

SD can bring benefits to SFC modelling. Such benefits include the ability to intuitively eliminate an artificial long-run/short-run distinction, as time dimensions can easily be overlaid as required, and arguably a better way to formulate behaviour and institutional restrictions. SD aids SFC modelling in relation to the nature of money. Godley & Lavoie (2007, p.14) cite Godley & Cripps when reiterating "the fact that money stocks and flows must satisfy accounting identities in individual budgets and in an economy as a whole provides a fundamental law of macroeconomics analogous to the principle of conservation of energy in physics" (Godley & Cripps, 1983, p.18). However, PK-SFC modelling arguably does not account well for sources and sinks. Quadruple entry accounting implies a conserved flow whereas in fact the flow may be endogenously growing or contracting — e.g., a bank may be two nodes of a quadruple entry, "lending" on one hand and creating (ex nihilo) an asset and liability on the other. This is not accounted for in a standard SFC matrix because the bank is acting as a source and a sink: the quantity of money is not being conserved, but is sometimes expanded and sometimes contracted within the banking sector itself. SD is a useful adjunct to modelling money in this regard as the explicit representation of sources and sinks enables the differentiation of exogenous and endogenous money (whereby sources and sinks may be beyond the model boundary or accounting terms within the conceptual boundary), along with the nature of money creation.
5.2.3 Behavioural microfoundations of models

The well-known model closures of PK economics demonstrated in Godley & Lavoie (2007) have been critiqued as "programmatic Walrasianism" (Coleman, 2010), whereas SD is well established as developing bounded rationality in decision making as a complement to classical behavioural economics (CBE). The sector agent behaviours in the models in this thesis adopt a combination of the complementary PK, CBE and SD approaches. Morecroft regards as CBE a kind of language which describes feedback structure of SD models "in terms of the models' treatment of information flow and information processing in decision making" (Morecroft, 1983, p.141). The literature implies five key concepts adopted in both CBE and explicitly included in SD modelling (Sterman, 1987):

1) descriptive account focused on actual human behaviour, including heuristics and routines — not utility maximisation;
2) limitations of cognitive abilities;
3) questions of information availability and quality (e.g., bias, misinterpretation, distortion, delay);
4) limitations imposed by physical and institutional structure of the system;
5) disequilibrium dynamics, focus on feedback impacts of exogenous disturbances.

Integrating the concepts of complex decision making under bounded rationality has been problematic for incorporating in orthodox macroeconomic modelling (Sterman, 1989), although arguably, the connection between bounded rationality and SD is more recognised in management science and operations research than in economics. Morecroft (2015, p.218) describes policy functions which drive decisions: information processors pass through five filters represented in a policy "bullseye" diagram. The key filters are:

1) Cognitive limitations;
2) Goals, rewards, incentives;
3) Information, measurement, communication systems;
4) Organisation and geographical structure;
5) Tradition, culture, folklore and leadership.

Figure 7. Morecroft's (2015, p.218) bullseye diagram of bounded rationality

This may be regarded as ecological rationality, relating decision-making to simple rules dependent upon environmental context (Todd & Gigerenzer, 2012).

The micro foundations of the models here are developed within this PK/SD/CBE approach: they are necessarily dependent on socio-political/institutional context and open to interpretation.

5.3 Model evaluation (part 1)

A brief note on model evaluation is useful before the modelling process begins. While an absolute notion of "validation and verification of models is impossible" (Sterman, 2000, p.846), evaluation is ongoing throughout the modelling process, primarily relating to the validity of its internal structure, established with a confluence of qualitative and quantitative methods. These include parameter and structure testing such as: boundary testing; walkthroughs; dimensional consistency testing; parameter variation (sensitivity analysis) and extreme value
testing (Barlas, 1996; Forrester & Senge, 1980; Sterman, 2000, p.858ff.). These approaches are both implicit and explicit in the following discussion, and will be reviewed at the end of the chapter.

### 5.4 Groundwork for the core model

SD methodology favours an endogenous point of view, but the ability to narrow the model boundary where appropriate is welcomed (Richardson & Pugh, 1981). Boundary tests are a key part of the iterative process of modelling, and defining the system boundary and the degree of aggregation are the most difficult problems in formulating appropriate models (Forrester, cited in Sterman, 2000, p.100). Richard Cantillon's (1755) approach explicitly created a rural-urban split in Law's system. This can be conceptualised in a sub-system diagram:

![Sub-system diagram conceptualisation of Cantillon's monetary circuit](image)

**Figure 8.** Sub-system diagram conceptualisation of Cantillon's monetary circuit

Applying Cantillon's conceptual analysis, it is clear that much of what goes on in a national macroeconomic model is unnecessary for evaluating local currencies:
the local economy has to passively accept what happens beyond the control of its resident agents. Monetary inflows and some outflows can be usefully condensed into exogenous parameters, because they are largely determined outside of the local economy. Adapting Cantillon’s notion, a sub-system diagram for the generic local economy of the core model can be presented.

Figure 9. Sub-system diagram of conceptual model

Dynamics of the local economy are driven by a combination of exogenous parameters and internal parameters and structures; the external economy is invariant to changes within the local economy. This plausible abstraction allows for a fuller investigation of the local dynamics, without unnecessary external complicating factors. It is essentially an economy embedded within a larger economy where there is no feedback from the local into the national. A stock-flow diagram (SFD) of the minimum monetary flows of such a model are represented in Figure 10. This model has the necessary monetary stock-flow consistency at the internal level of the local economy, but the external economy is essentially kept beyond the model boundary. While this appears quite
primitive, a key objective of SD modelling is to find the simplest model possible that appropriately addresses the problem at hand. This is akin to "the minimum necessary model" in economics which "requires a lot of hard thinking to make the models look trivial" (Krugman, 1993, p.27).

![SFD of "minimum necessary model" of regional monetary economy](image)

**Figure 10. SFD of "minimum necessary model" of regional monetary economy**

This forms the basis for the submodel of local economy money flows: there are two sectors, households and local producers; each has a stock of money; each has a single source of external income, and external spending; but the two monetary stocks are now reciprocally connected through local consumption and payment of income. In such a regional economic model we can abstract from the financial system and assume that national currency (GBP, including government fiat money and bank credit transfers) is exogenous. Local resilience requires maximising the local circular flow of money while reducing the external outflows. The structure essentially represents a simplified monetary flow akin to that narratively presented in Ward & Lewis (2002), with the objective of
"plugging the leaks" in the local economy monetary bucket. While these monetary flows are the minimum necessary structure at the heart of the model, the behaviour of households and producers (including the employment constraint in production) has to be developed. Figure 11 represents a simplified conceptual map of the overall model structure developed in this chapter, with each submodel exchanging information which drives the monetary flows.

Figure 11. Conceptual map of model structure

5.4.1 Microfoundations of behaviour

Consumer choice in orthodox macro models involves optimising decisions under various degrees of "rational" behaviour in an intertemporal expected-utility Euler equation. Post-Keynesian and Classical Behavioural economists (and system dynamics modellers) reject this behavioural axiom as a modelling fiction. For household behaviour in models in this thesis, two key concepts are introduced:

1. an approach adapted from classical behavioural economics of presenting a standard Keynesian consumption function as a processual, behavioural control loop (a form of cybernetic control); and
2. from PK microeconomics, the taxonomic, or lexicographic ordering of needs (Lavoie, 2015).

Operationalising household consumption behaviour in this way is novel. It is argued that this is a key issue to recognise the non-neutrality of money, particularly in regional economies. Households have a hierarchy of goals to fulfil, and each time-step \((dT)\) in the model feeds back the "error term" via the circular flow and adjusts flows as appropriate for the next time-step. This is the monetary servomechanism of Smith's "invisible hand". SD defines this in terms of the goal-seeking behaviour and the servomechanism (autopilot) type response of the system. Each sector agent has constraints, goals and a strategy for achieving the goals, including a target time-frame. This procedural approach to consumer spending is consistent with both PK consumption theory and CBE, based on computable (algorithmic) logic, process and bounded rationality. Many economic decision concepts have this cybernetic control loop of a desired level and an actual level creating an "error term" — the difference that the agent seeks to correct (Goodwin, 1951a; 1951b). Essentially, it is a form of an iterative fast-and-frugal decision tree of a kind used as decision predictors in behavioural psychology (Gigerenzer & Goldstein, 2011). The goal-seeking behaviour of households is a key determinant of the overall model steady-state. The household's constraints and goals are:

- Money income + money wealth;
- desire for maximum consumption (spread across the hierarchy of consumption baskets) while achieving and maintaining target wealth in a targeted time-frame.

This implies exogenously given consumption/saving parameters which determine the amount of annual spending. In a traditional textbook style
Keynesian consumption function, consumption is driven by a proportion of income (the average propensity to consume), plus some given "autonomous" component. An improved Keynesian consumption function includes wealth (see Godley & Lavoie, 2007, p.65ff.). The traditional approach has the benefit of simplicity and familiarity, but including wealth in consumption is an essential aspect of SFC modelling. In SFC models, in terms of propensities to save/consume, the cybernetic feedback is only implicit — the "error control" is not overt. This relates to all agents' decisions, not just consumption:

[agents] set themselves norms and targets, and act in line with these and the expectations that they may hold about the future. These norms, held by agents, produce a kind of autopilot. Mistakes, or mistaken expectations, bring about piled-up (or depleted) stocks — real inventories, money balances, or wealth — that signal a required change in behaviour. (Godley & Lavoie, 2007, p.16)

However, throughout G&L's models (and even in recent large-scale empirical agent-based models (for example, Burgess et al., 2016)) the consumption function remains represented with a traditional formulation of symbolic parameters of a denoted propensity to consume out of income and wealth. Additionally, actual income and wealth are likely to differ from perceived and/or income and wealth. This leads to the charge that such models are not properly microfounded. Conversely, the propensity to consume and the multiplier it implies are regarded as somewhat sacrosanct in traditional Keynesian macroeconomics. These may in fact be regarded as artefacts conceptualised in an era before computer simulation: using this approach in modelling is an awkwardly symbolic concept.

Implicitly rejecting both orthodox rational choice optimising microfoundations, and traditional Keynesian consumption functions, the PK/CBE/SD synthesis
seeks to model decision policies based on concepts which have obvious real
world meaning and context. Rather than using a more traditional reduced form
approach modellers seek to communicate these processes by "unpacking"
them. G&L suggest that households are more likely to think explicitly in terms of
targeted wealth and a time-frame to accumulate such wealth, with a decision to
save, rather than as propensities to consume out of wealth and income. Being
explicit in this approach is more consistent with the SD/CBE approach:
households have a target and a perceived level, hence a perceived "error" they
seek to adjust, and a time frame over which they seek to adjust the error.

A traditional Keynesian representation of the households' consumption function
policy can be illustrated in a simple stock-flow diagram (SFD), where APC_Y is
the average propensity to consume from income, and an exogenous
autonomous consumption component is given.

![Diagram of Naive traditional Keynesian consumption function]

**Figure 12. Naïve traditional Keynesian consumption function**

The augmented consumption function, adjusting for wealth (hence being stock-
flow consistent), eliminates the arbitrary autonomous consumption and adds
APC_W as the average propensity to consume from wealth.
Using G&L's notation (2007, Ch.3), the propensities to consume from income ($APC_Y$ or $\alpha_1$) and wealth ($APC_W$ or $\alpha_2$) imply both a target wealth-to-income ratio ($\alpha_3$) — the goal the household sector seeks — and also an adjustment time in which the household sector seeks to achieve this goal. In the G&L text, $\alpha_3$ (target wealth-to-income ratio) is given by the formula:

$$\alpha_3 = \frac{1 - \alpha_1}{\alpha_2}$$

The parameter $\alpha_2$ is termed the "partial adjustment parameter" denoting the proportion of the wealth gap households seek to close each year (G&L, 2007, p.75). In system dynamics, the reciprocal of $\alpha_2$ is referred to as Adjustment Time (AT). AT implies a rate of accumulation of savings which attempts to close 63% of the perceived "error" in one AT. In Godley & Lavoie's standard run, $\alpha_2$ is set at 0.4; this is equivalent to closing 40% of the "error" each year; when $\alpha_2$ is 0.4, 63% closure would take 2 ½ years (i.e., $AT = 2.5$). 98% of the gap is closed in four ATs — this is termed "settling time" to steady state, and is a crucial notion in determining steady-state dynamics in SD (Sterman, 2000, p.279).

Table 3 represents G&L's given consumption parameters $\alpha_1$ and $\alpha_2$ in terms of the implied parameters $\alpha_3$ and AT.
Table 3. Turning Keynesian consumption propensities into cybernetic control

G&L's standard runs imply a target wealth to income ratio of 1, and an adjustment time of 2.5. The household sector's desire to achieve target wealth is a key determinant of both the model's ultimate steady state and its settling time to reach that steady state. Arguably, representing the traditional Keynesian parameters in this way adds transparency to the actual goal and adjustment process of household consumption: money is spent, income is received, and the "error term" of actual wealth relative to target wealth is monitored each time-step. The goal-seeking behaviour may be subject to being confounded by other agents' behaviour (either explicit or implicit), leading to a type of emergent behaviour of the model. The household sector's basic consumption decision can therefore be better represented (Figure 14):
Figure 14.  **SD re-interpretation of Keynesian consumption function**

The TargetWealthIncomeRatio_α3 gives a TargetWealth level which is monitored relative to actual MoneyWealth creating a WealthShortfall: the "error term". The error is then reduced by Saving (not spending), which is moderated by the AdjustmentTime_AT. Expenditure in excess of income reduces MoneyWealth, thus closing the control loop.

A form of conditional logic is required that payments can only be made when money is available. Following Forrester (1961), such institutional constraints in SD models may be termed "implicit decisions", as they are forced by institutional constraints. No money stock can become negative, hence "first order control" is required to ensure outflows diminish as stocks of money approach zero, and cease entirely before the stock becomes negative (see Sterman, 2000, p.545ff.) Such control avoids the discontinuities created by simple if-then-else statements inserted into each flow "decision" point. First order control (MaxSpend) is inserted which reduces Expenditure outflows as MoneyWealth approaches zero. This satisfies the so-called cash-in-advance requirement. Parameters of TargetWealthIncomeRatio_α3 and AdjustmentTime_AT are exogenously set in this model (as is, equivalently, standard practice for economic models). A simple simulation of the consumption
function model in Figure 14 is now undertaken. In the G&L models, the target wealth and adjustment time parameters are fixed at the equivalent used in this simulation. Income is set at £100, with a sinusoidal variation of the IncomeParameter (to demonstrate a stylised business cycle); a negative income shock of -£30 hits in year 10:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TargetWealthIncomeRatio_α3</td>
<td>1</td>
</tr>
<tr>
<td>AdjustmentTime_AT</td>
<td>2.5</td>
</tr>
<tr>
<td>Initial MoneyWealth</td>
<td>0</td>
</tr>
<tr>
<td>IncomeParameter</td>
<td>£10</td>
</tr>
<tr>
<td>Income</td>
<td>£100 + (IncomeParameter * sin(time()*/0.5)) + step(-£30,10)</td>
</tr>
<tr>
<td>Simulation time</td>
<td>20 years (all simulations in thesis)</td>
</tr>
<tr>
<td>dT</td>
<td>0.001 (all simulations in thesis)</td>
</tr>
</tbody>
</table>

Table 4. Table of parameters, Keynesian consumption function simulation

![Graphs showing consumption function simulation](image)

Figure 15. Keynesian consumption function simulation

5.4.2 A note on numerical methods

A note on numerical methods and time-steps is appropriate at this point. All simulations in this thesis are undertaken with the default numerical methods settings in the AnyLogic software: the simulation time step \((dT)\) is 0.001; the integration method is standard Euler. Altering default settings may impact simulation outcomes through generally small (but compounding) errors either in the form of integration errors or round-off errors (see Sterman, 2000, p.872ff. &
Appendix A). The trade-off between larger or smaller dT results in a trade-off between these two types of error: while a smaller dT requires more processing power, it is usually preferred in order to minimise integration error — the trade-off is to balance any potential errors thus created due to round-off. The dT should ideally be based on some reference to model logic in terms of simulation period and decisions within the model: the "rule of thumb" is to set it "between one-fourth and one-tenth the size of the smallest time constant" in the model (Sterman, 2000, p.907). The simulation time of all models in this thesis is one year hence all flows are measured as annual rates, with delays generally set to 0.25 years, or 0.08333 years (approximately 1 month); first order controls on money flows imply a time constant closer to one week. The default dT setting in AnyLogic of 0.001 implies a time-step roughly equivalent to 2-3 times per day in all the models in this thesis. A dT of 0.01 would imply a bi-weekly time-step; 0.1 would be roughly a monthly time-step. Experimentation was undertaken to ascertain differences in simulation based on alternative dT settings. Experimentation indicated negligible impacts of round-off error at lower time steps: while a dT of 1 is clearly inappropriate, 0.1 also implies some behavioural change with cyclicality muted. The results of dT of 0.001 (default) and 0.01 are similar. The default was chosen as the preferred option. More detailed comparative results are presented (after the core model has been developed) at the end of the simulation section of this chapter.

5.4.3 Lexicographic ordering of consumption
In addition to the control loop for overall spending demonstrated, the concept of lexicographic ordering of consumption needs is introduced from PK theory.
Households firstly need to meet basic subsistence needs (and contractual obligations) including food and lodging, before saving or further consumption needs can be addressed. This approach to consumption dates back to Menger and Ernst Engel, with evidence it remains highly relevant (Chai & Moneta, 2012). Lavoie (2015, Ch.2) details seven key principles of PK choice theory:

1) procedural rationality;
2) satiability of needs;
3) separability of needs;
4) subordination of needs;
5) growth of needs;
6) non-independence;
7) heredity.

To establish the appropriate stylised facts, it is useful to give the broader empirical context: the UN's recognised procedure for empirical measurement of national household spending data, COICOP (Classification Of Individual Consumption according to Purpose) is used by the ONS and is consistent with UK National Accounts (ONS, 2018a). The ONS has collected a variety of data for 60 years to breakdown consumer spending and now broadly follow the COICOP approach (see for example 2018b; ONS, 2018a). The 12 over-arching COICOP category codes listed are:

01 - Food and non-alcoholic beverages
02 - Alcoholic beverages, tobacco and narcotics
03 - Clothing and footwear
04 - Housing, water, electricity, gas and other fuels
05 - Furnishings, household equipment and routine maintenance
06 - Health
07 - Transport
08 - Communication
09 - Recreation and culture
10 - Education
11 - Restaurants and hotels
12 - Miscellaneous goods and services

In the PK context, these may be regarded as separable categories, *viz.*, having near-zero income/price elasticity of substitution. Having twelve individual categories unnecessarily complicates the modelling for purposes here. These consumption needs also need to be given a hierarchy. Therefore, it is useful to simplify. Using the approach from Lavoie (2015, p.118), alternative, complementary consumption baskets are aggregated into three broad categories: food; lodging; and entertainment. Within these categories is a hierarchy of consumption preferences: consumption baskets within each category are simply labelled as A, B, C … Z, categorised in order of need. Figure 16 is taken directly from Lavoie (2015). This greatly simplifies the presentation and modelling rather than adhering to the COICOP definitions, while keeping the concept of differentiable consumption baskets in mind.

![Diagram of consumer subordination and overlap in needs: decision tree and sub-needs (Lavoie, 2015, p.118)](image-url)
Figure 16 illustrates where A, D, and G are differing qualities of food (increasing in quality): A is subsistence; D is better quality food but only demanded after minimal needs of lodging (B) and entertainment (C) have been attained. The implied "utility cascade" can be illustrated with arrows (Figure 17): income will be dedicated to fulfilling each need in turn, until income is expended. Lavoie argues this is more appropriate when understanding typical consumer behaviour than the orthodox approach which seeks intertemporal optimisation of infinite period expected utility.

![Diagram of consumer expenditure](image)

**Figure 17.** Subordination and overlap of needs decision tree (adaptation, from original Lavoie, 2015, p.118)

This approach has previously been difficult to operationalise, and the methodology of orthodox macroeconomics assumes the problem away. The use of a computable methodology in system dynamics allows this processual approach to be operationalised in a simulation model, and may be seen as
crucial to understanding aspects of *Cantillon effects* and the non-neutrality of money.

Lavoie's conceptual approach needs to be adapted to represent a local/regional economy where there are likely to be particular flows of expenditure which may be categorised into external/internal expenditure, and additionally into discretionary/non-discretionary expenditure. Income streams also have to be considered. The recently formed Centre for Towns (2017) seeks to collate the kind of data which may be appropriate, demarcating locales into: villages; communities; small-towns; medium towns; large towns; and cities. One of the key issues in regional analysis is the heterogeneous nature of the regions and the degree of economic totipotentiality according to the size and location of the area chosen which may have a large influence on the parameterisation of any empirical model. The source of income and available channels of expenditure (thus the stylised facts for parameterisation of any specific model) are likely to vary widely according to locale. Key issues are outlined in Table 5:

<table>
<thead>
<tr>
<th>Difference to consider</th>
<th>Example of heterogeneity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geographic location</td>
<td>Access to employment and type of industry.</td>
</tr>
<tr>
<td>Settlement type</td>
<td>For example, a university, coastal or commuter town.</td>
</tr>
<tr>
<td>Size</td>
<td>A city or large town may likely have a smaller proportion of inflows and outflows relative to endogenous local economic activity. A village will likely have a very large proportion of external trade relative to the local economy.</td>
</tr>
<tr>
<td>Size/type of population</td>
<td>Relative proportions of workers (and commuting workers), pensioners, students, unemployed or welfare benefit dependents.</td>
</tr>
<tr>
<td>Relative wealth of population</td>
<td>A poorer locality will likely rely more on welfare payments and in terms of housing will likely have fewer owner-occupiers, and a higher proportion of absentee landlords. This means more external payments of rent, mortgage interest, on top of higher proportions dedicated to utility bills etc.</td>
</tr>
</tbody>
</table>
The potential for "export" sales | Potential exports may be limited or capital-intensive, or more reliant on labour inputs and local production (e.g., tourism)?
---|---

| Table 5. Issues to consider with parameterisation: the heterogeneity of regions |

These factors indicate that a regional model must be robust to parameterisation which may be highly variable according to context. SD modelling is useful when comprehensive data is not available as the structure of the model generally takes primacy over parametric accuracy (Forrester, 1980). The fundamental epistemology of SD accommodates approximations of variables deemed relevant for modelling but which may have no empirical data. The type and variability of income streams from outside the model boundary are regarded as exogenous to the model.

For the purposes of developing an operational model of a regional economy, the hierarchy and subordination of needs borrowed from Lavoie is adjusted to account for decisions impacting expenditure flows within or outside the regional economy model. Additionally, it is crucial to recognise (as seen the Law's model) that some monetary flows are discretionary and — to a greater or lesser extent — some are not. Rents and mortgage interest payments are largely non-discretionary spending: there may be an element of discretion amongst individuals able to re-contract over time, but as a region, there is an amount of rent to be paid which the region as a whole has no choice, and at any point in time, mortgage interest payments are set by the bank lending the money which will be external to the local monetary circuit (since the oligopolisation of the banking industry, even for large size city-regions of the UK outside London). There is little discretion in utility payments. Adapting Lavoie's original (Figure 16), this notion is presented as a decision between goods and services which
are consumed on a non-discretionary or discretionary basis, and additionally, as either external or local production (Figure 18):

**Figure 18. Simplified cascade of consumption needs**

Non-discretionary purchases must clearly be fulfilled before discretionary. An assumption implied in Figure 18 is that external goods/services appear higher in the hierarchy of demand than do local goods/services. This is a broad conclusion of the localisation literature that suggests that due to the wider choice and lower cost of goods produced in global value chains, demand for locally-produced goods and services (broadly) fulfils a different consumption objective, which has a lower priority than the satiation of external demand. There may also be an assumption that the contractual nature of external non-discretionary expenditure (such as taxation, or utility payments to multi-nationals) may be more aggressively pursued in default. The behaviour of implying initial priority for discretionary external expenditure over local discretionary expenditure is modelled by endogenising the proportion of local discretionary spending according to income (see commentary to Figure 21 below). The SFD of monetary flows can be annotated to illustrate the kind of
monetary flows which may be expected into (income) and out of (expenditures) the local economy monetary circuit.

Figure 19. SFD illustrating examples of consumer monetary flows

Expenditures must be demarcated into non-discretionary and discretionary expenditures. It is impossible (from the perspective of both ontology and epistemology) to create an accurate universal demarcation: there is a broad spectrum of possible parameterisation according to the size and nature of the region which accounts for the relative quantities of the external/local split, as well as the discretionary/non-discretionary spending split. A proposed working demarcation of household expenditure into a matrix of external/local and non-discretionary/discretionary is presented in Table 6. While this is merely a
heuristic, it is suggested as an essential framing for understanding the differentiable consumption needs of households.

<table>
<thead>
<tr>
<th>Consumption Choices</th>
<th>External (E)</th>
<th>Local (L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-discretionary</td>
<td><strong>Staples:</strong> Rent; mortgage; utilities; most food; most clothing.</td>
<td><strong>Staples:</strong> Transport; car-servicing; essential repairs; some food.</td>
</tr>
<tr>
<td>(ND)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discretionary (D)</td>
<td><strong>Non-staples:</strong> Car finance; luxuries; holidays; ‘Amazon’; some food; some clothing.</td>
<td><strong>Non-staples:</strong> Hospitality; personal services; construction; painting/decorating maintenance; some food.</td>
</tr>
</tbody>
</table>

Table 6. Matrix of consumption choices

Figure 20 reiterates the model flows, but creates separate flows for the four channels of expenditure, accounting for external and local household spending as discretionary and non-discretionary external and local spending:

1) NDE (Non-Discretionary External)
2) DE (Discretionary External)
3) NDL (Non-Discretionary Local)
4) DL (Discretionary Local)
Figure 20. **SFD with examples of external spending**

A hierarchical cascade of consumer demand between four baskets of goods/services and (saving) wealth accumulation can be illustrated with a lexicographic consumption model of households, adapting the earlier Keynesian consumption model. This is a "proof-of-concept" standalone model, subsequently adapted for the core model.
Figure 21. "Proof of concept" standalone model of lexicographic choice

The equations of the model are contained in the Appendix (section A.6). As a verbal walkthrough of the model, household purchasing power is a combination of both income and wealth (these are subject to perception delays, see section 5.4.4): NDE is demanded first, followed by NDL; when demand for NDE and NDL is satiated, disposable income may be saved or spent on discretionary goods DE and DL. The nature of how discretionary preferences cascade is open to legitimate interpretation. In the model developed here, the act of saving (non-spending) reduces discretionary demand from available disposable purchasing power; this is a measure of purchasing power after non-discretionary expenditure has been fulfilled. The smoothing implied by AdjustmentTime means that saving takes place contemporaneously with discretionary consumption. External and local discretionary purchases are
simultaneous, however, the intuitive notion of the primacy of external consumption (essentially, local consumption is a form of luxury good) is endogenised in the model: the proportion of spending between external discretionary (DE) and discretionary local (DL) is a function of spending power (using the look-up function \textit{DE\_DemandFractionLookUp}): as discretionary spending power rises relative to non-discretionary spending, the proportionate demand for external goods drops (to a minimum of 0.6).

![Look-up function for endogenising discretionary spending breakdown](image)

**Figure 22.** Look-up function for endogenising discretionary spending breakdown

### 5.4.4 Delays

The desire to accumulate wealth with a given \textit{AdjustmentTime} implies a smoothing delay in household consumption (and the creation of a buffer of money wealth). In addition, further consideration must be taken for other potential delays in the system. It is regarded as poor modelling practice in SD for decisions to be driven by flow rates (as opposed to stocks), as flows generally cannot be known with certainty in real-time. However, in economics it is widely understood that income flow is a key driver of behaviour. Real-time uncertainty may also be applied to stocks, and cybernetic control loops in social
systems must consider the potential for incomplete or inaccurate information, hence differences between actual errors and perceived errors (Goodwin, 1951a; 1951b): a view condoned by Forrester (1961). It is logical then when specifying demand as a function of wealth and income that both should be subject to some kind of perception error. The nature of plausible perception delays may be debated. Sterman (2000, Ch.11) offers a valuable source on the notion of modelling appropriate information delays: a third-order exponential smoothing, a form of distributed lag (where immediate reactions to changes are smoothed) is considered as the most appropriate in this context. While relatively short delays on both wealth and income are deemed most plausible, initially very short delays (equivalent to one week) are used to minimise their impact. Simulations of this lexicographic model illustrates how a generic income cycle may differentially impact consumption of the four baskets: experiment 1 sees the sinusoidal cycle in income with a shock of -£10 in year 10; experiment 2 increases the size of the shock to -£30.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TargetWealthIncomeRatio</td>
<td>1</td>
</tr>
<tr>
<td>AdjustmentTime</td>
<td>2.5</td>
</tr>
<tr>
<td>Initial MoneyWealth</td>
<td>0</td>
</tr>
<tr>
<td>NDE_Demand</td>
<td>40</td>
</tr>
<tr>
<td>NDL_Demand</td>
<td>40</td>
</tr>
<tr>
<td>FOCParameter</td>
<td>0.01923</td>
</tr>
<tr>
<td>DE_DemandFraction</td>
<td>DE_DemandFractionLookUp (DisposablePPAsPerCentDiscretionary)</td>
</tr>
<tr>
<td>IncomeParameter</td>
<td>£30</td>
</tr>
<tr>
<td>IncomeExpectationDelay</td>
<td>0.01923</td>
</tr>
<tr>
<td>WealthPerceptionDelay</td>
<td>0.01923</td>
</tr>
<tr>
<td>Socked parameter</td>
<td></td>
</tr>
<tr>
<td>Income</td>
<td>£100 + (IncomeParameter * sin(time() / 0.5)) +:</td>
</tr>
<tr>
<td></td>
<td>Experiment 1: step(-£10,10)</td>
</tr>
<tr>
<td></td>
<td>Experiment 2: step(-£30,10)</td>
</tr>
<tr>
<td>Simulation time</td>
<td>20 years</td>
</tr>
</tbody>
</table>
$dT = 0.001$

Table 7. Table of parameters for lexicographic model simulations

Figure 23. Lexicographic model, experiment 1, sinusoidal variation plus negative shock of -£10 in income
The flows generated by the household's consumption submodel illustrates how processual, lexicographic consumption behaviour without substitution impacts the four designated spending channels according to rising and falling income. A relatively small income shock in experiment 1 means some savings are accommodated while discretionary spending stops, but non-discretionary spending is still met. A larger shock in experiment 2 means wealth is temporarily eliminated, savings stops, and default on non-discretionary payments may occur.
5.4.5 Parameter variation (sensitivity analysis)

While a detailed discussion of the nature of specific delays and the cyclical dynamics they create is beyond the objectives of the research question here (which is focused primarily on generalisable structural possibilities across a family of heterogenous underlying systems), the nature of delays potentially creates confounding dynamics in large models which require some investigation. The parameters in all the models are stylised facts. The nature of general theory models is that the potential for plausible parameter variation within the "family" of models is potentially quite high; this is especially true with heterogenous local/regional economies. The epistemology of SD recognises that most structurally-determined systems are largely invariant to a potentially wide variation in parameters, but there are potentially key parameters which can have confounding effects. The sinusoidal variation of the simulation experiment is quite extreme in frequency and intensity and has been chosen specifically for the purpose of a robust illustration of the concept.

The proportion of income which is spent on non-discretionary and external consumption may have significant implications for discretionary and local spending. By holding all other parameters constant (from experiment 1) but varying the parameter $NDE_Demand$ from 40 to include 20, 60 and 80, the impact on the consumption baskets may be indicated (Figure 25):
While the length and depth of cycles and nature of expenditure may vary quite dramatically according to various plausible parameterisations, the model is robust to the general result that discretionary spending is more vulnerable to income (or wealth) shocks. If it is accepted that local expenditure is lower ranked than external expenditures, this has significant implications for local economic activity. Higher levels of NDE_Demand may be recognised as akin to the concept of “fuel poverty”.

Behavioural parameters impact the model primarily with respect to Expenditure and accumulated MoneyWealth (which acts as a buffer to income shocks) and
the speed of reaction to shocks. \textit{AdjustmentTime} and \textit{TargetWealthIncomeRatio} are initially varied.

\begin{figure}[h]
\centering
\begin{minipage}[c]{0.45\textwidth}
\includegraphics[width=\textwidth]{money_wealth_0.25.png}
\end{minipage}\hfill
\begin{minipage}[c]{0.45\textwidth}
\includegraphics[width=\textwidth]{expenditure_0.25.png}
\end{minipage}
\begin{minipage}[c]{0.45\textwidth}
\includegraphics[width=\textwidth]{money_wealth_1.0.png}
\end{minipage}\hfill
\begin{minipage}[c]{0.45\textwidth}
\includegraphics[width=\textwidth]{expenditure_1.0.png}
\end{minipage}
\begin{minipage}[c]{0.45\textwidth}
\includegraphics[width=\textwidth]{money_wealth_3.25.png}
\end{minipage}\hfill
\begin{minipage}[c]{0.45\textwidth}
\includegraphics[width=\textwidth]{expenditure_3.25.png}
\end{minipage}
\caption{\textit{MoneyWealth} & \textit{Expenditure}, varying \textit{TargetWealthIncomeRatio}}
\end{figure}
A TargetWealthIncomeRatio of zero implies no saving, with all income spent on consumption. Consumption is thus entirely driven by variations in income and the relative proportion of spending in each category. If TargetWealthIncomeRatio is significantly higher (e.g., 3.25), the cycles are somewhat ameliorated, although discretionary spending is reduced while a
A cushion of wealth is accumulated. This cushion of wealth means non-discretionary expenditure can be maintained for longer through income shocks. *AdjustmentTime* also has an impact on initial wealth accumulation. The nature of cyclicality is little different at larger values (implying slower time to accumulate wealth). *MoneyWealth* or *Expenditure* have an inclination to greater cyclicality when *AdjustmentTime* is less than 2 (i.e., when "settling time" is 8 years or less). Arguably, the lower measures are less plausible parameters. The parameters marking extremes have some implications for dynamics which are worth noting, but the variation ultimately has little impact on the structure of the model. The extreme parameters are well beyond the bounds of the plausible stylised facts used by the Godley & Lavoie models. It may be considered reasonable to thus stick with parameters implied in the G&L models, with *TargetWealthIncomeRatio* 1, and *AdjustmentTime* of 2.5 years.

The specific delay parameters *WithPerceptionDelay* and *IncomeExpectationDelay* can also have dynamic implications. Both parameters are set at the shortest plausible delay (equivalent to approximately one week) in the experiments. The parameters are varied with approximations to weekly, quarterly and annual delays (Figures 28 and 29). It can be illustrated that a plausible assumption of a one quarter delay has little discernible impact on the dynamics. When moving to less plausible delay periods (such as one year and beyond), cyclicality increases, and particularly with *WithPerceptionDelay*, more unstable dynamics arise. However, such long perception delays seem unwarranted, as it implies wealth may drop to zero without households being aware of it for a year. There does not appear to be a reason why a longer delay is plausible for the issue at hand.
Figure 28.  *MoneyWealth* and *Expenditure*, varying *WithPerceptionDelay*
First order control of money-flows can have implications for short-term dynamics. The purpose of first-order control is to ensure money stocks do not fall below zero: the cash-in-advance constraint, rather than a specific target-wealth objective (which is a separate parameter). The variations show the smallest 0.001, as well as approximating one week and one month.
If first-order control is set at a higher level (implicitly, keeping a month’s cash on hand) payments will cease more quickly than if cash balances are allowed to approach zero. In the model a low setting has been chosen: 0.01923, equivalent to one week’s cash balance. A smaller first order control may contribute to sharper, more frequent discontinuities under extreme cyclical
variation (and could imply a need for smaller model dT). Overall, there is some variability to be conscious of in the cyclicality of the model according to delay parameters. However, it seems reasonable to conclude that perception delays of both income and wealth are unlikely to be more than one quarter: these have little impact on the model. Long delays where behaviour becomes erratic do not seem plausible. However, the model is structured in such a way to make it robust to such extreme readings. Ultimately it must be recognised that the models are conceptual, rather than data-driven, and are presented as general theory insight models.

5.5 The core model

5.5.1 Conceptual map

Each submodel of the core model is developed in this section. A more detailed conceptual map (high-level overview) is included overleaf. Full model equations are in the Appendix (section A.7).

Figure 31. Simplified conceptual map of core model
Figure 32. High-level conceptual map of core model
5.5.2 Monetary flows submodel

The core monetary submodel is internally stock-flow consistent, but simple enough that representation in an SFC accounting matrix is unnecessary.
5.5.3 Household/consumer policy submodel

![SFD of consumer policy submodel](image)

Figure 34. SFD of consumer policy submodel

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ExtIncome</td>
<td>£50 per year (scale as appropriate, thousands, millions). Used to shock model for impulse response.</td>
</tr>
<tr>
<td>HHExpDelay</td>
<td>0.25 years</td>
</tr>
<tr>
<td>TargetWealthIncomeRatio</td>
<td>1</td>
</tr>
<tr>
<td>WithPerceptionDelay</td>
<td>0.25 years</td>
</tr>
<tr>
<td>AdjustmentTime</td>
<td>0.25 years</td>
</tr>
<tr>
<td>NDE_demand</td>
<td>£30 per year (scale as appropriate)</td>
</tr>
<tr>
<td>NDL_demand</td>
<td>£33 per year (scale as appropriate)</td>
</tr>
<tr>
<td>DE_DemandFraction</td>
<td>DE_DemandFractionLookUp (DisposablePPAsPerCentDiscretionary)</td>
</tr>
</tbody>
</table>

Table 9. Parameters of consumer policy submodel

The household sector receives external income as well as local income in the form of wages and profits from local producers. Total income is smoothed by a
function to account for perception. Total purchasing power is perceived income plus actual money holdings (adjusted by a function for perception). The level of non-discretionary external (NDE) spending is exogenously determined. When NDE spending is achieved, money is spent on exogenously determined non-discretionary local (NDL) spending. When both types of non-discretionary spending are achieved, a residual disposable income is adjusted for savings. This residual determines the level of discretionary spending, which is then distributed between external (DE) and local (DL) spending according to the look-up function.

### 5.5.4 Producer policy submodel

![SFD of model producer policy submodel](image)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ProdExportSales</td>
<td>£23 per year (scale as appropriate). Used to shock.</td>
</tr>
<tr>
<td>ImportFraction</td>
<td>0.3 (used to shock)</td>
</tr>
<tr>
<td>LabourProductivity1</td>
<td>£10 / hour</td>
</tr>
<tr>
<td>ProdExpDelay</td>
<td>0.25 years</td>
</tr>
</tbody>
</table>

Table 10. Producer policy submodel parameters
Producers make external sales (exogenously determined) and make local sales of both a non-discretionary and discretionary kind. External production expenses are a given fraction of total sales. Net-income is perceived with a short smoothing delay and paid out in the form of local wages (owners pay themselves wages and a dividend which accrues when labour is not demanded). If there are constraints on production due to unavailability of labour, export sales are rationed.

### 5.5.5 Employment submodel

![SFD of employment submodel](image)

Table 11. Employment submodel parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>WageRate</td>
<td>£10 / hour</td>
</tr>
<tr>
<td>LabourProductivity</td>
<td>£10 / hour</td>
</tr>
<tr>
<td>HiringTime</td>
<td>0.083333 years</td>
</tr>
<tr>
<td>WorkingPopulation</td>
<td>2.5 (scale as appropriate, thousands, millions)</td>
</tr>
<tr>
<td>HoursPerWorker</td>
<td>2 (thousands of annual hours)</td>
</tr>
</tbody>
</table>
Nominal labour demand is translated into hours of labour demanded based on given productivity. Labour hours demanded are taken from a pool of unemployed labour hours: the gap is adjusted with a short time-lag to enable hiring from a pool of unemployed labour hours defined by population and hours available for work.

5.5.6 Core model boundary table

A model boundary table indicates the structure of the modelling assumptions underpinning the model:

<table>
<thead>
<tr>
<th>Endogenous</th>
<th>Exogenous</th>
<th>Excluded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local income</td>
<td>External household income</td>
<td>National supply-side</td>
</tr>
<tr>
<td>Local spending</td>
<td>Money supply</td>
<td>Overseas sector</td>
</tr>
<tr>
<td>Local employment / unemployment rate</td>
<td>Price level / wage rates</td>
<td>External employment</td>
</tr>
<tr>
<td>Saving</td>
<td>Population and productivity</td>
<td>National banking system</td>
</tr>
<tr>
<td>Achieved wealth / income ratios</td>
<td>Target wealth / income ratios, perception delays and adjustment time</td>
<td></td>
</tr>
<tr>
<td>Split between discretionary / non-discretionary and local / external consumption</td>
<td>Producer external expense ratio</td>
<td></td>
</tr>
<tr>
<td>Constraint on export sales</td>
<td>Export sales outside the region.</td>
<td></td>
</tr>
</tbody>
</table>

Table 12. Core model boundary table

5.6 Simulation experiments of the core model

Core model simulations are now undertaken, graphing key variables. "Burn-in" is undertaken prior to graphing until a functional "steady-state" is reached.

Parameters of the model are shown in Table 13:
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDE_demand</td>
<td>30 (£ / year)</td>
</tr>
<tr>
<td>NDL_demand</td>
<td>33 (£ / year)</td>
</tr>
<tr>
<td>HHExpDelay</td>
<td>0.25</td>
</tr>
<tr>
<td>WithPerceptionDelay</td>
<td>0.25</td>
</tr>
<tr>
<td>TargetWealthIncomeRatio</td>
<td>1</td>
</tr>
<tr>
<td>AdjustmentTime</td>
<td>2.5</td>
</tr>
<tr>
<td>ProdExpDelay</td>
<td>0.25</td>
</tr>
<tr>
<td>HiringTime</td>
<td>0.08333</td>
</tr>
<tr>
<td>WorkingPopulation</td>
<td>2.5 (scale as appropriate)</td>
</tr>
<tr>
<td>HoursPerWorker</td>
<td>2 (thousand per year)</td>
</tr>
<tr>
<td>WageRate</td>
<td>10 (£ / hour)</td>
</tr>
<tr>
<td>LabourProductivity</td>
<td>10 (£ / hour)</td>
</tr>
<tr>
<td>LabourProductivity1</td>
<td>10 (£ / hour)</td>
</tr>
<tr>
<td>HHMoneyInitialValue</td>
<td>0</td>
</tr>
<tr>
<td>ProdMoneyInitialValue</td>
<td>0</td>
</tr>
</tbody>
</table>

**Table 13. Core model parameters**
5.6.1 Core model simulation base run

A base run of the model with the given parameters demonstrates the steady state: where consumption and savings objectives are being met, given the exogenous parameters. The unemployment rate is around 1%.

![Graphs showing various economic indicators over time.](image)

**Figure 37.** Core model simulation base run
5.6.2 Core model experiment 1, external income shock

The experiment cuts the *ExtInc* parameter from £50 to £30 in year 10.

![Graphs showing the impact of external income shock on various economic indicators.](image)

**Figure 38.** Core model experiment 1: external income shock
5.6.3 Core model experiment 2, sinusoidal variation in external income and shock

A sinusoidal variation of £10 with a negative shock of £20 in year 10 is applied to the ExtInc parameter as a useful "stress test" of the model.

Figure 39. Core model experiment 2, sinusoidal variation and shock to external income
5.6.4 Core model experiment 3, export sales shock

External household income is unchanged but the parameter \( \text{ProdExportSales} \) is cut from £23 to £10 in year 10.

Figure 40. Core model experiment 3, export sales shock
5.6.5 Core model experiment 4, increased producer import fraction

The parameter \textit{ImportFraction} increases from 0.3 to 0.5 in year 10,

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure41.png}
\caption{Core model experiment 4, increased producer import fraction}
\end{figure}
5.6.6 Core model experiment 5, external income shock and restoration

A large drop in the Extlnc parameter in year 10 (from £50 to £10) is partially restored back to £30 in year 15 (note extended time-scale).

Figure 42. Core model experiment 5, external income shock and restoration
5.7 Discussion of the core model

The core model is the basis of all the CC models. The original operationalisation of lexicographic consumption is arguably essential to understand the various effects of CC systems where money often enters and exits the economy in a differentiated manner to national currency. The model is effectively operationalising Cantillon Effects, noted almost 300 years ago yet difficult to make formally tractable. The intention is to keep the model as parsimonious as possible, thus certain restrictive assumptions are inevitable. These assumptions have the potential to be relaxed as appropriate for context. The decision to use four expenditure categories is deemed as the most parsimonious approach to making the problem tractable. The extent to which exogenous capital inputs are utilised may vary substantially based on the specifics of any region, although it is assumed (in line with Cantillon's approach (Hicks, 1990) and the broader CC literature) that local production is largely handicraft/services oriented, with some given fraction of external input necessary, hence physical resources have been largely abstracted from in the model's conceptual boundaries. This comports with the tradition of the Classical Dichotomy, but has only been undertaken here for parsimony. Models may be extended to include greater interaction with real resource constraints. For the models to contain the necessary logic, some form constraints have to be considered: while the actual physical form of inputs is abstracted from, external inputs into production include monetary payment for intermediate goods, tax, interest, rent, utilities etc. Exogenously determined national currency (GBP) is the nominal anchor of the system; other nominal contracts, for example, mortgage interest, rents, house prices, are beyond the
model boundary. The constraints on production are thus national currency available to buy external inputs and labour-hours-available.

The producer sector is assumed to pay out all its income in the form of wages; how many workers this income employs is a function of a given productivity factor, and given rate of wages. The potential for producers to build-up excess monetary holdings (not redistributed to workers) is reconciled by adding a profit/dividend payment to households. The addition of an employment submodel adds potential complications to the producer policy because of the possibility of sustained capacity constraints. The principle of a goal-seeking feedback is applied: the goal is a target number of workers employed at a given wage rate. The parameter of hiring time is an adjustment factor which can be altered to represent a short delay in hiring/firing. The issue of capacity constraints could be addressed in various ways including higher productivity, extensive over-time, or an increased external fraction of inputs. Labour hours available may be deemed inherently flexible in the short-term due to the possibility of overtime. The most likely scenario would be highly context dependent. In the model, a simple rationing of external demand is introduced when maximum capacity is reached: this may be seen as a proxy for inflationary pressures. The model’s perspective is ultimately focused on shorter-term monetary underconsumption problems as CCs are generally regarded as countercyclical concepts.

It would be relatively simple to construct a form of Phillips’ Curve relationship to investigate the issue of local employment and wage inflation; however, because minimum wage rates (which are logically applicable to the nature of local
spending and employment implied) are set at a national level, it is deemed most appropriate to regard wages in a region as exogenously determined and invariant with local employment. There is the limiting assumption that external income is not directly attributable in the model to external employment; if more specific estimates of unemployment are to be explored this assumption would need to be addressed in relation to specific examples, rather than in a general theory model.

Given the assumptions, the simulations of the core model are able to demonstrate the impact on local spending and employment given certain plausible exogenous shocks applied to the model. The base run demonstrates the steady state when income and expenditure are balanced, and money holdings are stable. Income/expenditure is stable at around £100 (with the split between local and external income approximately 50/50); "full-employment" (unemployment is around 1%) is achieved. Experiment 1 shocks external income (ExtInc) (from £50 to £30 in year 10) as a useful representation of the kind of exogenous shock that may hit a region. Discretionary consumption drops, local spending and income begins to fall and unemployment rises. The system settles relatively quickly with significantly less discretionary spending and 19% unemployment; non-discretionary spending is maintained. Experiment 2 repeats a sinusoidal cycle and shock in external income from the earlier model: external income varies by +/-£10 with a negative shock of £20 in year 10. This is a useful demonstration of the model dynamics in an extreme situation, with rationing indicated in early years of high demand, before the shock sees unemployment reach 21%. In experiment 3 external income is unchanged, but export sales (ProdExportSales) are cut from £23 to £10 in year
10. Although aggregate income is higher, endogenously created unemployment rises to 27%. In experiment 4 the import fraction of production (*ImportFraction*) increases from 0.3 to 0.5 (50%) in year 10: unemployment rises to 37%. Non-discretionary spending is maintained while discretionary spending nearly halves. In experiment 5, a large drop in external income in year 10 (from £50 to £10) is partially restored back to £30 in year 15; unemployment reaches nearly 70% before with even non-discretionary external spending failing. The economy regains some of its lost potential after the restoration of income and the money-wealth buffer (potential debt built-up are beyond the model boundary); unemployment eventually settles at 19%.

Each of these simulations demonstrate the varying effects of the kind of plausible shocks a region or locale may suffer in relation to the key parameters. The simulations illustrate that non-discretionary consumption is less affected, even with fairly large shocks to external income: discretionary consumption drops, local spending and income begins to fall and unemployment rises. The desire to restore discretionary local spending is a key goal of the CC movement. The CC solution is regarded as a form of endogenous response, with little cost to government by resolving a coordination problem that the money drain has created.

5.8 Model evaluation (part 2)

Boundary testing was the essential building block process, developing Law's island, informed by Cantillon's spatial analysis into a parsimonious minimum necessary model, establishing the crucial monetary flows into and out of the locale. This approach also encourages the walkthrough analysis where the
narrative is developed for each sector submodel appended to the core monetary sector. Dimensional consistency checking is an ongoing process, made somewhat simpler in this model because the principle stock-and-flow is money. Labour hours are maintained in a separate submodel. Some sensitivity of the lexicographic consumption model was undertaken to demonstrate the variation in some key parameters including NDE_Demand, AdjustmentTime, TargetWealthIncomeRatio, WithPerceptionDelay and IncomeExpectationDelay.

It can be seen that while cyclicality differs according to a variety of plausible parameter variations, the essential structural characteristics of the model remain. The nature of differences may ultimately be useful for future parameterisation of specific empirical models. Now the core model is established, some comparatives are given for differing time-steps in the simulation. A time-step of 1 and 0.1 can essentially be ruled out a priori based on Sterman's "rule of thumb" (Sterman, 2000, p.907), as the smallest time constant in the model is the first-order control on money flows (set to 0.01923, the equivalent of one week). However, a dT of 0.1 is still illustrated for comparison with the two principal alternatives: 0.01 and 0.001 (the default) are compared in Figures 43 & 44. Figure 43 illustrates when first-order control of money flows is set with a plausible parameter of 0.01923. Figure 44 illustrates the impact if the first-order control is arbitrarily set to a lower level, 0.001. Using the sinusoidal income shock, the model logic begins to break-down when the time-step is out of key, as PerceivedWealth can be seen to de-link from the actual holding of HouseholdMoney, rather than representing the given delay parameter. Time-steps faster than 0.001 are possible in the software but demonstrate no tangible difference to 0.001, and would be straying from the
rule of thumb. This confirms the desirability of maintaining the parameter of 0.01923 for first-order control in the models.

Figure 43. Core model time-step comparison with first-order control at 0.01923
Figure 44. Core model time-step comparison with first-order control at 0.001

5.9 Chapter Summary

The method of PK-SFC-SD has been outlined. The proof of concept of an original lexicographic consumption model has been developed and simulated according to narrative precepts of post-Keynesian theory according with classical behavioural economics. This groundwork has enabled a core monetary model of a regional/local economy, to be appended with appropriate
submodels. A number of experimentation simulation runs have been undertaken and discussed. Key aspects of model evaluation have been illustrated. Final model development for the specific secondary money and simulation chapter utilises these insights in developing models of regional secondary money systems.
Chapter 6 Complementary currency models

6.1 Introduction

Models in this chapter relate to three key types of complementary currency systems:

1) convertible local currency (CLC);
2) mutual credit clearing (MCC);
3) local government currency (LGC).

In order to better understand the nature of CC systems and how arguments in literature may be demonstrated through simulation, a submodel of each of these CCs is separately appended to the core model, representing a form of structural intervention. While the CC components exchange information with the other submodels, the types of money (modelled one at a time) are maintained in distinct circuits.

Figure 45. Conceptual map of CC models added to core model

The models detail structure and behaviours which are argued to make the role of secondary money important to the development and resilience of
Local/regional economies. It is the inherently socio-political/institutional framing of money systems which require structures to be in place which have to be treated as exogenous assumptions which need not (arguably cannot) be explained by individual behaviour or search-and-matching models; these assumptions must accompany the models as narrative. Essentially the models seek to demonstrate what is possible, and the assumptions needed to make this possible. The models are informed by a conceptual ordering of themes earlier developed from literature, set out in tables below.

### 6.2 Convertible Local Currency (CLCs)

The thematic conceptual ordering derived from the literature is presented in a table to indicate key institutional considerations of a CLC and how these have been addressed in the modelling framework.

<table>
<thead>
<tr>
<th>Questions that need to be addressed when assessing CLCs:</th>
<th>Assumptions in modelling framework</th>
</tr>
</thead>
<tbody>
<tr>
<td>Who is responsible for the monetary infrastructure?</td>
<td>Local voluntary groups usually organised as a form of corporate body such as a Community Interest Company (CIC).</td>
</tr>
<tr>
<td>Do the organisers make a profit (or cover costs)?</td>
<td>Primarily voluntary, but some charges may allow some wages to be paid.</td>
</tr>
<tr>
<td>What power or authority do they have?</td>
<td>Purely voluntary participation.</td>
</tr>
<tr>
<td>Are the money issuers prepared to accept their issues back at face value?</td>
<td>Yes.</td>
</tr>
<tr>
<td>What underlying value does the money have or represent?</td>
<td>Linked to national currency.</td>
</tr>
<tr>
<td>Is the creation of money endogenous or exogenous (or both)?</td>
<td>Exogenous.</td>
</tr>
</tbody>
</table>

Implicit in model. Costs are abstracted from. Implicit in model. Explicit in model.
<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is the money creation endogenous to the creation of underlying value, or exogenous to it?</td>
<td>Exogenous.</td>
<td>Implicit in model.</td>
</tr>
<tr>
<td>Is there collateral backing?</td>
<td>Yes, the national currency deposited in a bank.</td>
<td>Explicit in model.</td>
</tr>
<tr>
<td>Is the unit of account different or fixed with primary national currency?</td>
<td>Fixed.</td>
<td>Explicit in model.</td>
</tr>
<tr>
<td>If the unit of account if fixed, how is this maintained/guaranteed?</td>
<td>Redemption at face value is guaranteed – 100% reserve-backed.</td>
<td>Explicit in model.</td>
</tr>
<tr>
<td>What physical form does the money take?</td>
<td>Notes and electronic entry.</td>
<td>Implicit in model.</td>
</tr>
<tr>
<td>Are transactions recorded — is &quot;monitoring&quot; required?</td>
<td>Monitoring is not required although electronic data may be collected.</td>
<td>Abstracted from in model.</td>
</tr>
<tr>
<td>Can contracts be legally enforced?</td>
<td>As participation is voluntary and no credit is created, it is not clear it has ever needed to be tested.</td>
<td>Beyond model boundary.</td>
</tr>
<tr>
<td>Is the money intended to stay in circulation permanently?</td>
<td>Yes.</td>
<td>Producer reflux is a behavioural parameter of the model.</td>
</tr>
<tr>
<td>How can it be withdrawn?</td>
<td>Voluntary buy-backs or natural reflux.</td>
<td>Reflux is explicit in model. Buy-backs are abstracted from.</td>
</tr>
</tbody>
</table>

Table 14. **Thematic conceptual ordering for CLC**

The following pages illustrate the SFDs of each submodel. The model equations are detailed in the Appendix (section A.8). Figure 46 illustrates the key monetary flows: the CLC provider takes households' GBP and creates a CLC note which accrues to the households' CLC balances. The CLC provider holds GBP as an asset against the liability. CLCs notes are 100% backed by GBP deposits which are warehoused by the CLC. Households spend CLCs into the local economy with producers. Producers may then offer to pay incomes in CLC in the form of wages (the bottom loop). Outstanding CLCs will be held either by
households or producers, with a matching liability held by the provider (offset by cash holdings in GBP). Neither Households nor producers desire long-term holdings of CLC, so they are spent (or refluxed to the provider to be converted back into GBP) after a short delay.

Figure 46. SFD of the monetary submodel including CLC
Complementary currency models

Figure 47. **SFD of CLC consumer policy submodel**

Figure 48. **SFD of CLC producer policy submodel**
Simulating the models, all parameters are left unchanged from the core model unless otherwise stated.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDE_demand</td>
<td>30 (£ / year)</td>
</tr>
<tr>
<td>NDL_demand</td>
<td>33 (£ / year)</td>
</tr>
<tr>
<td>HHExpDelay</td>
<td>0.25</td>
</tr>
<tr>
<td>WithPerceptionDelay</td>
<td>0.25</td>
</tr>
<tr>
<td>TargetWealthIncomeRatio</td>
<td>1</td>
</tr>
<tr>
<td>AdjustmentTime</td>
<td>2.5</td>
</tr>
<tr>
<td>ProdExpDelay</td>
<td>0.25</td>
</tr>
<tr>
<td>HiringTime</td>
<td>0.08333</td>
</tr>
<tr>
<td>WorkingPopulation</td>
<td>2.5 (scale as appropriate)</td>
</tr>
<tr>
<td>HoursPerWorker</td>
<td>2 (thousand per year)</td>
</tr>
<tr>
<td>WageRate</td>
<td>10 (£ / hour)</td>
</tr>
<tr>
<td>LabourProductivity</td>
<td>10 (£ / hour)</td>
</tr>
<tr>
<td>LabourProductivity1</td>
<td>10 (£ / hour)</td>
</tr>
<tr>
<td>HHMoneyInitialValue</td>
<td>0</td>
</tr>
<tr>
<td>ProdMoneyInitialValue</td>
<td>0</td>
</tr>
<tr>
<td><strong>Shocked Parameters</strong></td>
<td><strong>Value [and indication of experiments]</strong></td>
</tr>
<tr>
<td>ExtInc</td>
<td>50 (£ / year) [ + (10 * sin(time() / 0.5)) + step(-20, 10)]</td>
</tr>
<tr>
<td>RelocalisationDrive</td>
<td>1 [ + step(-0.2, 12)]</td>
</tr>
<tr>
<td>ProdExportSales</td>
<td>23 (£ / year)</td>
</tr>
</tbody>
</table>
Complementary currency models

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ImportFraction</td>
<td>0.3 [ + \text{step}(-0.05,12)]</td>
</tr>
<tr>
<td>Additional CLC Parameters</td>
<td>Value [and indication of experiments]</td>
</tr>
<tr>
<td>CLCDemandFraction</td>
<td>0.5 [ + \text{step} (0.3,12)]</td>
</tr>
<tr>
<td>CLCPropWith</td>
<td>0.05</td>
</tr>
<tr>
<td>ProducerRefluxDelay</td>
<td>0.01923</td>
</tr>
<tr>
<td>VoluntaryFraction</td>
<td>0 [ + \text{step}(1,12)]</td>
</tr>
<tr>
<td>Simulation time</td>
<td>20 years</td>
</tr>
<tr>
<td>(dT)</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Table 15. CLC model parameters
6.2.1 CLC simulation base run

This replicates the base run of the core model but where CLC is 50% of local discretionary spending, and target HouseHoldCLC is 5% of PerceivedWealth.

![Graphs showing CLC simulation base run](Image)

Figure 50. CLC simulation base run
6.2.2 CLC experiment 1, external income shock

$\textit{ExtInc}$ is cut from 50 to 30 in year 10.

Figure 51. CLC experiment 1, external income shock
6.2.3 CLC experiment 2, external income sinusoidal variation and shock

The sinusoidal variation of £10 and shock of -£20 in ExtInc in year 10.

Figure 52. CLC experiment 2, external income sinusoidal variation and shock
6.2.4 CLC experiment 3, external income shock and CLC response

An impulse shock of $ExtInc$ falling from £50 to £30 in year 10, but in response in year 12: $CLCDemandFraction$ is increased to 0.8 (from 0.5); and the $VoluntaryFraction$ of CLC income received increases to 100% from 0%.

Figure 53. CLC experiment 3, external income shock and CLC response
6.2.5 CLC experiment 4, external income shock and relocalisation drive

Experiment 2 is repeated, but includes a re-localisation drive in year 12:

$DE\_DemandFraction$ is reduced by 20%; $ImportFraction$ is cut to 0.25 from 0.3.

Figure 54. CLC experiment 4, external income shock and relocalisation drive
### 6.3 Mutual Credit Clearing (MCCs)

<table>
<thead>
<tr>
<th>Questions that need to be addressed when assessing MCCs:</th>
<th>Assumptions in modelling framework</th>
</tr>
</thead>
<tbody>
<tr>
<td>Who is responsible for the monetary infrastructure?</td>
<td>A corporate entity of some form (potentially non-profit), or a government entity</td>
</tr>
<tr>
<td>Do the organisers make a profit (or cover costs)?</td>
<td>An organisation may seek profit or simply cover costs through fees or interest charges.</td>
</tr>
<tr>
<td>What power or authority do they have?</td>
<td>Like any commercial venture, participation is voluntary. Some value must be comprehended by users.</td>
</tr>
<tr>
<td>Are the money issuers prepared to accept their issues back at face value?</td>
<td>Under some circumstances the MCC may issue loans in the currency and would redeem an equivalent quantity at face value. However, money-issuers generally are individuals participating in the system, so this cannot be guaranteed. Members are generally required to commit to a minimum percentage of price paid in the CC.</td>
</tr>
<tr>
<td>What underlying value does the money have or represent?</td>
<td>The value is predominantly created through the underlying value of the transactions.</td>
</tr>
<tr>
<td>Is the creation of money endogenous or exogenous (or both)?</td>
<td>Endogenous.</td>
</tr>
<tr>
<td>Is the money creation endogenous to the creation of underlying value, or exogenous to it?</td>
<td>Primarily endogenous, although similar to a bank, the MCC may offer some credit.</td>
</tr>
<tr>
<td>Is there collateral backing?</td>
<td>Similar to banking, collateral of some kind is</td>
</tr>
<tr>
<td><strong>Is the unit of account different or fixed with primary national currency?</strong></td>
<td>Parity is established, but it cannot be guaranteed and may fluctuate with demand/supply. A grey market may develop (although this may result in punishment by the MCC entity).</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td><strong>If the unit of account if fixed, how is this maintained/guaranteed?</strong></td>
<td>Potentially the MCC could be exchangeable back into GBP, but this risks undermining the whole purpose of the MCC (the WIR bans exchange into CHF).</td>
</tr>
<tr>
<td><strong>What physical form does the money take?</strong></td>
<td>Electronic entry.</td>
</tr>
<tr>
<td><strong>Are transactions recorded — is &quot;monitoring&quot; required?</strong></td>
<td>As with banking, monitoring is required to ensure credit standards are maintained.</td>
</tr>
<tr>
<td><strong>Can contracts be legally enforced?</strong></td>
<td>This is likely essential as part of the infrastructure to maintain confidence. LETS have failed partly due to failure to enforce contracts.</td>
</tr>
<tr>
<td><strong>Is the money intended to stay in circulation permanently?</strong></td>
<td>No — mutual credits are expected to clear.</td>
</tr>
<tr>
<td><strong>How can it be withdrawn?</strong></td>
<td>Primarily through clearing or paying-off of debt.</td>
</tr>
</tbody>
</table>

**Table 16. Thematic conceptual ordering for MCC**

The MCC submodel is separated from the monetary core as there is no attempt to interchange currency (as in the CLC model). A distinct secondary monetary circuit includes some relatively simple behavioural assumptions.
The full model equations are in the Appendix (section A.9). The initiating purchase is undertaken by an SME member as a function of perceived spare capacity: when overall aggregate production is perceived to be at full capacity no credits will be spent; when excess capacity is perceived, credits are used. A randomised variable is used to denote a degree of uncertainly with regard to the
degree of spare capacity. Transactions are initiated within the SME sector, and credit is created, spent with another SME, thus the model splits producers into creditor SMEs and debtor SMEs. According to employee preferences (as a parameter of the employment submodel), the creditor SMEs may pay a given portion of these credits to their employees. Neither employees (households) nor SME creditors seek to hold credits long-term as they do not regard them as a long-term store of wealth: both spend after a short delay. All spent credits create demand while extinguishing themselves in aggregate. The system is thus endogenous to the needs of trade of SMEs.

Figure 57. SFD of MCC producer policy submodel
Results & discussion

Figure 58. SFD of MCC employment submodel

*Employment submodel (labour measured in thousands of hours)*
Simulating the models, all parameters are left unchanged from the core model unless otherwise stated.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDE_demand</td>
<td>30 (£ / year)</td>
</tr>
<tr>
<td>NDL_demand</td>
<td>33 (£ / year)</td>
</tr>
<tr>
<td>HHExpDelay</td>
<td>0.25</td>
</tr>
<tr>
<td>WithPerceptionDelay</td>
<td>0.25</td>
</tr>
<tr>
<td>TargetWealthIncomeRatio</td>
<td>1</td>
</tr>
<tr>
<td>AdjustmentTime</td>
<td>2.5</td>
</tr>
<tr>
<td>ProdExpDelay</td>
<td>0.25</td>
</tr>
<tr>
<td>HiringTime</td>
<td>0.08333</td>
</tr>
<tr>
<td>WorkingPopulation</td>
<td>2.5 (scale as appropriate)</td>
</tr>
<tr>
<td>HoursPerWorker</td>
<td>2 (thousand per year)</td>
</tr>
</tbody>
</table>
### Results & discussion

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value [and indication of experiments]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WageRate</strong></td>
<td>10 (£ / hour)</td>
</tr>
<tr>
<td><strong>LabourProductivity</strong></td>
<td>10 (£ / hour)</td>
</tr>
<tr>
<td><strong>LabourProductivity1</strong></td>
<td>10 (£ / hour)</td>
</tr>
<tr>
<td><strong>HHMoneyInitialValue</strong></td>
<td>0</td>
</tr>
<tr>
<td><strong>ProdMoneyInitialValue</strong></td>
<td>0</td>
</tr>
<tr>
<td><strong>RelocalisationDrive</strong></td>
<td>1</td>
</tr>
<tr>
<td><strong>ProdExportSales</strong></td>
<td>23</td>
</tr>
<tr>
<td><strong>ImportFraction</strong></td>
<td>0.3</td>
</tr>
<tr>
<td><strong>Shocked Parameters</strong></td>
<td></td>
</tr>
<tr>
<td><strong>ExtInc</strong></td>
<td>50 (£ / year) [ + (10 * sin(time()/0.5)) + step(-20,10)]</td>
</tr>
<tr>
<td><strong>Additional MCC Parameters</strong></td>
<td></td>
</tr>
<tr>
<td><strong>ProportionInitiate</strong></td>
<td>0.5</td>
</tr>
<tr>
<td><strong>CreditorDelayParameter</strong></td>
<td>0.08333 [ increases to 1 in exp. 4]</td>
</tr>
<tr>
<td><strong>EmployeeDelayParameter</strong></td>
<td>0.25</td>
</tr>
<tr>
<td><strong>VoluntaryFraction</strong></td>
<td>0 or 0.5</td>
</tr>
<tr>
<td><strong>RandomVar</strong></td>
<td>RandomVar=triangularAV( 0.9, 0.1,[Random]NoiseSeed)</td>
</tr>
<tr>
<td><strong>Simulation time</strong></td>
<td>20 years</td>
</tr>
<tr>
<td><strong>dT</strong></td>
<td>0.001</td>
</tr>
</tbody>
</table>

**Table 17. MCC model parameters**
6.3.2 MCC simulation, base run

The base run simulation is undertaken with no shocks.

Figure 60. MCC simulation, base run
Figure 61. MCC simulation, base run details of MCC subsystem
6.3.3 MCC experiment 1, external income shock

A drop of 20 in $Exlnc$ in year 10 is simulated.

Figure 62. MCC experiment 1, external income shock
Figure 63. MCC experiment 1, external income shock, MCC subsystem
6.3.4 MCC experiment 2, external income sinusoidal input and shock

Figure 64. MCC experiment 2, external income sinusoidal input and shock
Results & discussion

Figure 65. MCC experiment 2, MCC subsystem
6.3.5 MCC experiment 3, external income shock, employees receive pay

Figure 66. MCC experiment 3, employees receive pay in MCC
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Figure 67. MCC experiment 3, MCC subsystem
6.3.6 MCC experiment 4, sinusoidal variation and shock in external income, varying delays

No payment of MCC to employees; \textit{CreditorDelayParameter} increased to 1-year.

Figure 68. MCC experiment 4, external income sinusoidal input and shock, with longer creditor spending delay parameter
Figure 69. MCC experiments 2 and 4, external income sinusoidal input and shock, comparing MCC creditor spending delay parameter.
### 6.4 Local Government Currency (LGCs)

<table>
<thead>
<tr>
<th>Questions that need to be addressed when assessing LGCs:</th>
<th>Assumptions in modelling framework</th>
</tr>
</thead>
<tbody>
<tr>
<td>Who is responsible for the monetary infrastructure?</td>
<td>Local government (likely top tier, e.g., county or unitary authority)</td>
</tr>
<tr>
<td>Do the organisers make a profit (or cover costs)?</td>
<td>Act as a responsible fiscal authority.</td>
</tr>
<tr>
<td>What power or authority do they have?</td>
<td>A legal power to tax-and-spend within their jurisdiction.</td>
</tr>
<tr>
<td>Are the money issuers prepared to accept their issues back at face value?</td>
<td>Yes, in the payment of services and taxes.</td>
</tr>
<tr>
<td>What underlying value does the money have or represent?</td>
<td>As a fiat money, its ultimate value is as a form of tax-credit, susceptible to a potential premium to the (uncertain) future obligation, based on network externalities.</td>
</tr>
<tr>
<td>Is the creation of money endogenous or exogenous (or both)?</td>
<td>Endogenous to the region, exogenous to the money users.</td>
</tr>
<tr>
<td>Is the money creation endogenous to the creation of underlying value, or exogenous to it?</td>
<td>This depends upon how it is spent into existence: is it used to pay for consumption or investment, workers or as a transfer payment?</td>
</tr>
<tr>
<td>Is there collateral backing?</td>
<td>Ultimately the local government as the fiscal authority is the backer.</td>
</tr>
<tr>
<td>Is the unit of account different or fixed with primary national currency?</td>
<td>This is a key question. Parity may be established, but similar to any conundrum over fixed vs. floating exchange rates, it cannot be guaranteed and may fluctuate with demand/supply. The LGC is fixed parity with national currency in the model.</td>
</tr>
<tr>
<td>If the unit of account if fixed, how is this maintained/guaranteed?</td>
<td>The local government would have to run an active fiscal policy to ensure demand and</td>
</tr>
</tbody>
</table>
### Results & discussion

Capital controls could be placed on the currency. National government may have a role as guarantor.

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>What physical form does the money take?</td>
<td>Notes and electronic entry.</td>
<td>Implicit in model.</td>
</tr>
<tr>
<td>Are transactions recorded — is &quot;monitoring&quot; required?</td>
<td>Because no credit is being offered, monitoring is not required.</td>
<td>Abstracted from in model.</td>
</tr>
<tr>
<td>Can contracts be legally enforced?</td>
<td>Various laws would apply according to situation (currently EU law precludes creation of this kind of system).</td>
<td>Implicit in model.</td>
</tr>
<tr>
<td>Is the money intended to stay in circulation permanently?</td>
<td>Yes, local government money would act just like national currency but in a restricted geographic domain.</td>
<td>Explicit in model. The quantity of LGC in circulation is a function of household demand and fiscal policy.</td>
</tr>
<tr>
<td>How can it be withdrawn?</td>
<td>Taxation and/or the sale of goods/services offered by the local government.</td>
<td>Taxation is explicit in model. The potential to sell services is abstracted from.</td>
</tr>
</tbody>
</table>

**Table 18.** Thematic conceptual ordering for LGC
Equations for the model are in the Appendix (section A.10). The local government (LG) "prints" money (physically or electronically) and spends it into circulation with producers. Producers in receipt of LGC pay a portion of wages to households in the form of LGC and pay tax in LGC; households (who do not regard LGC as a long-term store of wealth) spend it back into local circulation and pay tax as necessary. The LG receives payment in taxes, and on receipt it "destroys" the currency (in accounting terms). The annual difference between spending and tax revenue is a budget deficit. The annual deficit accumulates into a stock of currency liabilities. The quantity of LGC liabilities outstanding (held as assets by households and producers) is determined according to delays in the system which imply the relatively small quantity households and producers desire to hold.
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Figure 71. SFD of LGC producer submodel

Figure 72. SFD of LGC employment submodel
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Figure 73. **SFD of LGC household submodel**

All parameters are left unchanged from the core model unless otherwise stated.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDE_demand</td>
<td>30 (£ / year)</td>
</tr>
<tr>
<td>NDL_demand</td>
<td>33 (£ / year)</td>
</tr>
<tr>
<td>HHEExpDelay</td>
<td>0.25</td>
</tr>
<tr>
<td>WlthPerceptionDelay</td>
<td>0.25</td>
</tr>
<tr>
<td>TargetWealthIncomeRatio</td>
<td>1</td>
</tr>
<tr>
<td>AdjustmentTime</td>
<td>2.5</td>
</tr>
<tr>
<td>ProdExpDelay</td>
<td>0.25</td>
</tr>
<tr>
<td>HiringTime</td>
<td>0.08333</td>
</tr>
<tr>
<td>WorkingPopulation</td>
<td>2.5 (scale as appropriate)</td>
</tr>
<tr>
<td>HoursPerWorker</td>
<td>2 (thousand per year)</td>
</tr>
<tr>
<td>WageRate</td>
<td>10 (£ / hour)</td>
</tr>
<tr>
<td>LabourProductivity</td>
<td>10 (£ / hour)</td>
</tr>
<tr>
<td>LabourProductivity1</td>
<td>10 (£ / hour)</td>
</tr>
<tr>
<td>HHMoneyInitialValue</td>
<td>0</td>
</tr>
<tr>
<td>ProdMoneyInitialValue</td>
<td>0</td>
</tr>
<tr>
<td>RelocalisationDrive</td>
<td>1</td>
</tr>
<tr>
<td>ProdExportSales</td>
<td>23</td>
</tr>
</tbody>
</table>
### Results & discussion

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value [and indication of experiments]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ImportFraction</strong></td>
<td>0.3</td>
</tr>
<tr>
<td><strong>Shocked Parameters</strong></td>
<td></td>
</tr>
<tr>
<td><code>ExtInc</code></td>
<td>50 (£ / year) [+ (10 * sin(time()/0.5)) + step(-20,10)]</td>
</tr>
<tr>
<td><strong>Additional LGC Parameters</strong></td>
<td></td>
</tr>
<tr>
<td><code>LocalGovSpend</code></td>
<td>0 until increase in year 12 [alternatively step(4,12) in experiments 3 and 4; ramp(2,12,16) in experiment 5]</td>
</tr>
<tr>
<td><code>HhLGTaxRate</code></td>
<td>0.3</td>
</tr>
<tr>
<td><code>ProdLGTaxRate</code></td>
<td>0.3</td>
</tr>
<tr>
<td><code>AT_LGMoney</code></td>
<td>0.25</td>
</tr>
<tr>
<td><code>Simulation time</code></td>
<td>20 years</td>
</tr>
<tr>
<td><code>dT</code></td>
<td>0.001</td>
</tr>
</tbody>
</table>

Table 19. LGC model parameters
6.4.1 LGC Simulation, base run

The base run demonstrates the model's behaviour replicating the previous model runs; there are no shocks and the LGC circuit is silent.

Figure 74. LGC simulation, base run
6.4.2 LGC experiment 1, external income shock

ExtInc is reduced by 20 in year 10.

Figure 75. LGC experiment 1, external income shock
6.4.3 LGC experiment 2, external income sinusoidal variation and shock

The same sinusoidal variation and shock to $\text{ExtInc}$ from previous experiments is applied. Again, the LGC circuit is silent.

![Graphs showing economic variables over time](image)

**Figure 76.** LGC experiment 2, external income sinusoidal variation and shock
6.4.4 LGC experiment 3, external income shock and local government response

The shock is responded to by the local government spending: a step increase in $LGSpend$ in year 12 of 4L/year (compared to the income shock of 20GBP).

Figure 77. LGC experiment 3, external income shock and LG response
6.4.5 LGC experiment 4, sinusoidal variation in external income shock and local government step response

A step increase in $LGSpend$ of 4/year.

Figure 78. LGC experiment 4, sinusoidal variation and shock in external income, step in LG spend
6.4.6 LGC experiment 5, sinusoidal variation in external income shock and local government ramp response

Rather than step increase of 4, $LGSpend$ in year 12, a 2/year ramp begins (ending in year 16), giving a total local "fiscal boost" of 8.

Figure 79. LGC experiment 5, sinusoidal variation and shock in external income, ramp in LG spend
6.5 Discussion of models

6.5.1 Convertible Local Currency (CLC)
In the UK, CLCs are the most well known and most popular form of local currency reform, yet what the model helps elucidate is that CLCs do not create endogenous purchasing power: they are tokens which are purchased pound-for-pound with national currency and can only be used in the local circuit where retailers agree to participate. In the model, households opt to buy a quantity of CLC currency as a given portion of their discretionary local spending. The CLC provider holds GBP as an asset against its CLC liability. It may be apparent that the CLC provider is providing a role similar to a narrow bank, with the key difference that the CLCs notes are 100% backed by GBP deposits which are warehoused by the CLC. The CLC is spent into the local economy and refluxed back by the producer sector in exchange for GBP at face value. Additionally, there is the option that workers may be paid some portion of the CLC spent back in wages. Neither households nor producers regard the CLC as a long-term form of wealth, but merely as a medium of exchange to be either spent (with some delay) into circulation or refluxed to the provider.

The base run replicates the core model base run simulation. Even with 50% of discretionary local spending taking place in CLC, there is no discernible difference in the model outcome. The small holding of CLC is essentially the cash-in-advance requirement (which can be reduced to near zero). Replacing GBP with CLC has no impact on the monetary circuit. Experiment 1 replicates the cut in external income from 50 to 30 in year 10: again, there is no discernible impact on the simulation outcome. Experiment 2 is the sinusoidal
variation; again, there is no difference from the core model. From a narrative perspective it could be argued that the rationing implied in the upswing of the cycle when the economy is over sustainable capacity would imply that Producers would reject CLC and sell to outside consumers for GBP instead. There are various ways to close the model in that regard, but the key purpose here is to relate to periods of underconsumption: in periods of excess demand it is unlikely that CLCs would be in high demand as forms of money.

Experiment 3 sees a drop in income followed by a change in behaviour whereby the fraction of discretionary local spending in CLC is increased to 80% from 50%, and CLC expenditure is now wholly accepted by employees as pay from producers. Perhaps surprisingly there is no discernible impact on the outcome compared to no-change scenario in the core model simulation (core model experiment 1, section 5.6.2). An almost intangible fall in unemployment takes place as a function of the implied higher velocity of circulation of CLCs relative to GBP. No recovery takes place. Experiment 4 sees the shock to external income followed by a re-localisation drive in year 12, whereby the fraction of external discretionary consumption is reduced to 40% from 60%, and the input fraction of production is reduced to 25% from 30%. This relocalisation drive has a powerful effect, reducing unemployment from 19% to 7%; spending and income recovers somewhat, although the economy is still materially worse off than without the external shock. Such a response can be endogenised in the model, although the nature of any behavioural response must be recognised as external to the monetary system per se and could occur without any need for local currency. This implies both consumers changing habits and producers spending more within their supply chain.
The notion of a lack of desire to hold CLC as wealth, and the shorter adjustment time, imply an individual's desire to spend more quickly. What the simulations are able to clarify is that the notion of an increase in monetary velocity — often touted as a benefit of CLCs — is essentially a behavioural property of the model implicit in the parameters of the model, merely reflecting broader behavioural change. Again, this is possible without any recourse to CLCs. The parameters imply a negligible impact from the pure velocity perspective, whereas producers may try and spend CLC into their local supply chain (and act which must be accommodated by their suppliers), although this cannot be represented within the aggregated national accounting framework (B2B intermediate transactions would not appear in GDP transactions or in this model aggregation — the parameter of reduced external input may be used as a proxy).

CLC providers are usually established as a form of non-profit social enterprise, such as a Community Interest Company (CIC). Additionally, they may interact with a local credit union. Where this is so (for example, the Bristol Pound has followed this model), there is an additional potential to expand the local supply of GBP through lending. However, this is an additional way of financing local expansion, akin to local banking and the model does not develop this approach as it is not an intrinsic aspect of a CLC approach: models may be further adapted to explore the implications as required. Some staff of Bristol Council have also volunteered to be paid partially in Bristol Pounds. Whether staff (at any firm) agree to be paid in CLC is a behavioural parameter which may be seen as an aspect of proportion of money spent locally. Such questions likely require specific investigation and likely trial and error in practice. They will largely be institutionally determined. However, the simulation does not indicate
that this is a useful monetary function, over and above any behavioural change implied in choosing to spend more locally rather than externally.

The CLC project overall may better be seen as a behavioural change instigator, both on the part of consumers and producers, and the marketing that comes with the adoption of CLC acceptance for the producers is a key part of the objective. The extent to which adoption of a CLC by a locality engenders behavioural change is an appropriate (but alternative) research question. The velocity of circulation is endogenous, and it has been argued that CLCs circulate more rapidly, thus creating more local demand. The model indicates that although this is indeed potentially true in principal, the reality is that this is merely a manifestation of a behavioural change: an individual (or group) cannot decide to increase the velocity of circulation of a currency — they can only decide to spend more locally. The extent to which local suppliers reflux the notes to the supplier or successfully spend them into their supply chain becomes a key issue for velocity, but again, this is an argument about behavioural change within the supply chain, as opposed to a monetary impact. CLCs should not be denigrated as useless, but it should be recognised that the transmission mechanism and their ultimate purpose is that they may help to engender behavioural change in consumers and producers, and act as a form of marketing. As a form of currency, they serve no direct monetary purpose.

6.5.2 Mutual Credit Clearing (MCC)

When building the model from the narrative description, the MCC system is not as intuitive as the CLC system; the ability to generate endogenous credit clearly has impact on the ability to undertake local trade but various potential problems
of behaviour are introduced. In the base run, it is of interest that the rate of activity and hence unemployment is subject to minor disturbance. It may be argued that this is an artefact of the model as the random variable is used to denote perceptions of spare capacity in the economy. However, the randomness is intentional as a stylised fact of the nature of uncertainty over the state of spare capacity. The MCC circuit is active, but in a very minor way (spare capacity is assessed at less than 1%).

Experiment 1, replicating the drop in external income in year 10, demonstrates that the lack of demand generated by the absence of GBP is swiftly ameliorated by MCC creation/spending, as local spare capacity is perceived. Similarly, experiment 2 replicates the sinusoidal variation and income shock and again demonstrates the ability of the MCC to give an endogenous counter-cyclical response to the loss of purchasing power. In both experiments, the rise in MCC activity is pronounced. Whereas in the equivalent experiments on the core model and the CLC system, unemployment remains elevated close to 20%, with the MCC, unemployment peaks at around 12% and drops to 3% with no government intervention. The key — in contrast to CLCs — is the endogenous creation of purchasing power within the local system appropriate to the needs of local trade. Credits cannot leak out of this system but have to be spent within it. Where there remains a loss of external flows of funds into the local economy, discretionary external spending, where national currency is required, does not recover. Although some unemployment remains, the rise is ameliorated relatively quickly. In experiment 3, the economy has reached a functional steady-state, albeit at a lower level of consumption, with some residual unemployment. It is a significant improvement on either no CC or the CLC
model. However, it should be noted that in the instance that MCC credits are spent by producers (rather than paid-out to employees as income), there is a sharp-drop recorded in discretionary consumption by households. This is because evaluating MCC systems does not fit comfortably into conventional GDP accounting; spending may be disguised final consumption, but business-to-Business (B2B) transactions are recorded as transactions in intermediate goods and may be surmised as adding value to the business (potentially, but not necessarily, as capital formation), but not as GDP; implicitly this may represent a behavioural change, reducing the import fraction of business costs.

A basic LETS is an informal Person-to-Person (P2P) arrangement whereas a formal MCC is primarily a (B2B) operation. However, there may also be Business-to-Employee (B2E) transactions where wages are paid in credits and spent on final consumption. The model adopts the structure of a ‘B2E’ circuit whereby SME members of the clearing circle pay wages in the credits. Experiment 3 essentially "turns on" such a B2E circuit by allowing households to volunteer to be paid in MCC for 50% of MCC credits spent. What the simulation demonstrates is that there is little discernible difference between the behaviour of the economy whether the MCC credits are paid to and spent by households or producers (albeit transactions may be recorded differently in GDP accounts). While slightly differing assumptions may be made about behaviour (delay in spending for example), neither sector regards MCCs as a store of wealth, and both wish to spend them back into the circuit.

It is assumed here that the numéraire is benchmarked against GBP, but is distinguishable from it. This opens up questions as to how parity can be
maintained, and what issues may occur to undermine parity. The model helps elucidate that this issue is largely a narrative of appropriate assumptions. At a minimum, faith in the system is key. A private enterprise which establishes itself as an MCC may not engender the appropriate confidence or trust that has become culturally embedded over generations in the banking system. This is likely an indication as to why an MCC provider should be established with a level of guarantee and backing equivalent at least to a bank, implying need for state intervention and the appropriate "expert systems" (Giddens, 1990) to ensure stability.

If faith in the system's stability can be assumed, the principal reason an MCC system may see currency devalue is if there is an imbalance between debtors and creditors in the system. If creditors accumulate beyond their demand for holdings, they may refuse to accept MCC credits at par, implying a devaluation (essentially internal inflation within their monetary circuit). This is essentially a corollary of Keynes' critique of Say's Law as being violated in a monetary-production economy, albeit reversed in that the agents want to dump currency rather than hoard it. The MCC system is a good way to demonstrate this, although how to model such a potential for an imbalance is a difficult question of appropriate assumptions of the model and arguably is more appropriate to use a dialectic rather than simulation of failure: the question is more about what institutional assumptions must be fulfilled in order for the system to work as simulated. The system is always "in balance" by definition that creditors and debtors always cancel. However, this accounting balance may not represent a behavioural balance. The assumption is that credits are supposed to clear and are not meant to be accumulated as wealth, but it may be posited that an
imbalance may occur for several reasons. Firstly, too much of the currency may be created in the form of loans by the MCC operator. In the model, the ability for the MCC operator to issue credit has been abstracted from, because this is not an integral element of an MCC system (and arguably, based on the assumptions here, is more likely a problem). Secondly, there may be too narrow a choice for expenditure within the system. Again, this is abstracted from as an institutional constraint that is a question of system design, arguably within the purview of government intervention to ensure critical mass of such systems; this is an age-old issue relating to a question of geographic spread, and reflects Cantillon and Smith’s analysis about the size of market relative to product variety. CCs are no panacea: they are monetary solutions which are able to facilitate coordination in the absence of appropriate national currency — they cannot create wealth or "interesting" transactions out of nothing, or when supply is not available. Finally, if the economy recovers in the course of the issuance of credits, there may be enough GBP that the desire to hold MCC credits as a secondary (inferior) currency may deteriorate relative to plans to hold. What experiment 4 demonstrates is that the assumed delay in the expenditure of credits — essentially the parameter denoting the target time-frame to clear all credits — is likely a key parameter here: if the expenditure delay is short (for example one month), the sales cycle is better coordinated, and the accumulation of credits/debits is much smaller compared to a delay of a year: the potential for excess accumulation is greatly mitigated.

Mutual credit clearing is a way to create and transmit money information markers between various actors within the economy. A monetary monoculture enables money to exit the local region, whereas, to use Law's terminology, a
mutual credit currency is like an estate entailed — it has to stay and be spent within the local area. This necessarily makes it an inferior currency, yet, in times of economic stress, such an inferior currency is better than no currency.

6.5.3 Local Government Currency (LGC)
A local government currency may enable an increased local circulation of newly created spending power within the local economy. This is useful when national currency is lacking due to, for example, funding cuts. Conceptually, the LGC model may be the most ambitious as this represents a fully-fledged dual-currency system, with an authority essentially imposing an exogenous monetary form into the local economy.

Creating a model for an LGC can be expressed as a secondary monetary circuit, similar to Law's island model, being appended to the core model. The local government (LG) is an entity that can create money only spendable within the boundary of the local economy given value initially by the population's obligation to pay tax, and the obligation of the issuer (local government rather than a landlord) to accept these notes back in payment of tax at face value. An assumption is that any LGC would be implemented by requiring that local taxes are at least partially be paid in the LGC. In line with chartalist theory, this is what creates demand for the currency.

While the institutional structure of the model — the "plumbing" — is straightforward, key issues revolve around the decisions of the key sectoral agents: local government, producers, and households. Similar to the conundrum faced by Law's landlord, some knowledge of the potential demand to hold this currency would be essential. In the model, the assumption is that
LGC is not regarded as wealth, and is merely stored by households and producer in order to make local payments and pay taxation.

In LGC experiment 1, with the drop of 20 in external income in year 10, no LGC is spent into circulation, the circuit is dormant. There are no impacts on other aspects of the model, relative to the core model. The same applies to LGC experiment 2. In LG experiment 3, the loss of external income is reacted to by the LG. The LG "prints" money (physically or electronically) and spends it into circulation: $LG_{Spend}$ has a step increase from 0 to 4 in years 12. The nominal anchor is the national currency, and it makes sense for the local government to consider its own currency as akin to the national currency and seek to replicate spending in that currency with its own. Producers receive payment from local government in the form of LGC, and treat it as any other payment in as much as this represents demand they are able to supply (i.e., no resource constraints). Households receive some income payment in LGC, and have some saving function — assumed to be relatively small — which enables them to manage tax cash-flows. LGC experiment 3 shows a recovery in local employment and spending. Steady state unemployment is reduced to 7%, down from 19%. The simulation indicates that it is likely that little LGC would actually need to be created relative to the income shock, because of the increase in velocity implied by a currency whose primary attractiveness for holding is merely to pay a tax obligation. The illustration that such a currency would likely have a higher velocity of circulation would indicate a circumspect evaluation of the potential magnitude of directed LG spending. Equally it demonstrates the potential for a recovery in private sector activity due to the availability of a widely acceptable medium of exchange which remains in the local circuit. Experiment 4 repeats
the sinusoidal variation and shock in external income and again demonstrates the ability to reduce unemployment. Experiment 5 uses a ramp in spending over 4 years (an increase at a rate of 2LG per year from years 12 to 16). Experiment 5 indicates when the local government has spent too much money into the local economy. While unemployment falls essentially to zero, rationing begins as a proxy for the inflationary consequences of too much local spending. This represents a caveat that applies to local government becoming a fiscal authority, that judgement and expertise along the lines of national fiscal policy management are required. Additionally, it may be noted that while very short delay parameters have been chosen as plausible, if such delay parameters on the part of households become longer (or unstable due to changing levels of confidence in the system), this may add oscillation to the economy as spending decisions take their time to work through the economy. This would be especially true with a sharp step function of government spending. A lesson from these simulations is that if local governments are intended to become fiscal authorities — which if they potentially have the power to create such reductions in local unemployment, arguably they should — small scale, conservative experimentation is likely the only way to develop greater insight into some of the debatable behavioural issues and to reduce disruptive behaviour of the economy.

The simulations highlight the need for several areas of discussion. One of the uses of the LGC model and simulation is the demonstration that many important questions over operation of the system conform to the heterodox notions of monetary theory, viz. that it is inherently socio-political, hence represent
questions about model structure and assumptions rather than specific simulation results.

What encourages households to accept money must be an institutional arrangement: taxation, and likely legal tender laws, at least in order to establish the culture of acceptance. From a psychological perspective, an overt marketing campaign by LG that local spending is improving the local economy and infrastructure would likely encourage adoption, and potentially network effects.

The quantity of external costs in local production is an important issue. LGC can only be spent locally, so expenditure with producers (although in the model it is not distinguished from the overall cost structure) may usefully be seen as encouraging local government to procure services locally. In the model this could imply a behaviourally induced reduction in the external inputs, which would lower increase local income and reduce unemployment further. The ability for producers to localise their supply-chains become important, although localisation of consumption/production remains a contended point: while it may be possible to fill pot-holes with little to no external sourcing, complex goods and household consumption are likely to require ongoing external input. Local government can be selective according to its particular sustainable development goals about what it needs to spend money on, and what has the key multiplier effect in the local economy. There may be certain a priori assumptions about what best serves such goals (e.g., filling pot-holes, street-cleaning, environmental work, paying for social care), but it is likely something that would require a degree of experimentation; a more comprehensive model
including more detailed real resources constraints would be able to more fully explore these possibilities.

As with any government finance, the annual difference between spending and tax revenue is a budget deficit; this accumulates into a stock of outstanding liabilities. The issue of whether government produced fiat notes are debt or not is a germane topic in monetary debates: they may be argued to be zero-cost liabilities, a form of equity shares in the State, or merely a memorandum in public accounts. Modelling an LGC arguably sheds light on some of the topics. Local government action is specified in three exogenous parameters: annual spending, and the tax rates on households and producers. In reality there are various choices an LG has to make. The local government's key responsibilities are those of Functional Finance (Lerner, 1951), primarily being non-inflationary full employment. LGC is merely a particular form of fiat currency with a domain of a sub-national region rather than as a whole nation. There is no explicit need to "balance the budget" (flow): the key objective is to match the quantity (stock) of currency in issue, to the quantity of currency (stock) demanded to be held by the public. What the simulations demonstrate is that while the LG determines the spending and tax-rate, the actual flow of tax payments is a function of expenditure, hence the model expresses the goal-seeking nature of household demand for currency as a determinant of both expenditure and the outstanding quantity of currency.

This brings up the crucial issue of how to determine the "correct" quantity of currency which may, implicitly, have consequences for the sustainable exchange rate between LGC and GBP. As an exogenous money, if too much of
the currency is created (relative to household demand for balances), LGCs may potentially suffer from pressure to devalue (essentially internal inflation within their monetary circuit). In the simulations, if money creation by the LG is too large, expenditure will exceed resources and rationing occurs: this is a proxy for pressuring LGC parity with GBP. While an LG would be sensible to try and avoid an overissue/overspending of LGC, the estimate of potential output gaps is not an exact science, hence an important question becomes how does the local government ensure LGC remains at parity with GBP? Initially this is a function of household and producer demand for LGC holdings. It is assumed in the model that they would only want to hold LGC in balance to ensure payment of taxes and other short-term cash-flow requirements, hence the implied target wealth to income ratio is much lower in the model, hence velocity of circulation is higher. It is possible the demand for cash balances may grow over time as people see the utility in the currency, hence the LG would be implicitly required to run an annual budget deficit in order to satisfy demand for the currency. If producers do not wish to accumulate more than necessary to pay annual tax, similar to the MCC system, this may entail an increase in velocity of payments between producers within the supply chain; these are not picked up in the model (which is based on GDP accounting of current income), but may indicate behavioural changes (such as reducing the import fraction of production) which increases resilience of the local economy. The LG could encourage this with tax policy.

There is an analogous situation in foreign exchange markets referred to as the *Impossible Trinity* regarding the choice between independent monetary policy, fixed exchange rates, and free-flowing capital. With an LGC there would not be
free flowing capital movements. Indeed, a key purpose of an LGC would be to encourage localisation, which makes it impossible for the money to leave the region (because it has no value outside the region). This may involve a tax policy which essentially limits capital exodus: for example, while a local income tax may be the most obvious way to anchor the currency (and the local government may seek to compete on a tax basis, thus encouraging local spending), alternatively, an *ad valorem* property tax (or a Land Value Tax (LVT)) may be a way to anchor a local currency according to property (or land) values. Such a tax may additionally help to ameliorate the impact of external ownership of property (absentee landlords), by forcing a demand for the LGC and an element of local spending by absentee owners. Ultimately, the national government may be required to act as guarantor, acting as a form of back-up "Domestic Monetary Fund", which may require LG fiscal credibility rules, akin to the EU's *Stability and Growth Pact*.

These are primarily arguments of institutional arrangements: if the LG wish to peg their exchange rate to GBP and defend it, particularly with national government support, they will be able to do so. The mechanism for defending it is beyond the model boundary, but at an extreme would simply mean buying available notes on the open market for GBP (paid for by the national government). Ultimately, the restraints on an LGC are akin to that faced by a currency issuing nation: levels and types of taxation, openness of markets, capital controls etc. — these are all political choices which have to be weighed against the espoused benefits of currency sovereignty.
While small experiments in CLC and MCC systems are perhaps ignored or tolerated, the idea that regional governments should produce their own currency is perhaps the thorniest issue both from the perspective of politics and economics. However, arguably, it is also the most germane and crucial issue. It is an argument that may be applied from a city or locality, all the way through regions to nations: Devon; the South West of England; Scotland, Greece or Italy. Debates over the Eurozone problems have encouraged a debate focusing on national level currencies. It is a smaller step in the established direction of evolution than is the rejection of the pound/euro and the wholesale adoption of a new currency entirely.

### 6.6 Concluding remarks

The simulations are able to demonstrate what is possible, based on the given assumptions around structure and behaviour. From a critical realist perspective, arguably the most important purpose of the models and simulations is to frame a dialectic over the nature of such assumptions. Changed assumptions relating to either structure or behaviour may drive differing outcomes. It is not possible within the space to be exhaustive with the potential domain of changed assumptions. The modelling choices are necessarily simplified and incomplete descriptions of the underlying system; however, it is argued that they represent a plausible structure and boundary for the model at this level of aggregation, as well as plausible behavioural characteristics. Longer-term endogenous structural shifts could be engineered into consumer choice, substituting between different categories.
Potentially one of the most confounding issues for modelling choice relates to the decision by agents within the model to use one currency rather than another. The question of why anyone would accept money is key. The notion that there exists a hierarchy of monies in any economy, and that anyone can create money again recalls Minsky's dictum that "everyone can create money; the problem is to get it accepted." (Minsky, 1986 [2008], p.255). It is presented as that the plausible minimum necessary behavioural characteristic (with reference to Law's island) is that the choice is made purely on the basis of perceived, anchored need relative to availability: if there is no national currency, then a different — inferior — one will do. If this approach is adopted — with confidence — by the whole community there appears no logical objection to this approach. Households and businesses must trust that this money is better than none at all, and that is largely a function of institutional structure, not individual behaviour. It is argued that on reflecting on the models, there is no justification for orthodox arguments of a need for search-and-matching models of currency: the appropriate agent behaviour can be assumed if the appropriate expert systems are in place enabling coordination. If the appropriate expert systems are not in place, agents may potentially approximate to such an idealised situation, but would likely face various coordination failures in attaining the supposed optimal state. The demise of numerous LETS schemes may attest to this.

6.7 Chapter Summary

The three SD models demonstrate the minimum necessary monetary "plumbing" required to operate two monetary circuits within a local area; the
behaviour of each sectoral agent has been demonstrated as according with the logic of classical behavioural economics to simulate what is possible. The selection of model simulations helps reveal the key differing characteristics of three key types of CCs. Base simulation runs have been undertaken, and exogenous shocks have been applied to experiment with each currency model, indicating the nature of impacts on various key variables which give useful proxies for the notion of decline and hysteresis within the locale. The three models of distinct CC systems seek to demonstrate that there is a variety of approaches, each with relative benefits and drawbacks, which may be appropriate in various contexts, according to the need of any particular locality. The three models demonstrate a key distinction of how money is created and enters the system. Numerous parameter and structural adaptations may be undertaken to interrogate alternative hypotheses about model closure which may enable further explanation of alternative real-world scenarios.
Chapter 7 Conclusions

7.1 Contributions

Can a parsimonious theoretical macroeconomic model be created to demonstrate the avowed benefits of secondary money systems in addressing the economic problem? The initial intention of the research had been simply to present a model of secondary money systems to give more formal elucidation to narrative arguments from across the literature. However, once the question was unpacked it became apparent that the economic problem cannot be solved if we are forced by academic convention to only rely on our current approach to economic methodology which acts as gatekeeper as to what formal methods are deemed admissible. Addressing the research question is inextricably linked with problems of meta-methodology and methodology in justifying method. It has been argued that the disciplinary tendency of economics for promoting a fallacy of exclusiveness in methodology has solved the research question by assumption, and helps explain why the economic problem has remained so intractable.

The thesis necessarily has a combination of qualitative and quantitative objectives, broadly: to bring together cross-disciplinary literature about the nature of secondary money systems; to develop conceptual themes based on this literature; to critique the existing (or lack of existing) economic theory addressing the themes; and to develop these themes into more appropriate general theory economic models to formally elucidate narrative arguments.
7.1.1 Contribution to literature

The research question motivates the development of an original narrative framing recognising a hierarchy of four "problems". Each problem is implied by — and partially explained by — the problem one higher up the hierarchy: the economic problem is implied by the money problem; the money problem is implied by the coordination problem, and the failure to resolve the coordination problem in economic theory is argued to be the result of the mode of thought problem of how economists conceive problems in theory.

Heterodox economics broadly recognises the inappropriateness of the axiom of money neutrality; this becomes more apparent when the money problem is argued at a sub-national level rather than across a nation as a whole. At the core of this thesis is the notion that an untenable axiom has been maintained because of a methodological blind-spot. Heterodox literature recognises that money is essentially a social technology intimately tied to questions of time, place and space. This literature is supported by other disciplines arguing for complementary currencies. Money does not spontaneously emerge in a vacuum, but is shaped by socio-political institutions and (ultimately) habit. The conceptual themes developed in this thesis reflect this perspective: monetary systems are designed. Search-and-matching models have implicitly assumed this perspective away. The analysis of a monetary economy must come under the broader auspices of Political Economy. Proper monetary macroeconomics thus necessitates a more pluralist methodology. This should include dialectics and narrative, as well as mathematical models, using a micro-meso-macro approach able to be explicit in detailing institutional structure. The inherently processual, dynamic nature of monetary economics means these models must
be based on algorithmic reasoning, using precepts of classical behavioural economics.

Institutional analysis of the monetary architecture is a useful approach to see the broader issues. This is initially offered here in the building block model, Law’s island, which has been recreated here for the first time. The model uses a secondary money to demonstrate the ability for a token currency to replace silver: money is merely a particular form of information for enabling and carrying-out mutually beneficial exchange. The notion (oft repeated in times of austerity) that there is not enough money to enable optimal outcomes of interactions between individuals and resources must be interpreted either as human (political) choice to limit the appropriate information (for purposes of rent-seeking), or a failure of appropriate systems to distribute the information.

In the Law model, the farm-owning landlord class is paramount in beginning the circular flow process: while agriculture creates the value, the contractual nature of rent payments ensured that tenant farmers are obliged to pay their rent. What becomes apparent is distribution between different classes/sectors is paramount in understanding monetary — hence ultimately real — flows around the economy. Poorly specified aggregates may hide key factors. How labourers accumulate wealth, relative to capitalists, and landlords is key. The three key classes are labourers, capitalists and landlords (rentiers). Cantillon expanded Law’s arguments, creating spatial differences, facilitating a more direct inspiration for the core model in this thesis. Macroeconomic models assume-away the role of landlords by replacing the landlord (and rent) with government (and tax). However, government taxation is primarily ad valorem, and the
potential for non-payment is low, whereas default on contractual rent payments is a real possibility. Both a government and landlord sector are thus required to elucidate the nature of the circular flow in a properly specified macroeconomic model. It is reasonable to assume each class has differing characteristics and motivations. How and why they spend money into the economy is crucial. This inherent non-neutrality of money in a capitalist economy was identified by Richard Cantillon. This thesis has argued that Cantillon's crucial notion of what have been termed Cantillon Effects can only be understood from a procedural, algorithmic approach to modelling, including lexicographic choice, such as that offered in this thesis.

It may be argued that money is a veil, but in the sense that it hides the true nature of the underlying economic system and relations between "actors". This comports with Heilbroner's (1985) perspective, that capitalism is a control mechanism: a form of creating hierarchy and social control through markets. Property ownership remains at the centre of the system, and the question — simply put — is whether the current money system is designed to facilitate an equitable distribution of property and ownership (part of the sustainable development agenda), or whether it helps consolidate ownership: is the economic system trickle-down or trickle-up? Only economic models which have concepts of institutional design, process, time, space, and algorithmic calculation rooted in their analysis can be applied to problems in this domain.

7.1.2 Contribution to methodology
Macroeconomics needs to be recognised as a branch of systems theory, within which several alternative and complementary approaches may be suited to
different problems. The systems approach to economics is an argument made explicitly by Boulding, Kornai, Weintraub, and Forrester. However, Structuralist macroeconomics, and in particular PK-SFC modelling, while being systems oriented — argued here to be overtly implicit in Godley's work — a formal systems approach has not been recognised or adopted within the discipline. System dynamics is an approach widely adopted in various disciplines, but has struggled to find traction as a tool of economists, despite the fact that it developed as a computer simulation methodology to provide an alternative to extant methods in economics. It has been argued here that that this relates to the mode of thought problem. While the philosophy of science or meta-methodology has often been kept at a distance from underlying methods of analysis, an appreciation of the ontological and epistemological critique of the methodology of economics is argued here to be crucial to understanding the failure of economics as a discipline to address the economic problem.

The development of computing technology in the last half-century enables the critique of orthodoxy to be more fully appreciated enabling the insights of Simon's classical behavioural economics to be incorporated into computable (algorithmic) macroeconomic models. In this thesis these arguments have been developed into the method used. The models develop an original and novel formalisation and operationalisation of household purchasing behaviour. The cybernetic concept implicit in the Keynesian consumption function of standard PK-SFC models is combined with the lexicographic ordering of a PK consumption model which has not previously been formalised. This combined approach, utilising the concept of algorithmic behaviour, enables the development of what may be called a Cantillon Logic Gate, enabling a model
which generates Cantillon effects through the differentiated introduction of money into the model economy. The lexicographic consumption model of households is argued to be crucial in understanding the key arguments for complementary currencies.

This approach is more flexible and realistic than the orthodox neo-Walrasian approach to macroeconomic modelling which is ultimately based on a combination of (abstract) real/physical constraints and formalist mathematical reasoning. Structuralist macroeconomics enables a framework whereby the variety of potential equilibrium outcomes is constrained by transparent institutional relationships in the model. Post-Keynesian SFC modelling has in particular developed this approach in relation to focusing on the monetary accounting constraints essential for understanding the dynamics of a monetary production economy. However, such models have been critiqued as having what may be regarded as simplistic behavioural closures. While PK-SFC modelling is proving to be a fruitful methodology, the conscious adoption of systems theory within a system dynamics framework is argued to make the approach more intuitive and more insightful. The models in this thesis seek to combine the benefits of a structuralist PK-SFC modelling approach with the systems concepts, and algorithmic behaviour contained with the methodology of system dynamics. These models allow much leeway in defining realistic behavioural relationships to close the models and simulate the various potential paths to the various steady-state "equilibria". This approach explicitly seeks justification from a mode of thought consistent with critical realism and the approach of graphical causal inference. The systems approach harks back to cybernetics and control engineering which seemed to provide new impetus to
the economics of Keynes back in the 1970s but was eclipsed by the then more tractable — but arguably inferior — rational expectations approach which extended the life of the extant paradigm of neo-Walrasian macroeconomics. Arguably the approach is more generalisable, more extensible, and useful for pedagogy; such characteristics are useful measures of the value of economic theory (Caldwell, 1984).

7.1.3 Contribution of simulated models
The models are argued to be the first formalisation of a general theory approach to CC models in economics. The simulations serve the intention of developing a more formal understanding of narrative arguments in CC literature. The caveat, widely accepted in the PK-SFC approach, is that the simulations can only demonstrate what is possible: no analytic solutions (known in orthodox economics as equilibrium) can be offered. The simulation of John Law’s island model (in the Appendix) demonstrates Law’s fundamental argument that with given resource constraints, a lack of silver money is not a constraint on consumption if a secondary fiat currency can be introduced by the landlord. As long as an assumption can be maintained that other parties accept this fiat money as a replacement/supplement for silver, economic activity can continue essentially unchanged. How such necessary assumptions are maintained becomes part of the modelling narrative of the socio-political institutional framework, not an equation or parameter within the model. The simulations highlight Lawson’s critical realist perspective and McCloskey’s argument for rhetoric, that economic modelling is inherently narrative and dialectic in nature.
The nature of the fundamental finding from Law's model is how all the models and simulations must inevitably be treated.

The simulations support the notion that money can facilitate coordination where coordination has previously broken down. External shocks to the system can be ameliorated by the intervention of monetary systems. The real wealth of the area will remain a function of its ability to produce, export and, in turn, purchase goods/services. The simulations do not suggest that money can create wealth out of nothing: real resources, including labour hours and external inputs (measured in money) demonstrate that constraints matter. However, regarding local production as demand-led, the models show that a lack of national medium of exchange (GBP) relative to a pre-shock condition need not disable the coordination of demand-led production. The simulations are able to clarify key differences between the three types of system in terms of possible scenarios, and hence the type of policies which may be needed.

Not all forms of CC are useful for the purposes espoused. The simulations support the view that Convertible Local Currencies do not serve a direct monetary purpose: there can be no direct creation of purchasing power beyond an increase in velocity. Velocity of circulation may be modelled to increase as a behavioural change on the part of households. However, contrary to arguments supporting CLC schemes, plausible increases in velocity appear to have little impact on the resulting economic activity. Changing behavioural parameters of households in terms of purchasing preferences can have a powerful impact on outcomes. What this demonstrates is that CLCs may represent the potential to support behavioural change; the mechanism for such a behavioural change was
held beyond the model boundary, although it could be incorporated in future research. Behavioural change is perhaps the most powerful justification for CLCs. This is likely why CLC projects have appeared primarily in relatively well-to-do areas rather than poorer areas, and equally an explanation for their failure to gain more critical mass.

The simulations demonstrate that beyond an assumed behavioural change any form of useful CC must create additional purchasing power, ideally attributed to real value creation within a locality. The Mutual Credit Clearing model demonstrates the endogenous nature of this creation of a secondary monetary circuit. Mutual Credit Clearing is a framework which may scale from small LETS schemes to national B2B/B2E corporate networks: the underlying mechanism is broadly the same for both. Similar to Law's model, assuming an anchored understanding about capacity, an exogenous monetary shock to the economy can be addressed by the creation of purchasing power in the form of a new medium of exchange. The simulations demonstrate the countercyclical nature of an MCC system (an empirical claim of Stodder & Lietaer (2016)) where the MCC acts as a form of trade-credit, helping firms to maintain business as usual when money and credit conditions in the national economy tighten. The model demonstrates the necessity of having particular institutional assumptions about behaviour of agents. It is not necessary that producers (or employee households) seek to save this form of money. Indeed, the purpose is that the money is created purely to be spent, but the money must be assumed to be acceptable.
Maintaining acceptability is likely to be a function of several factors. Assuming money is not lent into existence by the MCC network provider, the creation of credits is endogenous to the needs of trade. However, in order to ensure that excess quantities or inequalities of holdings build-up (which may undermine the acceptability of credits), the simulations show that the clearing period is important: spending credits relatively quickly is important to ensure the system does not get out of balance. Beyond this, institutional assumptions of the modelling framework, such as the availability of goods for sale, and the strength of contract law are the key factors to ensure the system does not breakdown. That LETS systems have not flourished as potential may have suggested is not an indication of failure of principal, but an indication that they need government/institutional support as a relatively low-cost intervention into community building and resilience. Institutional structures need to be consistent and reliable.

The model of Local Government Currencies indicates that an LGC is simply another form of secondary currency circuit similar to Law's island model, albeit one which is much more controlled by those in power. The simulations demonstrate that it is possible that a local government (just as in Law's model) can introduce a secondary currency through its spending which may circulate in the local economy. They have a similar purpose to Law's island economy in that economic activity — of locally produced goods and services — is able to be maintained without the need of an exogenous currency. The institutional assumptions of the framework are again key. LGCs may act as countercyclical stabilisers, but they must be recognised as exogenous interventions, and as such will require more detailed knowledge of economic activity and supply
potential, as well as policy judgement. The simulations indicate that a lack of desire to hold LGC as wealth implies a relatively high velocity of circulation, hence the local government probably does not need (or, perhaps more correctly, does not have the capacity) to spend a large amount of money into the local economy to create the secondary circuit. The constraint on the government is not financial (in as much as the budget can be in deficit), but the productive capacity constraints of the local economy. This implies that the choice of LG spending may be used to encourage increased localisation in the supply-chain, enabling a greater "bang-for-the-buck" of LGC spending. What the simulations highlight is that such government intervention can create unwanted side effects including rationing (implying a fall in value of the currency), and destabilising dynamics according to how intervention is created. Abrupt intervention may be too disturbing, so intervention should likely be small and incremental: small-scale experimentation would be appropriate.

7.2 Policy Implications

7.2.1 Sustainable Development obligation
While many EU Directives have been developed with Sustainable Development at their heart, uncertainty over Brexit negates the impact of EU Directives on UK policymaking. However, the UK Cabinet Office coordinates delivery of government policy across departments and states that "The UK is committed to the delivery of the Sustainable Development Goals. The most effective way to do this is by ensuring that the Goals are fully embedded in planned activity of each Government department" (UK Cabinet Office, 2018). The SDG framework thus provides a useful framework for establishing the role of government policy
intervention. If one accepts that there is a potentially significant role for secondary money systems to play in ameliorating the economic problem with respect to local production and employment, this fits into the SDG framework, specifically: Goal № 1, "No Poverty": Goal № 8, "Decent Work and Economic Growth": Goal № 10, "Reduced Inequalities": and Goal № 11, "Sustainable Cities and Communities". The SDGs may therefore be recognised as placing at a minimum a moral obligation upon government to act by enabling policy which seeks to deliver these goals. Action may be both to remove impediments which have been put in the way (such as restrictive and centralising regulations) and to pro-actively facilitate the establishment of such money systems in order to deliver the SDGs. In contrast, the existing framework (MHCLG, 2018; UK Cabinet Office, 2018) specifically relates policy to SDGs and associated targets, but currently has no role for re-engineering local/regional money systems. The purpose of sustainable development at a regional level is, in large part, the employment of labour for the end purposes of employing labour; place-based, "low-skilled" work needs to become more commonly accepted as part of the technology revolution (Dellot, 2018). The kind of resilience implied in the SDGs encourages increased totipotentiality of towns and regions. Intervention to facilitate and encourage a monetary ecosystem is argued to be essential for such purposes.

7.2.2 Methodological acceptance, coordination and intervention
Economic policy is currently driven by existing theoretical models constructed in the orthodox manner. Differing assumptions may drive different conclusions, but the method is rarely questioned or challenged, let alone the ontological
Conclusions

underpinning of theory construction. Performative notions of deregulation, more money (from central government), and more productivity from the private sector are the standard fall-back policy positions. The focus on productivity is often presented as a kind of panacea. In the context of the simulation models, productivity is neutral, but the relative power of property ownership and the geographic spread of expenditure are more important. National/universal monies are able to move value around geographically, often outside of their network of value creation. It is the ability of money to disembody value creation in a locality, and store that value elsewhere which is at the root of non-neutrality. The models are able to demonstrate and explain that the relative power and long-term accumulation of economic actors whose income is largely contractual (such as banks and investor landlords, many of whom are likely to be outside the locale in question) may accumulate claims against defaulting households; entrepreneurs who sell discretionary consumption goods/services are more likely to be impacted, especially if only selling into local markets.

When coordination problems arise, there is clear justification for intervention to improve efficiency (Stiglitz, 2002). Economics recognises the concept of the Specificity Rule when justifying government intervention: the most direct action to address the specific cause of the problem. One of the simplest (and most powerful) forms of intervention in systems is the creation of new information channels between decision makers. What the models have sought to demonstrate is that money is both a carrier of information, and a form of information that enables coordination. Hence logic dictates that if the role of CCs has implicitly identified an information and coordination problem when universal currency is absent, the correct role of government is to address this...
problem specifically. When national currency leaks out of a locality it essentially drains crucial information about the ability of that locality to produce value, thus inducing lack-stress manifested in a fall in economic activity. It is argued that for local economies suffering monetary lack-stress, the creation of local money systems may be seen as engineering a new information channel which had effectively been closed. Such a "free information" intervention by government engineering of the system encourages the potential for freer contracting in trade of mutually-interesting transactions in the local community.

Various types of CC could enhance the productive potential of a nation. They may be engineered to engender an endogenous supply-side response, whilst delivering these gains in a more socially equitable manner. This appears to have significant implications, for example: there are increasing calls for either a Universal Basic Income (UBI) (Standing, 2016) and/or a national Job Guarantee (JG) (Tcherneva, 2014). The idea that a JG would be administered at a local level is commonplace, but the idea that either UBI or the JG could be paid for as part of a local currency has not been explored, but may be a useful way for government to deliver on macroeconomic objectives at a local level without impacting central budgets. The implication that effective demand (and supply) can both be more efficiently managed at a microeconomic level not through complicated intervention, but by the removal of co-ordination problems, may allow society to move closer toward the model served by a theoretical Walrasian auctioneer. Indeed, once the role of CCs is understood to enable sustained effective demand in a region or locale, the role of traditional regional input-output models becomes more important. These must be understood as a different class of models, answering a different question: that of assumed
coordinated activity constrained by real resources, while the models developed here complement that approach by focusing on the coordinating role of money in sustaining monetary demand at a local level.

7.2.3 Expert Systems: reform, create and support

The Structuralist and Intuitionalist critique of orthodox economics is that it fails to model the institutional structure: a policy of laissez-faire and liberalisation à la the "Washington Consensus" becomes the default approach through implicit assumption. In reality, there is a necessity of policy intervention to build structures and institutions supporting monetary plurality. Such institutional structures must be assumed within the modelling environment rather than emerging from a market search process. In the modelling they are informed by Sterman's (1989) institutional limitations of decision-making and Morecroft's (2015, p.218) five filters of bounded rationality: the key is to try and understand the nature of behaviour which necessitates certain institutional frameworks for monetary plurality which comport with the wider perspective of money in heterodox economics.

Institutional intervention may be either in terms of establishing and underwriting CC systems, or giving them legal/regulatory structure that households can have confidence in. More transparency regarding tax implications is a particular example, perhaps with tax benefits for localisation. Such "expert systems", the tools which "organise large areas of the material and social environments in which we live today" (Giddens, 1990, p.27) are crucial in encouraging a broader acceptance of local currency systems; appropriate expert systems are lacking in the UK today. Recently the Exeter Pound has announced it will cease trading, in
part due to "a lack of progress nationally to develop the regulatory framework for digital complementary currencies" (Exeter Pound, 2018). Similarly, the Totnes Pound experiment is ending partly because of the uncertainty in the move to cashless payments (Hopkins, 2019). The nature of developing appropriate institutions is itself a problem of coordination. It is apparent why CLCs have tended to predominate in socioeconomic areas of high education and little economic deprivation: it is the simplest system to implement by grass-roots reformers seeking social change, yet still they have failed. It may be argued that CLCs could be "leveraged" by local government if expert systems could be created to encourage increased velocity and broader use; however, Bristol's experience indicates that without national support the effort may be in vain. Similarly, LETS systems have floundered because while being valid in principle, they have run into practical problems of funding the administration, contractual enforcement, and the inevitably limited choice of products/services that the lack of critical mass (a function of lack of institutional structure) entails. Although private or Third Sector activity is appropriate, what the models imply is that the workability of these systems is largely a function of appropriate institutional arrangements, largely as a choice of government.

Our existing monetary system did not emerge in isolation from political reality, and it is perpetually sustained by explicit or implicit government intervention (such as through regulation, bailing-out "too big to fail" banks, deposit insurance etc.). In the centuries' long transition from commodity-based money to our existing system, Law's currency model has been adopted by all mature economies: our credit money systems are primarily based on land-backed credit agreements turned into media-of-exchange by the monopoly-privileged, highly-
regulated banking system. Participants in the economy no-longer have to make decisions about which "currency" to use because all differing forms of domestic currency are treated as one, with fungibility and parity in exchange guaranteed by regulation and custom. Our expert systems today specifically encourage universal banking models, and are actively detrimental to embryonic models. It is clear that the reason customers will accept any banks' liabilities as wholly fungible at par with national fiat currency is because the legal and regulatory system has been structured to support this contractual certainty. Such contractual certainty is key: if national currency is preferred merely for its contractual certainty, then the task of government is to use its power to replicate this contractual certainty for secondary monies. A simplified current example is of Tempo Time Credits in the social space (Tempo, 2018): any business committing to dealing with such an enterprise will require confidence-building legal regulations on par with the existing banking system. Even then, it may be argued that it may take time for society to more widely accept localised B2B mutual credit clearing as being as natural as our current universal banking model of mutual credit clearing.

Mutual credit clearing groups should be encouraged to regularly clear credits, and not accumulate them. This could potentially involve legislation effectively creating an annual "Jubilee" which forces credit clearance, or creates dated credits which must be spent within a fixed period of time from their date of creation (such electronic dated money could be enabled with blockchain technology). Although MCCs have the potential to coordinate, they are clearly not sufficient to produce value from nowhere. The supply-side of the economy needs to be made responsive to any ability to increase local coordination.
Despite the networking and marketing offered by various MCC types schemes, such an endogenous response cannot be guaranteed and, again, likely requires some government intervention to enable community coordination of such efforts to enable legitimate relocalisation efforts as an end in itself, including such as by the provision of comprehensive data on local economic activity and available resources.

The models have sought to demonstrate that Local Government Currency may seem radical in the context of decisions which have been taken historically about how to design our monetary monoculture, but there is no logical reason why regional governments should not create and spend their own money into the local economy and demand it back in taxation. While it is beyond the realms of this thesis to argue the legal intricacies of such a system, the concept has been demonstrated as at least plausible. Upper Tier or Single Tier regional authorities becoming their own combined monetary-fiscal authority would imply the need for significant support at many levels to enable them to make such a transition. The mooted notion of a Domestic Monetary Fund would be a significant institutional commitment.

7.3 Future work

The SD models are presented as generalisable, foundational models, as the basis for understanding the potential power of complementary currency systems. With a parsimonious core model established, the models are potentially extensible to further research questions and other areas of study. Many variations on the selection of given simulations could be offered. Model boundaries may be extended, more complex behaviours may be developed,
historical/empirical data may be gathered with alternative closures and scenarios considered. The nature of the micro-meso-macro distinction implicit in the modelling framework is useful for understanding this potential.

7.3.1 Agent-Based Modelling
Part of the attraction of the methodology is that the mesoeconomic, hierarchic modelling technique ensures a high degree of macroeconomic closure, but can accommodate various microeconomic behavioural assumptions. The algorithmic behaviour presented in the models was developed in the vein of Simon's Classical Behavioural Economics. It may be argued that as desired detail of decision-making increases, Agent based Computational Economics (ACE) (Caiani et al., 2016; Leijonhufvud, 2006; Orcutt, 2016; Swinerd & McNaught, 2012; Tesfatsion, 2003) may better lend itself to such analysis. AnyLogic software was, in part, chosen for its ability to incorporate agent-based methods into system dynamics models. Combining SD and ACE (Borshchev & Filippov, 2004; Scholl, 2001) is a novel approach which remains little explored. While existing ACE models may help develop what has been termed post-Walrasian macroeconomics, it can be argued that SD models represent a useful intermediate step, being consciously systems oriented, and the natural and intuitive exposition of the structure of micro-meso-macro interactions seems appealing.

7.3.2 Pedagogic insight and history of economic thought
From a pedagogical perspective, small SD simulation models may be regarded as more intuitive than either ACE or standard PK-SFC simulations. The notion of more comprehensively presenting the developing tool of SFC-SD
macroeconomics, particularly at a simple, pedagogic level — operationalising circular flow theorising in an algorithmic, computable form — comports with the agenda for "Rethinking economics" (Fischer et al., 2017) or "Rebuilding macroeconomics" (NIESR, 2018). Research has already indicated potential for this approach (Wheat, 2007). Alongside something like re-purposing the Phillips Machine for the modern age, gaining deeper understanding of the early macroeconomic theorists such as Law and Cantillon in a more appropriate modelling environment opens up an interesting vein of research in the history of economic thought. Simplified narratives and metaphor, enabled by "toy-models", will remain key tools of economists.

7.3.3 Historical and empirical analysis
Adapting the mesoeconomic framework of the models to represent differing socio-institutional frameworks may enable case-studies of historical or contemporary complementary currency systems The Wörgl experiment has taken on mythical status; it may be re-created in the framework to explore research questions such as if the very real reported impacts — including full employment and capital development — during the depression could have been sustained long-term, and what are the limiting factors under such circumstances (particularly in light of the fact that one of the reported effects of the experiment was a significant pre-payment of local taxes). Similarly, the Keynes/Schumacher proposal for an International Clearing Union at Bretton Woods was perhaps the grandest complementary currency scheme ever suggested. The framework is ideal for further exploring this issue, to understand key concepts of sustainability and perhaps complications in the decision-making
criteria of participants. Alternative microeconomic behavioural closure of the model could, for example, borrow from Tobin and Godley & Lavoie's *Model PC (Portfolio Choice)* (2007, p.99ff.) whereby income and return parameters are introduced to the model to allow portfolio choice of other types of competing financial assets. Commercial bank-money is simply a specific form of secondary money that sits alongside national fiat chartalist money. This commercial bank-money is given special privileges by sovereign diktat. Much of the structure of the modern finance system could perhaps be better understood as a complex form of competing CCs, favoured with varying degrees of the prerogative of implicit or explicit State backing. The framework is well-suited for understanding and exploring the inherently socio-institutional aspects of monetary systems. Correct elucidation and wider recognition of these principles could entail profound political and social consequences, as all money systems are ultimately a political choice.

Regional modelling may benefit from combining real input-output analysis with a monetary accounting model. Such an approach for regional analysis has been indicated (Wheat & Pawluczuk, 2014). In this regard, it is important to note that Richard Cantillon and Francois Quesnay’s insights into capital accumulation (which inspired Leontief’s input-output approach) were developed from Law’s model. Modern input-output models being empirically driven, tend to be large, complicated models; they also tend to be static and hence present difficulties in combining with dynamic accounting models. Adapting Cantillon/Quesnaysian PK-SFC-SD models may present a useful platform for both historical investigation and exploration of combining the approaches while being shielded
from the complicating factors of large-scale empirical analysis in a relatively simplified historical model.

7.3.4 **Designing new money and social systems**
Monetary reformers through the years have clearly regarded the money system as facilitating consolidation of ownership. A universal money monoculture may be seen as a reinforcing feedback loop of wealth and power that serves Heilbroner's (1985) argument that capitalism replaces feudalism's power hierarchy with a market hierarchy. Beyond better understanding and elucidation of existing monetary choices, the development of other types of money system may be possible. Further elaboration of the geographic limitations and assumptions about institutional structure of appropriate money systems would be useful research to understand for instance what is the optimal area for an MCC system to operate: should it be a district authority, or county, or larger regional agglomeration? Alongside the three types of CC elaborated in this thesis, there is potential for other types of money system to emerge. For example, the provision of global liquidity by grass-roots created *bottom-up-money* institutionally validated at the level of supra-national institutions such as the IMF or UN (potentially facilitated by blockchain technology), could complement exogenously imposed Special Drawing Rights (SDRs), and be more efficient and equitable way to encourage delivery of SDGs at a global level. The framework offers a way to explore this hypothesis. Additionally, the potential to combine more amorphous social and environment measures in a macroeconomic model, combined with, for example, Hayden's Social Fabric Matrix approach (Hayden, 1982; 2011) opens up various possibilities.
7.4 Concluding comments

Complementary currency systems are complex, context dependent social constructions, representing key information which may help ameliorate the economic problem on a regional basis. They do not represent a panacea, but they may well be regarded as having a potentially profound impact on a favourable rather than a forced deglobalisation. They could help contribute to a resilient and sustainable economic future, alongside and facilitating other potential reforms. A more realistic and pluralist macroeconomics, set within the broader context of systems theory and computable mathematics, appears to be essential for understanding the issues and a fruitful avenue for future research and pedagogy.
Appendix

A.1 Law's Island: "building block" conceptual model

Law's model is argued to have the most relevance and potential, with a credible historical (still relevant) narrative. It is parsimonious in structure and use of assumptions: the kind of a small model extremely useful in elucidating macrodynamics (Turnovsky, 2011). The model developed here is taken directly from Law in his few short pages of outline (Law, 1705, p.182 ff.) and Murphy (1993; 1997), and adapted and extended.

![Diagram of the circular process between landlord, manufacturing workers, and farmers.](image)

**Figure 80.** Murphy's illustration of Law's island, (Murphy, 1993, p.53)

There is a simple circular process between the landlord, manufacturing workers and farmers. This may be regarded as a specific form of the "Wicksell Triangle" of payments; such "payment systems" are the crucial underpinnings of monetary exchange (see Roberds, 2016). The landlord issues tokens equivalent to the value of one year's rent and spends them into the manufacturing economy. The structuring of the SD model is informed by Godley & Lavoie's simplest SFC *Model SIM* (2007, Ch3). The initial model is very primitive, merely to demonstrate the technique and the simplest model possible, while reflecting Law's narrative.
Figure 81.  **Basic circular flow SFD of Law’s island**

The balance sheet matrix is simple illustration of the stocks of the single monetary asset. A transactions flow-matrix reflects the key variables in the model (positive signs show where payment flows accrue, negative signs show from where payment flows are disbursed).

<table>
<thead>
<tr>
<th></th>
<th>Landlord</th>
<th>Manufact’g</th>
<th>Farm</th>
<th>∑</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silver money</td>
<td>$ +S_f $</td>
<td>$ +S_m $</td>
<td>$ +S_f $</td>
<td>$ +S $</td>
</tr>
</tbody>
</table>

**Appendix Table 1.  Balance Sheet Matrix of Law’s Island**

<table>
<thead>
<tr>
<th></th>
<th>Landlord</th>
<th>Manufact’g</th>
<th>Farm</th>
<th>∑</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mfg goods</td>
<td>$ -M $</td>
<td>$ +M $</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Food</td>
<td></td>
<td>$ -F $</td>
<td>$ +F $</td>
<td>0</td>
</tr>
<tr>
<td>Rent</td>
<td>$ +R $</td>
<td></td>
<td>$ -R $</td>
<td>0</td>
</tr>
<tr>
<td>Chg in stock of silver</td>
<td>$ +ΔS $</td>
<td>$ -ΔS $</td>
<td>$ -ΔS $</td>
<td>0</td>
</tr>
<tr>
<td><strong>∑</strong></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Appendix Table 2.  Accounting (transactions) Matrix of Law’s Island**

- $R$ - spending on rent
- $M$ - spending on manufactured goods
- $F$ - spending on food
The matrix shows an assumption that the landlord accumulates and the other two sectors decumulate (by accounting constraint, at least one sector must balance the others). Combining system dynamics with SFC modelling, it is useful to highlight the causality of the flows by appending SD iconography, demonstrating the shared properties of SFC and SD modelling:

<table>
<thead>
<tr>
<th></th>
<th>Landlord</th>
<th>Manufact’g</th>
<th>Farm</th>
<th>∑</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mfg goods</td>
<td>-M_l</td>
<td>+M_m</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Food</td>
<td>-F_m</td>
<td>+F_f</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rent</td>
<td>+R_l</td>
<td>-R_f</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Chg in stock of silver</td>
<td>+ΔS</td>
<td>-ΔS</td>
<td>-ΔS</td>
<td>0</td>
</tr>
<tr>
<td>∑</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Figure 82. Combined SFC-SD matrix of Law's Island**

Figure 82 represents the following behaviours:

- $M_l$ — Landlord instigates demand for manufactured goods
- $M_m$ — Manufacturers’ revenues for supplying manufactured goods
- $F_m$ — Manufacturers instigate payment for food
- $F_f$ — Farmers' revenues for supplying food
- $R_f$ — Farmers make rent payments
- $R_l$ — Landlord's demand rental payments
### Endogenous | Exogenous | Excluded
--- | --- | ---
Income | Silver stock | Supply side
Distribution of silver (wealth) | Price level / wages | Overseas sector
Employment | Target wealth / income ratios (propensities to consume) | Profits
Wealth/income ratios | | Paper money

**Appendix Table 3. Boundary Table interpreting Law's island model**

#### A.1.1 Model Equations: Law's Island

Parameter: RentDemandPolicy

| Value | 720 / year |

Description: Law's narrative implies annual rent of 720, denominated in a numéraire he refers to as "number", #.

Stock: LandLordSilver

| Formula | $d(\text{LandLordSilver})/dt = \text{FarmRent} - \text{LandLordDemand}$ |

| Initial value | 720 |

Stock: MfgSilver

| Formula | $d(\text{MfgSilver})/dt = \text{LandLordDemand} - \text{MfgFoodDemand}$ |

| Initial value | 0 |

Stock: FarmerSilver

| Formula | $d(\text{FarmerSilver})/dt = \text{MfgFoodDemand} - \text{FarmRent}$ |

| Initial value | 0 |

Flow: LandLordDemand

| Formula | LandLordDemandPolicy |

Flow: MfgFoodDemand

| Formula | MfgDemandPolicy |

Flow: FarmRent

| Formula | RentDemandPolicy |

Dynamic Variable: LandLordDemandPolicy

| Formula | RentDemandPolicy |

Dynamic Variable: MfgDemandPolicy

| Formula | LandLordDemand |
A.1.2 Law's Island model limitations
While demonstrating structure and causality, the model is currently "timeless". While it offers a computed solution "equilibrium", the immediacy implied within a barter model is not possible in the real world: something performing the role of money is essential. There is no credit (debt). In orthodox language, money implicitly enters the utility function, and cash-in-advance becomes a simple requirement for the model to work. Silver in this model is a closed circuit: a conserved flow of a fixed amount of silver circulating. The model needs to have time.
A.2 Law’s Island 2

Law’s key argument was that silver had flowed out of Scotland, leaving the country reduced to a state of barter. The model needs a plausible way to represent decumulations of silver. Overseas investment acts as a sink; it might potentially be a source (this was the mercantilists’ obsession with bullion for trade) but this is abstracted from the model. Adding plausible delays adds time to the model. The overseas policy is simple at this point, merely to demonstrate that silver can drain from the island (reducing the money supply), based on the misfortune of the landlord.

Figure 84. Expanded SFD with silver drain in Law’s Island 2

Updating the matrices notes that the total stock of silver can increase/decrease through overseas transactions (the overseas sector is beyond the model boundary).
Appendix

<table>
<thead>
<tr>
<th></th>
<th>Landlord</th>
<th>Manufact’g</th>
<th>Farm</th>
<th>$\sum$</th>
<th>Additions or subtractions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silver money</td>
<td>+$S_t$</td>
<td>+$S_w$</td>
<td>+$S_f$</td>
<td>+$S_t$</td>
<td>Overseas trade and investment</td>
</tr>
</tbody>
</table>

Appendix Table 4. Expanded balance sheet of Law’s Island 2 indicating overseas drain

<table>
<thead>
<tr>
<th></th>
<th>Landlord</th>
<th>Manufact’g</th>
<th>Farm</th>
<th>$\sum$</th>
<th>Overseas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mfg goods</td>
<td>-$M$</td>
<td>+$M$</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Food</td>
<td>+$R$</td>
<td>-$R$</td>
<td>+$F$</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Rent</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Overseas investment - $OI$</td>
</tr>
<tr>
<td>Chg in stock of silver</td>
<td>-$\Delta S$</td>
<td>-$\Delta S$</td>
<td>-$\Delta S$</td>
<td>0</td>
<td>+$\Delta S$</td>
</tr>
<tr>
<td>$\sum$</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-$OI$</td>
<td>+$S$</td>
</tr>
</tbody>
</table>

Appendix Table 5. Expanded transactions matrix of Law’s Island 2 including overseas drain

A.2.1 Model Equations: Law’s Island 2

Parameter: RentalDemandPolicy
Value 720 / year
Description Annual rent.

Parameter: RentalTiming
Value 1
Description Timing of annual rent demand; 1 = annualised continuous flow. Potential to be set to quarterly to create artificial dynamic.

Stock: LandLordSilver
Formula $d(LandLordSilver)/dt = FarmRent - OverseasSpend - LandLordDemand$
Initial value 720
Description Stock of landlord's silver holdings.

Stock: MfgSilver
Formula $d(MfgSilver)/dt = LandLordDemand - MfgFoodDemand$
Initial value 0
Description Stock of manufacturers' silver holdings.

Stock: FarmerSilver
Formula $d(FarmerSilver)/dt = MfgFoodDemand - FarmRent$
Initial value 0
Description Stock of farmers' silver holdings.

Flow: LandLordDemand
Formula: limitMax(LandLordDemandPolicy, LLMaxDSpend)
Description: Flow of payments from landlord to manufacturers, controlled by silver holdings.

Flow: MfgFoodDemand
Formula: limitMax(MfgDemandPolicy, MfgMaxSpend)
Description: Flow of payments from manufacturers to farmers, controlled by silver holdings.

Flow: FarmRent
Formula: limitMax(FarmPayRentPolicy, FarmMaxSpend)
Description: Controlled flow of rental payments from farmers to landlord.

Flow: OverseasSpend
Formula: limitMax(OverseasInvestmentLoss, LLMaxOseasSpend)
Description: Controlled flow of overseas flow of silver.

Dynamic Variable: LLMaxDSpend
Formula: LandLordSilver / 0.01923
Description: First order control on landlord consumption spending, ensuring minimum holding approx. 1 week's supply.

Dynamic Variable: LLMaxOseasSpend
Formula: LandLordSilver / 0.01923
Description: First order control on overseas silver drain, ensuring minimum holding approx. 1 week's supply.

Dynamic Variable: MfgMaxSpend
Formula: MfgSilver / 0.01923
Description: First order control on manufacturer spending.

Dynamic Variable: FarmMaxSpend
Formula: FarmerSilver / 0.01923
Description: First order control on farmers' rent payments.

Dynamic Variable: FarmPayRentPolicy
Formula: RentalDemandPolicy * RentalTiming
Description: The annual rent demanded of farmers.

Dynamic Variable: LandLordDemandPolicy
Formula: RentalDemandPolicy
Description: Annual landlord expenditure.

Dynamic Variable: MfgDemandPolicy
Formula: delay(LandLordDemand, MfgDelayParameter)
Description: Manufacturer spending delayed by parameter.

Parameter: MfgDelayParameter
Value: 0.08333
Description: 1-month delay = 0.08333
Dynamic Variable: OverseasInvestmentLoss
Formula step(700,5)
Description Exogenous variable driving silver flow drain in year 5

A.2.2 Law's Island 2 comment and simulation
A silver drain (of #700) hits in year five. Unless the manufacturing and farm sectors have been endowed with initial stocks of silver, economic activity breaks down: the creation of a silver drain combined with a cash-in-advance constraint and the contractual nature of rent leads to a sharp drop in demand. Implicitly, there is an accumulation of rent arrears farmers owe the landlord. It is useful to add a rent arrears submodel. Rent arrears approach #3000 by end of year 10.
Figure 85. Simulation of Law 2 with silver drain of #700 in year 5

A.2.3 Equation of rent arrears submodel

Flow: RentDemanded
Formula: FarmPayRentPolicy
Description: Annual rent demanded.

Stock: CumRentDemanded
Formula: \( \frac{d(CumRentDemanded)}{dt} = RentDemanded \)
Initial value: 0
Description: Cumulative rent demanded.
Appendix

Flow: RentPaid
Formula FarmRent
Description Annualised flow of rental payments.

Stock: CumRentPaid
Formula \( \frac{d(CumRentPaid)}{dt} = RentPaid \)
Initial value 0
Description Cumulative rent paid

Dynamic Variable: RentArrears
Formula CumRentDemanded - CumRentPaid
Description Cumulative rent arrears.

Figure 86. SFD of Rent arrears submodel in Law 2

Figure 87. Accumulated rent arrears in Law 2
A.3 Model: John Law Augmented Circular Flow

While maintaining separate farm and manufacturing sectors, a household sector is added. The household sector represents workers who are paid to work and demand food based on their income. Additionally, it is appropriate to expand the detail of each sector with more plausible behaviour. The updated model structure is presented in a sub-system diagram, a balance sheet, and accounting matrix.

![Sub-system diagram of Circular Flow](image)

**Figure 88.** Sub-system diagram of Circular Flow

<table>
<thead>
<tr>
<th>Silver money</th>
<th>Landlord</th>
<th>Manufact’g</th>
<th>Household</th>
<th>Farm</th>
<th>( \Sigma )</th>
<th>Additions or subtractions</th>
</tr>
</thead>
<tbody>
<tr>
<td>+( S_l )</td>
<td>+( S_m )</td>
<td>+( S_h )</td>
<td>+( S_f )</td>
<td>+( S_r )</td>
<td>+( S_i )</td>
<td>Overseas trade and investment</td>
</tr>
</tbody>
</table>

**Figure 89.** Balance sheet matrix of Circular Flow

<table>
<thead>
<tr>
<th></th>
<th>Landlord</th>
<th>Manufact’g</th>
<th>Household</th>
<th>Farm</th>
<th>( \Sigma )</th>
<th>Overseas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mfg goods</td>
<td>-M</td>
<td>+M</td>
<td></td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Wages</td>
<td>-W</td>
<td>+W</td>
<td></td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Food</td>
<td>-F</td>
<td>+F</td>
<td></td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Rent</td>
<td>+R</td>
<td>-R</td>
<td></td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Overseas investment</td>
<td>-OI</td>
<td></td>
<td>-OI</td>
<td>+OI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chg in stock of silver</td>
<td>-( \Delta S )</td>
<td>-( \Delta S )</td>
<td>-( \Delta S )</td>
<td>-( \Delta S )</td>
<td>0</td>
<td>+( \Delta S )</td>
</tr>
</tbody>
</table>

**Appendix Table 6.** Accounting matrix of Traditional Circular Flow

| \( \Sigma \) | 0 | 0 | 0 | 0 | -OI | +S |
A.3.1 High level conceptual map

A high-level conceptual map of the model is illustrated, broadly indicating each sector's behavioural policy, and the money-flow connecting each sector:

Figure 90. High-level conceptual map of Circular Flow
A.3.2 Landlord Policy

Rents are payable at an exogenously defined rate, in an exogenously defined manner; a minimum target level of silver wealth is defined as an exogenously given ratio of normal income (i.e., annual rent); perceived wealth shortfall is a smoothed function of actual wealth shortfall; the exogenously given adjustment time defines the rate of saving and spending; spending is subject to fluctuations in actual income received, with demand being based on expected income, defined as a smoothed function of actual income.
A.3.3 Manufacturer Policy

There is a given target level of wealth-to-income, with a given adjustment time. Nominal demand for labour is not allowed to be greater than demand for products (i.e., the manufactures' income), hence the manufacturer may hold silver which it will not spend employing labour if there is no demand from the landlord. Income not accumulated is spent employing workers with an assumed supply-side response. A smoothing delay is added to account for income expectations.
A.3.4 Household Policy

Figure 93. Household policy

Household income is determined externally to the sector and perceived with a smoothing delay; a target wealth-to-income ratio is given with a time to achieve this target, creating savings. Demand for food is defined as income less savings with any "excess" wealth spent.

A.3.5 Farmer Policy

Figure 94. Farmer policy
The farm sector has little agency other than to decide what target level of wealth is desired (and in what time-frame): income is determined outside the sector, and outgoings are primarily determined outside the sector. Rental payments are demanded and the farm sector is expected to pay if silver is available. Several conditional statements have to be applied relating to the cash-in-advance constraint and both implicit and explicit decisions relating to it: rent-payments cannot be negative; a first-order control loop ensures silver holdings cannot go to zero, but in doing so rent payments cannot be made when silver holdings reach a critical level; over-payment of rent is precluded (if the farm sector has excess silver, farmers have no other outlet for spending); farmers reduce payments when below their target wealth level.

**A.3.6 Model equations: John Law Augmented Circular Flow Model**

Where equations are repeated or self-explanatory, descriptions are omitted.

Parameter: AnnualRent
Value 720 / year

Parameter: OverseasInvestmentLoss
Value 0
Details: subject to shock, step(700, 5)

Parameter: HHSilverInitVal
Value 60

Parameter: LLSilverInitVal
Value 720

Parameter: MfgSilverInitVal
Value 65

Parameter: FarmSilverInitVal
Value 125

Parameter: LLTargetWealthRatio
Value 1
Parameter: LL_AT
Value 2.5
Description Landlord AdjustTime, implies a rate of accumulation of savings targeting to close 63% of the wealth-gap in one AT, and 98% in four ATs.

Parameter: LLWealthPercDelay
Value 0.5
Description Six months.

Parameter: LLRentExpDelay
Value 0.25
Description One quarter.

Parameter: FarmerTargetWealthRatio
Value 12
Description 1 month's rent

Parameter: Farmer_AT
Value 2.5

Parameter: FarmDelayFactor
Value 0.25

Parameter: MfgTargetWealthRatio
Value 0.08333
Description 1 month = 0.08333

Parameter: Mfg_AT
Value 2.5
Description Adjustment time = 2.5 years.

Parameter: MfgDelayFactor
Value 0.25

Parameter: HHTargetWealthRatio
Value 0.08333
Description Targeting 1-month expected income as wealth.

Parameter: HH_AT
Value 2.5

Parameter: HHDelayFactor
Value 0.25

Stock: LandLordSilver
Formula \( d(\text{LandLordSilver})/dt = \text{FarmRent} - \text{OverseasDrain} - \text{LandLordDemand} \)
Initial value 720

Stock: MfgSilver
Appendix

Formula \[ \frac{d(MfgSilver)}{dt} = \text{LandLordDemand} - \text{MfgWages} \]
Initial value \(65\)

Stock: HouseHoldSilver
Formula \[ \frac{d(HouseHoldSilver)}{dt} = \text{MfgWages} - \text{HHFoodPayment} \]
Initial value \(65\)

Stock: FarmerSilver
Formula \[ \frac{d(FarmerSilver)}{dt} = \text{HHFoodPayment} - \text{FarmRent} \]
Initial value \(150\)

Flow: LandLordDemand
Formula \[ \text{limitMax}(\text{LandLordDemandPolicy}, \text{LLMaxDSpend}) \]

Flow: MfgWages
Formula \[ \text{limitMax}(\text{NominalMfgDemand}, \text{MfgMaxSpend}) \]

Flow: HHFoodPayment
Formula \[ \text{limitMax}(\text{HHFoodDemand}, \text{HHMaxSpend}) \]

Flow: FarmRent
Formula \[ \text{limitMax}(\text{FarmRentPayment}, \text{FarmMaxSpend}) \]

Dynamic Variable: LLMaxDSpend
Formula \(\frac{\text{LandLordSilver}}{0.0192}\)

Dynamic Variable: MfgMaxSpend
Formula \(\frac{\text{MfgSilver}}{0.0192}\)

Dynamic Variable: HHMaxSpend
Formula \(\frac{\text{HouseHoldSilver}}{0.0192}\)

Dynamic Variable: FarmMaxSpend
Formula \(\frac{\text{FarmerSilver}}{0.0192}\)

Dynamic Variable: RentDemandPolicy
Formula \((\text{AnnualRent} \times \text{RentalTiming})\)

Dynamic Variable: LLTargetWealth
Formula \(\text{AnnualRent} \times \text{LLTargetWealthRatio}\)

Dynamic Variable: LLWealthShortfall
Formula \(\text{LLTargetWealth} - \text{LandLordSilver}\)

Dynamic Variable: LLPerceivedWealthShortfall
Formula \(\text{smooth3}(\text{LLWealthShortfall}, \text{LLWealthPercDelay})\)
Description: Third-order smoothing of wealth shortfall, with a perceived delay.

Dynamic Variable: LLSaving
Formula \(\frac{\text{LLPerceivedWealthShortfall}}{\text{AdjustmentTime_AT}}\)
Description: Saving is a function of perceived wealth shortfall, with a given adjusted time.

Dynamic Variable: LandLordDemandPolicy
Formula: limitMin(0, (IncomeExpectation - LLSaving))
Description: Landlord demand is equal to expected income less saving with a minimum of zero.

Dynamic Variable: IncomeExpectation
Formula: smooth3(FarmRent, ExpectationDelay)

Flow: OverseasDrain
Formula: limitMax(OverseasInvestmentLoss, LLMaxOseasSpend)

Dynamic Variable: LLMaxOseasSpend
Formula: LandLordSilver / 0.01923

Dynamic Variable: FarmerTargetWealth
Formula: AnnualRent / FarmerTargetWealthRatio

Dynamic Variable: FarmerWealthShortfall
Formula: FarmerTargetWealth - FarmerSilver

Dynamic Variable: FarmerSaving
Formula: FarmerWealthShortfall / Farmer_AT

Dynamic Variable: FarmRentPayment
Formula: min((RentDemanded - FarmerSaving), RentDemanded)
Description: Adjusts rent demand for saving and stops rent overpayment if negative saving is targeted.

Dynamic Variable: FarmerIncome
Formula: HHFoodPayment

Dynamic Variable: FarmIncome_exp
Formula: smooth(FarmerIncome, FarmDelayFactor)

Dynamic Variable: MfgTargetWealth
Formula: MfgIncome_exp * MfgTargetWealthRatio
Description: Target to keep one month’s income (0.0833 times annualised flow) in silver.

Dynamic Variable: MfgWealthShortfall
Formula: max ((MfgTargetWealth - MfgSilver), 0)
Description: Cannot go negative. The manufacturing sector may accumulate silver if there is no demand for production.

Dynamic Variable: MfgSaving
Formula: MfgWealthShortfall / Mfg_AT
Dynamic Variable: NominalMfgDemand  
Formula \( MfgIncome\_exp - Mfg\text{Saving} \)

Dynamic Variable: MfgIncome\_exp  
Formula \( \text{smooth}(MfgIncome, MfgDelayFactor) \)  
Description First-order smoothed perception delay for income.

Dynamic Variable: MfgIncome  
Formula \( \text{LandLordDemand} \)

Dynamic Variable: LabourIncome\_exp  
Formula \( \text{smooth}(LabourIncome, HH\text{DelayFactor}) \)

Dynamic Variable: HHFoodDemand  
Formula \( \text{LabourIncome}\_exp - \text{HHSaving} \)  
Description Food demand is total household expenditure. It expected income minus saving.

Dynamic Variable: HHTargetWealth  
Formula \( \text{LabourIncome}\_exp \times \text{HHTargetWealthRatio} \)

Dynamic Variable: HHWealthShortfall  
Formula \( \text{HHTargetWealth} - \text{HouseHoldSilver} \)

Dynamic Variable: HHSaving  
Formula \( \text{HHWealthShortfall} / \text{HH\_AT} \)

Dynamic Variable: LabourIncome  
Formula \( \text{MfgWages} \)

**Rent submodel**

Stock: CumRentDemanded  
Formula \( \frac{d(\text{CumRentDemanded})}{dt} = \text{RentDemanded} \)  
Initial value 0

Dynamic Variable: RentArrears  
Formula \( \text{CumRentDemanded} - \text{CumRentPaid} \)

Stock: CumRentPaid  
Formula \( \frac{d(\text{CumRentPaid})}{dt} = \text{RentPaid} \)  
Initial value 0

Flow: RentPaid  
Formula \( \text{FarmRent} \)

Flow: RentDemanded  
Formula \( \text{RentDemandPolicy} \)

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A.3.7 Comment and simulation

Delays in the system imply demand for money stocks. This requires stocks of silver to be distributed as initial parameter values: parameters are given which allow the model to settle in steady state. The increased complexity in terms of demands for savings and delays means the simulation may demonstrate different paths according to both the quantity of silver initially in the system, and the allocation of silver wealth among the sectors. The rent demanded and the landlord's spending are key determinants of overall economic activity. Because the value of rent is determined by the product of the land, it represents a form of nominal anchor (in terms of inflation).

In year 5, a shock hits the system of the landlord's investment losses, hence the landlord's spending decreases sharply. Reverberations on the circular flow are spread through the system, with lower wage payments, lower household demand for food, and a fall in farm income; this means farmers are forced to run-down silver holdings and eventually default on rent payment, thus accruing arrears. The landlord receives less silver income, further cutting spending (a reinforcing feedback loop) in an attempt to restore silver wealth. The emergence of informal credit relationships is notable in what may be considered a "cash" economy.\(^5\) In this model the landlord does not consider rent owed as wealth. Eventually the landlord accrues the vast majority of the silver and the other sectors are left "penniless".

Law’s essential narrative — the *Law Doctrine* — which underpins most later underconsumptionist theory from Owen and Proudhon to Hobson and Keynes, is that the quantity of money matters, hence the island economy needs paper money spent into circulation by the landlord. The classical critique is that money is neutral and that prices should merely flex downward to adjust for a lower quantity of money in circulation. In a second simulation a sense of continuity may be temporarily restored by endogenising the price of rent (the only numéraire in the system) to the quantity of silver in the economy by inducing a price cut in rent from 720 to 360 in year 6. Temporary relief is created, and rent
Appendix

Arrears are smaller. Because the landlord's income is cut, spending is also reduced: this is a demonstration of the emergent property known as the "Paradox of Thrift".

Figure 97. Simulation 2 of Augment Circular Flow (with rent reduction in year 6)

Figure 98. Distribution of money in simulation 2
A.4 Adding Secondary Money

The augmented circular flow model is developed by the introduction of a secondary monetary circuit; this complements the silver circuit which runs dry.

![Simplified SFD of dual monetary circuits Secondary Money model](image)

**Figure 99.** Simplified SFD of dual monetary circuits Secondary Money model

The token circuit is theoretically infinitely expandable because token creation is endogenous as a policy of the landlord. The token money flow is therefore alternatively represented as an open circuit with a defined source and a sink.
Illustrating conservation principle of monetary stock-flow models

This representation helps emphasise the distinction between *exogenous* (outside) and *endogenous* (inside) money. The accounting of the landlord's token deficit needs to be represented separately. A graphical representation of the quadruple-entry book-keeping seen in PK-SFC modelling, albeit with more explicit reference to the sources and sinks of money creation and destruction.\(^6\)

Although there are two separate monetary circuits, because of the interrelated nature of the decisions, it is necessary to nest the decision points into overall policies for each agent/sector. This is a form of Tobin's (1969) general equilibrium problem for two competing financial assets. Each of the other three sectors similarly have two interrelated decisions to make and will have a policy encompassing these. The balance sheet matrix now shows all sectors with two types of money-information markers: silver is an *exogenous* money; token money is a form of *endogenous* money created by the landlord deficit spending ("emitting liabilities" or issuing IOUs).

---

\(^6\) The need for quadruple-entry bookkeeping in social accounting was first noted by Copeland Copeland, M. A. (1949) 'Social Accounting for Moneyflows'. *Accounting Review*, 24 (3). pp 254. (see Godley & Lavoie (2007, p.47ff)).
Appendix Table 7. Dual circuit balance sheet matrix

Each transaction should be represented as a distinct row according to whether the payment is in silver or tokens to emphasize that tokens and silver are in separate circuits. This begins to make the transactions matrix quite unwieldy; arguably the matrix now gives less clarity than the SFD:

<table>
<thead>
<tr>
<th></th>
<th>Landlord</th>
<th>Manufact’g</th>
<th>Household</th>
<th>Farm</th>
<th>∑</th>
<th>Overseas trade and investment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silver money</td>
<td>+S_l</td>
<td>+S_m</td>
<td>+S_h</td>
<td>+S_f</td>
<td>+S_l</td>
<td></td>
</tr>
<tr>
<td>Token money</td>
<td>-T_l</td>
<td>+T_m</td>
<td>+T_h</td>
<td>+T_f</td>
<td>0</td>
<td>Landlord deficit spending</td>
</tr>
</tbody>
</table>

Appendix Table 8. Expanded dual circuit transactions flow matrix

<table>
<thead>
<tr>
<th></th>
<th>Landlord</th>
<th>Manufact’g</th>
<th>Household</th>
<th>Farm</th>
<th>∑</th>
<th>Overseas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mfg goods (silver)</td>
<td>-M^s</td>
<td>+M^s</td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Wages (silver)</td>
<td></td>
<td>-W^s</td>
<td>+W^s</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Food (silver)</td>
<td></td>
<td>-F^s</td>
<td>+F^s</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Rent (silver)</td>
<td></td>
<td>+R^s</td>
<td>-R^s</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Mfg goods (tokens)</td>
<td>-M^t</td>
<td>+M^t</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wage (tokens)</td>
<td></td>
<td>-W^t</td>
<td>+W^t</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food (tokens)</td>
<td></td>
<td>-F^t</td>
<td>+F^t</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rent (tokens)</td>
<td></td>
<td>+R^t</td>
<td>-R^t</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overseas investment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-O^f + O^f</td>
</tr>
<tr>
<td>Chg in stock of silver</td>
<td>-ΔS</td>
<td>-ΔS</td>
<td>-ΔS</td>
<td>-ΔS</td>
<td>0</td>
<td>+ΔS</td>
</tr>
<tr>
<td>Chg in stock of tokens</td>
<td>+ΔT</td>
<td>-ΔT</td>
<td>-ΔT</td>
<td>-ΔT</td>
<td>0</td>
<td>-O^t + S</td>
</tr>
<tr>
<td>∑</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-O^t + S</td>
</tr>
</tbody>
</table>
A.4.1 Landlord dual-currency policy

Figure 101. Landlord policy in dual circuit

The landlord is the nexus of the fiat token circuit as an initiating decision has to be taken to spend tokens into circulation. The landlord has an anchored expectation about what normal income and expenditure is: #720 annual rent and #720 expenditure. When silver drains, the landlord coins and spends tokens.

A.4.2 Manufacturing dual-currency policy

Figure 102. Manufacturer policy in dual circuit
Manufacturers receive silver and tokens from the landlord. They pay wages in silver and tokens. There is an assumed preference to hoard silver rather than tokens: any tokens received as payment are paid out. Payment in silver is checked against preferred levels of savings, and if savings targets are being achieved, the rest of the silver is paid out as wages.

### A.4.3 Household dual-currency policy

![Household Policy Diagram](image)

**Figure 103. Household policy in dual circuit**

Households have an implicit preference for holding silver and spend (with a short perception delay) any income received in tokens. As long as wealth targets are being met, spending in silver will also occur to account for any shortfall in token demand.
A.4.4 Farmer dual-currency policy

The payment of rent is dictated not by income but by the contractual demand of the landlord. If tokens are available then rent is paid in tokens, otherwise, subject to the desire to accumulate wealth (now measured in silver and tokens), the rent is paid in silver.

A.4.5 Model equations: John Law Secondary Money

Parameter: AnnualRent  
Value 720 / year

Parameter: InvestmentLoss  
Value 0  
Description Used to shock: step(700,5)

Parameter: RentalTiming  
Value 1

Parameter: HHSilverInitVal  
Value 60

Parameter: LLSilverInitVal  
Value 720
Parameter: MfgSilverInitVal
Value 65

Parameter: FarmSilverInitVal
Value 125

Parameter: LLTargetWealthRatio
Value 1

Parameter: LL_AT
Value 2.5

Parameter: LLRentExpDelay
Value 0.25

Parameter: LLWealthPercDelay
Value 0.5

Parameter: FarmerTargetWealthRatio
Value 12

Parameter: Farmer_AT
Value 2.5

Parameter: MfgDelayFactor
Value 0.5

Parameter: MfgTargetWealthRatio
Value 0.0833

Parameter: Mfg_AT
Value 2.5

Parameter: HHDelayFactor
Value 0.5

Parameter: HHTargetWealthRatio
Value 0.0833

Parameter: HH_AT
Value 2.5

Stock: LandLordSilver
Formula \( \frac{d(LandLordSilver)}{dt} = \text{FarmRentSilver} - \text{OverseasDrain} - \text{LandLordSilverDemand} \)

Stock: MfgSilver
Formula \( \frac{d(MfgSilver)}{dt} = \text{LandLordSilverDemand} - \text{MfgWagesSilver} \)
Stock: HouseHoldSilver
Formula \( \frac{d(\text{HouseHoldSilver})}{dt} = \text{MfgWagesSilver} - \text{HHFoodPayment} \)

Stock: FarmerSilver
Formula \( \frac{d(\text{FarmerSilver})}{dt} = \text{HHFoodPayment} - \text{FarmRentSilver} \)

Flow: LandLordSilverDemand
Formula \( \text{limitMax} (\text{LandLordDemandPolicy}, \text{LLMaxDSilvSpend}) \)

Flow: MfgWagesSilver
Formula \( \text{limitMax} (\text{MfgDemandSilver}, \text{MfgMaxSilvSpend}) \)

Flow: HHFoodPayment
Formula \( \text{limitMax} (\text{HHDemandSilver}, \text{HHMaxSilvSpend}) \)

Flow: FarmRentSilver
Formula \( \text{limitMax} (\text{FarmRentSilverPayment}, \text{FarmMaxSilvSpend}) \)

Dynamic Variable: LLMaxDSilvSpend
Formula \( \frac{\text{LandLordSilver}}{0.0192} \)

Dynamic Variable: MfgMaxSilvSpend
Formula \( \frac{\text{MfgSilver}}{0.0192} \)

Dynamic Variable: HHMaxSilvSpend
Formula \( \frac{\text{HouseHoldSilver}}{0.0192} \)

Dynamic Variable: FarmMaxSilvSpend
Formula \( \frac{\text{FarmerSilver}}{0.0192} \)

Stock: MfgToken
Formula \( \frac{d(\text{MfgToken})}{dt} = \text{LandLordDemandToken} - \text{MfgWagesToken} \)
Initial value 0

Stock: HouseholdToken
Formula \( \frac{d(\text{HouseholdToken})}{dt} = \text{MfgWagesToken} - \text{HouseholdFoodDemandToken} \)
Initial value 0

Stock: FarmToken
Formula \( \frac{d(\text{FarmToken})}{dt} = \text{HouseholdFoodDemandToken} - \text{FarmRentToken} \)
Initial value 0

Flow: CreationOfToken
Formula \( \text{LandLordDemandToken} \)

Stock: TokensCreated
Formula \( \frac{d(\text{TokensCreated})}{dt} = \text{CreationOfTokens} \)
Initial value 0
Flow: DestructionOfToken
Formula FarmRentToken

Stock: TokensDestroyed
Formula \( \frac{d(\text{TokensDestroyed})}{dt} = \text{DestructionOfTokens} \)
Initial value 0

Flow: LandLordDemandToken
Formula LandLordTokenDemandPolicy

Flow: MfgWagesToken
Formula limitMax(MfgDemandToken, MfgMaxTokenSpend)

Flow: HouseholdFoodDemandToken
Formula limitMax(HholdTokenDemand, HHMaxTokenSpend)

Flow: FarmRentToken
Formula limitMax(FarmTokenRentPayment, FarmMaxTokenSpend)

Dynamic Variable: MfgMaxTokenSpend
Formula MfgToken / 0.01923

Dynamic Variable: HHMaxTokenSpend
Formula HouseholdToken / 0.01923

Dynamic Variable: FarmMaxTokenSpend
Formula FarmToken / 0.01923

Dynamic Variable: RentDemandPolicy
Formula (AnnualRent * RentalTiming)
Description Can add RentArrears if necessary

Dynamic Variable: LLTargetWealth
Formula AnnualRent * LLTargetWealthRatio

Dynamic Variable: LLWealthShortfall
Formula LLTargetWealth - LandLordWealth

Dynamic Variable: LandLordWealth
Formula LandLordSilver - LandLordTokenLiability + RentArrears
Description RentArrears accrue as perceived landlord wealth.

Dynamic Variable: LLPPerceivedWealthShortfall
Formula smooth3(LLWealthShortfall, LLWealthPercDelay)

Dynamic Variable: LLSaving
Formula LLPPerceivedWealthShortfall / LL_AT

Dynamic Variable: LandLordDemandPolicy

Formula \[ \text{limitMin}(0, (L\text{LIncome} - \text{LLSaving})) \]

**Dynamic Variable: LandLordTokenDemandPolicy**
Formula \[ \text{AnnualRent} - \text{LandLordSilverDemand} \]

**Dynamic Variable: L\text{LIncome}**
Formula \[ \text{FarmRentSilver} + \text{FarmRentToken} \]

**Dynamic Variable: L\text{LIncome}_\text{exp}**
Formula \[ \text{smooth3}(\text{L\text{LIncome}}, \text{LLRentExpDelay}) \]

**Dynamic Variable: LandLordTokenLiability**
Formula \[ \text{TokensCreated} - \text{TokensDestroyed} \]

**Dynamic Variable: FarmerTargetWealth**
Formula \[ \frac{\text{AnnualRent}}{\text{FarmerTargetWealthRatio}} \]

**Dynamic Variable: FarmerWealth**
Formula \[ \text{FarmerSilver} + \text{FarmToken} \]

**Dynamic Variable: FarmerWealthShortfall**
Formula \[ \text{FarmerTargetWealth} - \text{FarmerWealth} \]

**Dynamic Variable: FarmerSaving**
Formula \[ \frac{\text{FarmerWealthShortfall}}{\text{Farmer_AT}} \]

**Dynamic Variable: FarmRentPayment**
Formula \[ \text{min}((\text{RentDemanded} - \text{FarmerSaving}), \text{RentDemanded}) \]

**Dynamic Variable: FarmTokenRentPayment**
Formula \[ \text{min}(\text{FarmToken}, \text{RentDemanded}) \]

**Dynamic Variable: FarmRentSilverPayment**
Formula \[ \text{FarmRentPayment} - \text{FarmRentToken} \]

**Dynamic Variable: FarmerIncome**
Formula \[ \text{HHFoodPayment} + \text{HouseholdFoodDemandToken} \]

**Dynamic Variable: M\text{fgIncome}**
Formula \[ \text{LandLordSilverDemand} + \text{LandLordDemandToken} \]

**Dynamic Variable: M\text{fgIncome}_\text{exp}**
Formula \[ \text{smooth3}(\text{M\text{fgIncome}}, \text{MfgDelayFactor}) \]

**Dynamic Variable: M\text{fgTargetWealth}**
Formula \[ \text{M\text{fgIncome}_\text{exp}} \times \text{MfgTargetWealthRatio} \]

**Dynamic Variable: M\text{fgWealthShortfall}**
Formula \[ \text{MfgTargetWealth} - \text{MfgWealth} \]
Dynamic Variable: MfgWealth
Formula \( \text{MfgSilver} + \text{MfgToken} \)

Dynamic Variable: MfgSaving
Formula \( \frac{\text{MfgWealthShortfall}}{\text{Mfg_AT}} \)

Dynamic Variable: NominalMfgDemand
Formula \( \min((\text{MfgIncome}_{\text{exp}} - \text{MfgSaving}), \text{MfgIncome}_{\text{exp}}) \)

Dynamic Variable: MfgDemandSilver
Formula \( \text{NominalMfgDemand} - \text{MfgWagesToken} \)

Dynamic Variable: MfgDemandToken
Formula \( \text{smooth3}(\text{LandLordDemandToken}, \text{MfgDelayFactor}) \)
Description Smoothed (delayed) demand just reflecting landlord demand in tokens.

Dynamic Variable: LabourIncome
Formula \( \text{MfgWagesSilver} + \text{MfgWagesToken} \)

Dynamic Variable: LabourIncome_{\text{exp}}
Formula \( \text{smooth3}(\text{LabourIncome}, \text{HHDelayFactor}) \)

Dynamic Variable: HHTargetWealth
Formula \( \text{LabourIncome}_{\text{exp}} \times \text{HHTargetWealthRatio} \)

Dynamic Variable: HHWealthShortfall
Formula \( \text{HHTargetWealth} - \text{HHWealth} \)

Dynamic Variable: HHWealth
Formula \( \text{HouseHoldSilver} + \text{HouseholdToken} \)

Dynamic Variable: HHSaving
Formula \( \frac{\text{HHWealthShortfall}}{\text{HH_AT}} \)

Dynamic Variable: HHFoodDemand
Formula \( \min((\text{LabourIncome}_{\text{exp}} - \text{HHSaving}), \text{LabourIncome}_{\text{exp}}) \)

Dynamic Variable: HholdTokenDemand
Formula \( \text{smooth3}(\text{MfgWagesToken}, \text{HHDelayFactor}) \)

Dynamic Variable: HHDemandSilver
Formula \( \text{HHFoodDemand} - \text{HouseholdFoodDemandToken} \)

Parameter: LLMaxOseasSpend
Formula \( \frac{\text{LandLordSilver}}{0.01923} \)

Flow: OverseasDrain
Formula \( \text{limitMax}(\text{InvestmentLoss}, \text{LLMaxOseasSpend}) \)
Rent submodel

Stock: CumRentDemanded
Formula \( \frac{d(CumRentDemanded)}{dt} = RentDemandPolicy \)
Initial value 0

Stock: CumRentPaid
Formula \( \frac{d(CumRentPaid)}{dt} = RentPaid \)
Initial value 0

Flow: RentPaid
Formula FarmRentSilver + FarmRentToken

Flow: RentDemanded
Formula RentDemandPolicy

Dynamic Variable: RentArrears
Formula CumRentDemanded - CumRentPaid

A.4.6 John Law Secondary Money comments and simulation

Law's intention was to present the landlord as a \textit{de facto} government with a public purpose of maintaining employment, effectively by deficit spending, although it also means the landlord can continue to accept rent and make payments for goods. Token money cannot be spent abroad, hence there is no overseas sink for tokens. The token circuit will always balance, with the expansion or contraction dictated by the difference in the rate of inflow and outflow of the landlord sector: the landlord essentially decides to run a budget deficit (as tokens are "coined") and repayment in rent represents an implicit destruction of tokens. A key issue in secondary currency literature is why a transactor would choose to accept an "inferior" money for transactions. Initially here, the simplest explanation is given — \textit{viz.}, because it is the only money available after the silver drain. Under such circumstances it is a decision of conditional logic: any notional demand not reflected in effective demand due to
lack of silver is directly translated into demand in tokens as the landlord decides to issue IOUs in place of silver.

Simulation 1 (replicating the outflow of silver at #700 / year in year 5) demonstrates that incomes need not sustain a fall after the external drain of silver as landlord spending in silver is replaced by spending in tokens accepted at face value (because the landlord guarantees to redeem them at face value). The chosen delay structures can alter the path and desired holdings of tokens, but earlier steady state is re-established with tokens replacing silver as the medium of exchange. How the landlord may ultimately account for rent arrears accumulated is left beyond the model boundary.
Figure 105. Secondary Money simulation 1, stocks and flows of silver and tokens
A.5 Cantillon: rural-urban split

Richard Cantillon's (1755) approach explicitly created a rural-urban split in Law's system. This can be conceptualised in a more comprehensive sub-system diagram:

Based on a Cantillonian interpretation, it is logical to dissect Law's island model geographically where local income excludes the landlord entirely; an additional manufacturing sector (outside the local geographic boundary) may also be added. While not modelled in detail there, this informs the conceptual development of the Core Model in the thesis.
Figure 107. SFD of Cantillon-inspired geographic split of circular-flow
A.6 Lexicographic consumption model equations

Parameter: InitialMoneyWealth
Formula 0

Parameter: FOCParameter
Value 0.01923
Description determines the size of the cash-in-advance buffer of money holdings.

Parameter: IncomeParameter
Value 20

Parameter: WItthPerceptionDelay
Value 0.25

Parameter: IncomeExpectationDelay
Value 0.25

Parameter: TargetWealthIncomeRatio
Value 1

Parameter: AdjustmentTime
Value 2.5

Parameter: NDE_Demand
Value 40

Parameter: NDL_Demand
Value 40

Flow: Income
Formula 100 + (IncomeParameter * sin(time()/0.5)) + step(-30,10)
Description used to shock the model.

Stock: MoneyWealth
Formula d(MoneyWealth)/dt = Income NDE_Expenditure – NDL_Expenditure – Consume_DE – Consume_DL
Initial value InitialMoneyWealth

Flow: NDE_Expenditure
Formula limitMax(MaxNDESpend, NDE_Demand)

Flow: NDL_Expenditure
Formula limitMax(MaxNDLSpend, (NDL_Demand * NDE_DemandMet))

Flow: Consume_DE
Formula limitMax(MaxDESpend, (DE_DemandFraction * DiscretionaryDemand))
Flow: Consume_DL
Formula \( \text{limitMax}(\text{MaxDLSpend}, (\text{DL}\_\text{DemandFraction} * \text{DiscretionaryDemand})) \)
Dynamic Variable: MaxDLSpend
Formula \( \frac{\text{MoneyWealth}}{\text{FOCParameter}} \)

Dynamic Variable: MaxNDESpends
Formula \( \frac{\text{MoneyWealth}}{\text{FOCParameter}} \)

Dynamic Variable: MaxNDLSpend
Formula \( \frac{\text{MoneyWealth}}{\text{FOCParameter}} \)

Dynamic Variable: MaxDESpend
Formula \( \frac{\text{MoneyWealth}}{\text{FOCParameter}} \)

Dynamic Variable: PerceivedWealth
Formula \( \text{smooth}(\text{MoneyWealth}, \text{WlthPerceptionDelay}) \)

Dynamic Variable: PerceivedIncome
Formula \( \text{smooth}(\text{Income}, \text{IncomeExpectationDelay}) \)

Dynamic Variable: TargetWealth
Formula \( \text{PerceivedIncome} \times \text{TargetWealthIncomeRatio} \)

Dynamic Variable: PerceivedPurchasingPower
Formula \( \text{PerceivedWealth} + \text{PerceivedIncome} \)

Dynamic Variable: PerceivedWealthShortfall
Formula \( \text{TargetWealth} - \text{PerceivedWealth} \)

Dynamic Variable: NDLPurchasingPower
Formula \( \max(((\text{PerceivedPurchasingPower} - \text{NDE}\_\text{Demand}) \times \text{NDE}\_\text{DemandMet}), 0) \)

Dynamic Variable: NDE\_DemandMet
Formula \( \text{NDE}\_\text{Expenditure} \geq \text{NDE}\_\text{Demand} \? 1 : 0 \)

Dynamic Variable: NDL\_DemandMet
Formula \( \text{NDL}\_\text{Expenditure} \geq \text{NDL}\_\text{Demand} \? 1 : 0 \)

Dynamic Variable: DiscretionaryPurchasingPower
Formula \( \max(((\text{NDL}\_\text{PurchasingPower} - \text{NDL}\_\text{Demand}) \times \text{NDL}\_\text{DemandMet}), 0) \)

Dynamic Variable: TargetSaving
Formula \( \frac{\text{PerceivedWealthShortfall}}{\text{AdjustmentTime}} \)

Dynamic Variable: ActualSaving
Formula \( \text{TargetSaving} > 0 \? \text{TargetSaving} \times \text{NDL}\_\text{DemandMet} : 0 \)
Dynamic Variable: DiscretionaryDemand
Formula (DiscretionaryPurchasingPower - ActualSaving) >= 0 ? (DiscretionaryPurchasingPower - ActualSaving) : 0

Dynamic Variable: DE_DemandFraction
Formula DE_DemandFractionLookUp(DisposablePPAsPerCentDiscretionary)

Dynamic Variable: DisposablePPAsPerCentDiscretionary
Formula DiscretionaryPurchasingPower / (NDE_Demand + NDL_Demand)

Lookup Table: DE_DemandFractionLookUp
<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>0.1</td>
<td>1.0</td>
</tr>
<tr>
<td>0.2</td>
<td>0.9</td>
</tr>
<tr>
<td>0.3</td>
<td>0.81</td>
</tr>
<tr>
<td>0.4</td>
<td>0.75</td>
</tr>
<tr>
<td>0.5</td>
<td>0.7</td>
</tr>
<tr>
<td>0.6</td>
<td>0.65</td>
</tr>
<tr>
<td>0.8</td>
<td>0.61</td>
</tr>
<tr>
<td>1.0</td>
<td>0.6</td>
</tr>
<tr>
<td>2.0</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Description: The input value is DisposablePPAsPerCentDiscretionary. The output value is DE_DemandFraction (the fraction of discretionary demand which is external).

Dynamic Variable: DL_DemandFraction
Formula 1 - DE_DemandFraction

Supplementary equations
Flow: Expenditure
Formula TotalConsumption
Description limitMax(TotalDemand, MaxSpend)

Dynamic Variable: TotalConsumption
Formula NDE_Expenditure + NDL_Expenditure + Consume_DE + Consume_DL

Flow: Expenditure
Formula TotalConsumption
Description limitMax(TotalDemand, MaxSpend)
A.7 Core model equations

Monetary submodel
Parameter: HHMoneyInitialValue
Value 0

Parameter: ProdMoneyInitialValue
Value 0

Stock: HouseholdMoney
Formula \( \frac{d(HouseholdMoney)}{dt} = LocalIncome + HHExternalIncome - DE - NDL - DL - NDE \)
Initial value HHMoneyInitialValue

Stock: ProducerMoney
Formula \( \frac{d(ProducerMoney)}{dt} = ProducerExternalIncome + NDL + DL - LocalIncome - ProdExtExpense \)
Initial value ProdMoneyInitialValue

Flow: HHExternalIncome
Formula ExtInc

Flow: NDE
Formula limitMax(ConsumeNDE, MaxNDE)
Description Non-Discretionary External expenditure

Flow: NDL
Formula limitMax(ConsumeNDL, MaxNDL)
Description Non-Discretionary Local expenditure

Flow: DE
Formula limitMax(ConsumeDE, MaxDE)
Description Discretionary External expenditure

Flow: DL
Formula limitMax(ConsumeDL, MaxDL)
Description Discretionary Local expenditure

Flow: LocalIncome
Formula limitMax((WagesPaid + AnnualOwnersDividend), MaxLocalIncome)

Flow: ProdExtExpense
Formula limitMax((ProducerSales * ImportFraction), MaxProdExp)

Flow: ProdExternalIncome
Formula ProdExportSales - Rationing

Dynamic Variable: MaxNDE
Dynamic Variable: MaxNDL
Formula: HouseholdMoney / 0.0192

Dynamic Variable: MaxDL
Formula: HouseholdMoney / 0.0192

Dynamic Variable: MaxDE
Formula: HouseholdMoney / 0.0192

Dynamic Variable: MaxProdExp
Formula: ProducerMoney / 0.0192

Dynamic Variable: MaxLocalIncome
Formula: ProducerMoney / 0.0192

**Consumer Policy**  
Parameter: ExtInc  
Value: 50 shocked in experiments.  
Description: Wages from external employers, Pensions, Benefits

Parameter: HHExpDelay  
Value: 0.25

Parameter: WlthPerceptionDelay  
Value: 0.25

Parameter: TargetWealthIncomeRatio  
Value: 1

Parameter: NDE_demand  
Value: 30

Parameter: NDL_demand  
Value: 33

Parameter: AdjustmentTime  
Value: 2.5

Parameter: RelocalisationDrive  
Value: 1  
Description: default value applies the lookup function; can be shocked to adjust relocatisation.

Dynamic Variable: DE_DemandFraction  
Formula:  
\[(DE\_DemandFractionLookUp(DisposablePPAsPerCentDiscretionary)) \times \text{RelocalisationDrive}\]
Dynamic Variable: DisposablePPAsPerCentDiscretionary  
**Formula**  \( \text{DisposablePurchasingPower} / (\text{NDE\_demand} + \text{NDL\_demand}) \)

Lookup Table: DE\_DemandFractionLookUp  
**Input**  **Output**  
0.0 1.0  
0.1 1.0  
0.2 0.9  
0.3 0.81  
0.4 0.75  
0.5 0.7  
0.6 0.65  
0.8 0.61  
1.0 0.6  
2.0 0.6  

**Description:** The input value is DisposablePPAsPerCentDiscretionary. The output value is DE\_DemandFraction (the fraction of discretionary demand which is external).

Dynamic Variable: TotalIncome  
**Formula**  \( \text{LocalIncome} + \text{HHExternalIncome} \)

Dynamic Variable: PerceivedIncome  
**Formula**  \( \text{smooth3}(\text{TotalIncome},\text{HHExpDelay}) \)

Dynamic Variable: PerceivedPurchasingPower  
**Formula**  \( \text{PerceivedIncome} + \text{PerceivedWealth} \)

Dynamic Variable: NDLPurchasingPower  
**Formula**  \( \max(((\text{PerceivedPurchasingPower} - \text{NDE\_demand}) \times \text{NDEDemandMet}),0) \)

Dynamic Variable: NDE\_Expenditure  
**Formula**  \( \text{NDE\_demand} \)

Dynamic Variable: NDEDemandMet  
**Formula**  \( \text{NDE} \geq \text{NDE\_demand} ? 1 : 0 \)

Dynamic Variable: NDL\_Expenditure  
**Formula**  \( \text{NDL\_demand} \times \text{NDEDemandMet} \)

Dynamic Variable: NDLDemMet  
**Formula**  \( \text{NDL} \geq \text{NDL\_demand} ? 1 : 0 \)

Dynamic Variable: DisposablePurchasingPower  
**Formula**  \( \max(((\text{NDLPurchasingPower} - \text{NDL\_demand}) \times \text{NDLDemMet}),0) \)

Dynamic Variable: TargetWealth  
**Formula**  \( \text{PerceivedIncome} \times \text{TargetWealthIncomeRatio} \)
Dynamic Variable: PerceivedWealth
Formula smooth3(HouseholdMoney, WlthPerceptionDelay)

Dynamic Variable: PerceivedWealthShortfall
Formula TargetWealth - PerceivedWealth

Dynamic Variable: TargetSaving
Formula PerceivedWealthShortfall / AdjustmentTime

Dynamic Variable: ActualSaving
Formula TargetSaving > 0 ? TargetSaving * NDLDemMet: 0

Dynamic Variable: DiscretionaryConsumption
Formula (DisposablePurchasingPower - ActualSaving) >= 0 ?
(DisposablePurchasingPower - ActualSaving) : 0

Dynamic Variable: ConsumeDE
Formula DE_DemandFraction * DiscretionaryConsumption

Dynamic Variable: DL_DemandFraction
Formula 1 - DE_DemandFraction

Dynamic Variable: ConsumeDL
Formula DL_DemandFraction * DiscretionaryConsumption

**Producer Policy**
Parameter: ProdExportSales
Value 23

Parameter: ImportFraction
Value 0.3

Parameter: LabourProductivity1
Value 10

Dynamic Variable: Demand
Formula DL + NDL + ProdExternalIncome

Dynamic Variable: ProducerSales
Formula Demand <= NominalCapacityLimit ? Demand :
NominalCapacityLimit

Dynamic Variable: NominalCapacityLimit
Formula (TotalLaborForceHours * LabourProductivity1) +
delay(ProdExtExpense, 0.25)

Dynamic Variable: Rationing
Formula \[ \text{Demand} \leq \text{NominalCapacityLimit} ? 0 : (\text{Demand} - \text{NominalCapacityLimit}) \]

Dynamic Variable: \text{ProducerNetIncome}
Formula \[ \text{ProducerSales} - \text{ProdExtExpense} \]

Dynamic Variable: \text{ProdPerceivedIncome}
Formula \[ \text{smooth3(ProducerNetIncome, ProdExpDelay)} \]

Dynamic Variable: \text{NominalLabourDemand}
Formula \[ \text{ProdPerceivedIncome} \]
Description Pounds total

Dynamic Variable: \text{AnnualOwnersDividend}
Formula \[ \text{ProducerMoney} \]

**Employment submodel**
Parameter: \text{LabourProductivity}
Value 10
Description Exogenously given nominal (monetary) output per hour.

Parameter: \text{HiringTime}
Value 0.08333
Description A delay in hiring. Monthly target 0.08333

Parameter: \text{WageRate}
Value 10
Description Exogenously given hourly wage, assumed to match productivity.

Parameter: \text{WorkingPopulation}
Value 2.5
Description Scale as appropriate.

Parameter: \text{HoursPerWorker}
Value 2
Description Measured in hours per year

Dynamic Variable: \text{LabourDemandHours}
Formula \[ (\text{NominalLabourDemand} / \text{LabourProductivity}) \]
Description Hours of labour

Dynamic Variable: \text{EmploymentGap}
Formula \[ (\text{LabourDemandHours} - \text{LabourHours}) \]

Flow: \text{Hiring}
Formula \[ \text{limitMax}((\text{EmploymentGap} / \text{HiringTime}), \text{MaxHireRate}) \]
Description Bi-directional flow of annualised rate of hiring hours for workers, with first-order control to ensure supply limits are respected.
Stock: LabourHours
Formula \( \frac{d(LabourHours)}{dt} = \text{Hiring} \)
Initial value 0
Description Labour hours currently utilised.

Stock: UnemployedLabourHours
Formula \( \frac{d(UnemployedLabourHours)}{dt} = -\text{Hiring} \)
Initial value TotalLabourForceHours
Description Total available annual hours.

Dynamic Variable: MaxHireRate
Formula UnemployedLabourHours / HiringTime

Stock: UnemployedLabourHours
Equation mode Classic
Initial value TotalLabourForceHours

Dynamic Variable: TotalLabourForceHours
Formula WorkingPopulation * HoursPerWorker

Dynamic Variable: UnemploymentRate
Formula \( \frac{(UnemployedLabourHours / TotalLabourForceHours) \times 100}{100} \)

Dynamic Variable: WagesPaid
Formula LabourHours * WageRate

Supplementary Equations
Dynamic Variable: WealthIncomeRatio
Formula HouseholdMoney / TotalIncome

Dynamic Variable: FractionLocalIncome
Formula LocalIncome / TotalIncome
Dynamic Variable: LocalSpending
Formula NDL + DL

Dynamic Variable: TotalSpending
Formula ExternalSpending + LocalSpending

Dynamic Variable: ExternalSpending
Formula NDE + DE

Dynamic Variable: DisSpend
Formula DE + DL

Dynamic Variable: DLAsPerCentTotalDisc
Formula zidz(DL, DisSpend)
A.8 CLC model equations

Monetary submodel
Stock: HouseholdGBP
Formula \( \frac{d(HouseholdMoney)}{dt} = LocalIncome + HHExternalIncome - HHDemandForCLC - DE - NDL - DL - NDE \)
Initial value 0

Stock: ProducerGBP
Formula \( \frac{d(ProducerMoney)}{dt} = ProdExternalIncome + CLCRepayment + NDL + DL - LocalIncome - ProdExtExpense \)
Initial value 0

Stock: CLCProviderGBP
Formula \( \frac{d(CLCP\text{roviderMoney})}{dt} = HHDemandForCLC - CLCRepayment \)
Initial value 0
Description A stock of GBP held by the CLC provider.

Stock: CLCProviderLiability
Formula \( \frac{d(CLCP\text{roviderLiability})}{dt} = CLC\text{Creation} - CLC\text{Destruction} \)
Initial value 0
Description The liability assumed by the CLC provider as it issues CLC.

Stock: ProducerCLC
Formula \( \frac{d(ProducerCLC)}{dt} = CLC\text{Spend} - CLC\text{Income} - CLC\text{Reflux} \)
Initial value 0

Stock: HouseHoldCLC
Formula \( \frac{d(HouseholdCLC)}{dt} = CLC\text{Income} + CLC\text{Flow} - CLC\text{Spend} \)
Initial value 0

Flow: HHExternalIncome
Formula ExtInc

Flow: NDE
Formula limitMax(NDE\_Expenditure, MaxNDE)

Flow: DE
Formula limitMax(ConsumeDE, MaxDE)

Flow: NDL
Formula limitMax(NDL\_Expenditure, MaxNDL)

Flow: DL
Formula limitMax(ConsumeDL, MaxDL)

Flow: ProdExtExpense
Formula \( \text{limitMax}((\text{ProducerSales} \times \text{ImportFraction}), \text{MaxProdExp}) \)

Flow: ProdExternalIncome
Formula \( \text{ProdExportSales} - \text{Rationing} \)

Flow: LocalGBPIncome
Formula \( \text{limitMax}((\text{GBPWages} + \text{AnnualOwnersDividend}), \text{MaxLocalIncome}) \)
Flow: HHCLCPurchase
Formula \( \text{limitMax}(\text{MaxCLC}, \text{HHDemandForCLC}) \)

Flow: RepaidCLC
Formula \( \text{limitMax}(\text{MaxCLCRepay}, \text{CLCDestruction}) \)

Flow: CLCCreation
Formula \( \text{HHCLCPurchase} \)

Flow: CLCFlow
Formula \( \text{CLCCreation} \)

Flow: CLCSpend
Formula \( \text{limitMax}(\text{MaxCLCSpend}, \text{ConsumeCLC}) \)

Flow: CLCDestruction
Formula \( \text{limitMax}(\text{MaxCLCDest}, \text{CLCReflux}) \)

Flow: CLCReflux
Formula \( \text{limitMax}(\text{MaxCLCReflux}, \text{ProducerCLCReflux}) \)

Flow: CLCIncome
Formula \( \text{limitMax}(\text{MaxCLCIncome}, \text{CLCPay}) \)

Dynamic Variable: MaxNDL
Formula \( \frac{\text{HouseholdGBP}}{0.01923} \)

Dynamic Variable: MaxDE
Formula \( \frac{\text{HouseholdGBP}}{0.01923} \)

Dynamic Variable: MaxDL
Formula \( \frac{\text{HouseholdGBP}}{0.01923} \)

Dynamic Variable: MaxNDE
Formula \( \frac{\text{HouseholdGBP}}{0.01923} \)

Dynamic Variable: MaxLocalIncome
Formula \( \frac{\text{ProducerGBP}}{0.01923} \)

Dynamic Variable: MaxCLC
Formula \( \frac{\text{HouseholdGBP}}{0.01923} \)
Dynamic Variable: MaxProdExp
Formula: ProducerGBP / 0.01923

Dynamic Variable: MaxCLCRepay
Formula: CLCProviderGBP / 0.01923

Dynamic Variable: MaxCLCReflux
Formula: ProducerCLC / 0.01923

Dynamic Variable: MaxCLCIncome
Formula: ProducerCLC / 0.01923

Dynamic Variable: MaxCLCDest
Formula: CLCProviderLiability / 0.01923

Dynamic Variable: MaxCLCSpend
Formula: HouseHoldCLC / 0.01923

**Household submodel**
Parameter: ExtInc
Value: 50

Parameter: HHExpDelay
Value: 0.25

Parameter: WlthPerceptionDelay
Value: 0.25

Parameter: TargetWealthIncomeRatio
Value: 1

Parameter: NDE_demand
Value: 30

Parameter: NDL_demand
Value: 33

Parameter: CLCPropWlth
Value: 0.05

Parameter: CLCAjustTime
Value: 0.08333

Parameter: AdjustmentTime
Value: 2.5

Parameter: CLCDemandFraction
Value: 0.5
Parameter: RelocalisationDrive
Value 1

Dynamic Variable: DE_DemandFraction
Formula
   (DE_DemandFractionLookUp(DisposablePPAsPerCentDiscretionary)) * RelocalisationDrive

Dynamic Variable: DisposablePPAsPerCentDiscretionary
Formula DisposablePurchasingPower / (NDE_demand + NDL_demand)

Lookup Table: DE_DemandFractionLookUp
Input  Output
0.0      1.0
0.1      1.0
0.2      0.9
0.3      0.81
0.4      0.75
0.5      0.7
0.6      0.65
0.8      0.61
1.0      0.6
2.0      0.6

Description: The input value is DisposablePPAsPerCentDiscretionary. The output value is DE_DemandFraction (the fraction of discretionary demand which is external).

Dynamic Variable: TotalGBPIncome
Formula LocalGBPIncome + HHExternalIncome

Dynamic Variable: PerceivedIncome
Formula smooth3(TotalGBPIncome, HHExpDelay)

Dynamic Variable: PerceivedWealth
Formula smooth3(HouseholdGBP, WlthPerceptionDelay)

Dynamic Variable: PerceivedPurchasingPower
Formula PerceivedIncome + PerceivedWealth

Dynamic Variable: TargetWealth
Formula PerceivedIncome * TargetWealthIncomeRatio

Dynamic Variable: PerceivedWealthShortfall
Formula TargetWealth - PerceivedWealth

Dynamic Variable: NDLPurchasingPower
Formula max(((PerceivedPurchasingPower - NDE_demand) * NDEDemandMet),0)

Dynamic Variable: NDL_Expenditure
Formula: \( NDL\_demand \times NDE\_DemandMet \)

Dynamic Variable: NDE\_Expenditure
Formula: \( NDE\_demand \)

Dynamic Variable: NDE\_DemandMet
Formula: \( NDE \geq NDE\_demand \) ? 1 : 0

Dynamic Variable: NDLDemMet
Formula: \( NDL \geq NDL\_demand \) ? 1 : 0

Dynamic Variable: DisposablePurchasingPower
Formula: \( \max(((NDLPurchasingPower - NDL\_demand) \times NDLDemMet),0) \)

Dynamic Variable: TargetSaving
Formula: \( \frac{PerceivedWealthShortfall}{AdjustmentTime} \)

Dynamic Variable: ActualSaving
Formula: \( \text{TargetSaving} > 0 \) ? \( \text{TargetSaving} \times NDLDemMet \) : 0

Dynamic Variable: DiscretionaryConsumption
Formula: \( (\text{DisposablePurchasingPower} - \text{ActualSaving}) \geq 0 \) ? \( \frac{\text{DisposablePurchasingPower} - \text{ActualSaving}}{0} \)

Dynamic Variable: DL\_DemandFraction
Formula: \( 1 - DE\_DemandFraction \)

Dynamic Variable: TotalDL
Formula: \( \text{DiscretionaryConsumption} \times DL\_DemandFraction \)

Dynamic Variable: ConsumeDL
Formula: \( \text{TotalDL} \times (1 - CLCDemandFraction) \)

Dynamic Variable: ConsumeDE
Formula: \( DE\_DemandFraction \times \text{DiscretionaryConsumption} \)

Dynamic Variable: TargetCLCHolding
Formula: \( \text{PerceivedWealth} \times CLCPropWlth \)

Dynamic Variable: DesiredSpend
Formula: \( \text{HouseHoldCLC} - \text{TargetCLCHolding} \)

Dynamic Variable: CLCDisSaving
Formula: \( \frac{\text{DesiredSpend}}{CLCAdjustTime} \)

Dynamic Variable: HHDemandForCLC
Formula: \( \max(\text{ConsumeCLC} - CLCDisSaving, 0) \)

Dynamic Variable: ConsumeCLC
Formula: \( \text{TotalDL} \times CLCDemandFraction \)
Producer submodel
Parameter: ImportFraction
Value 0.3

Parameter: ProdExportSales
Value 23

Parameter: LabourProductivity1
Value 10

Parameter: ProducerRefluxDelay
Value: 0.08333

Parameter: ProdExpDelay
Value: 0.25

Dynamic Variable: GBPDemand
Formula  NDL + DL + ProdExternalIncome

Dynamic Variable: CLCDemand
Formula  CLCSpend

Dynamic Variable: TotalDemand
Formula  GBPDemand + CLCDemand

Dynamic Variable: ProducerCLCReflux
Formula  smooth3((CLCSpend - CLCPay), ProducerRefluxDelay)

Dynamic Variable: Rationing
Formula  TotalDemand <= NominalCapacityLimit ? 0 : (TotalDemand - NominalCapacityLimit)

Dynamic Variable: NominalCapacityLimit
Formula  (TotalLabourForceHours * LabourProductivity1) + delay(ProdExtExpense, 0.25)

Dynamic Variable: ProducerSales
Formula  TotalDemand <= NominalCapacityLimit ? TotalDemand : NominalCapacityLimit

Dynamic Variable: ProducerNetIncome
Formula  ProducerSales - ProdExtExpense

Dynamic Variable: ProdPerceivedIncome
Formula  smooth3(ProducerNetIncome, ProdExpDelay)

Dynamic Variable: NominalLabourDemand
Formula $\text{ProdPerceivedIncome}$

Dynamic Variable: $\text{AnnualOwnersDividend}$
Formula $\text{ProducerGBP}$

**Employment submodel**
Parameter: $\text{LabourProductivity}$
Value 10

Parameter: $\text{WageRate}$
Value 10

Parameter: $\text{HiringTime}$
Value 0.08333

Parameter: $\text{WorkingPopulation}$
Value 2.5

Parameter: $\text{HoursPerWork}$
Value 2

Parameter: $\text{VoluntaryFraction}$
Value 0

Stock: $\text{LabourHours}$
Formula $\frac{d(\text{LabourHours})}{dt} = \text{Hiring}$
Initial value 0

Stock: $\text{UnemployedLabourHours}$
Formula $\frac{d(\text{UnemployedLabourHours})}{dt} = -\text{Hiring}$
Initial value $\text{TotalLabourForceHours}$

Dynamic Variable: $\text{LabourDemandHours}$
Formula $\frac{\text{NominalLabourDemand}}{\text{LabourProductivity}}$

Dynamic Variable: $\text{EmploymentGap}$
Formula $(\text{LabourDemandHours} - \text{LabourHours})$

Flow: $\text{Hiring}$
Formula $\text{limitMax}((\text{EmploymentGap} / \text{HiringTime}), \text{MaxHireRate})$

Dynamic Variable: $\text{MaxHireRate}$
Formula $\text{UnemployedLabourHours} / \text{HiringTime}$

Dynamic Variable: $\text{TotalLabourForceHours}$
Formula $\text{WorkingPopulation} \times \text{HoursPerWorker}$

Dynamic Variable: $\text{UnemploymentRate}$
Formula $(\text{UnemployedLabourHours} / \text{TotalLabourForceHours}) \times 100$
Dynamic Variable: WagesPaid  
Formula: LabourHours * WageRate

Dynamic Variable: GBPWages  
Formula: WagesPaid - CLCIncome

Dynamic Variable: CLCPay  
Formula: CLCSpend * VoluntaryFraction

**Supplementary equations**

Dynamic Variable: FractionLocalIncome  
Formula: LocalGBPIncome / TotalIncome

Dynamic Variable: LocalSpending  
Formula: NDL + DL + CLCSpend

Dynamic Variable: PerceivedWealthIncomeRatio  
Formula: PerceivedWealth / PerceivedIncome

Dynamic Variable: WealthIncomeRatio  
Formula: HouseholdGBP / TotalIncome

Dynamic Variable: ExternalSpending  
Formula: NDE + DE

Dynamic Variable: TotalSpending  
Formula: ExternalSpending + LocalSpending
A.9 MCC model equations

Monetary submodel
Stock: HouseholdMoney
Formula: \( \frac{d(HouseholdMoney)}{dt} = \text{LocalIncome} + \text{HHExternalIncome} - \text{DE} - \text{NDL} - \text{DL} - \text{NDE} \)
Initial value: 0

Stock: ProducerMoney
Formula: \( \frac{d(ProducerMoney)}{dt} = \text{ProducerExternalIncome} + \text{NDL} + \text{DL} - \text{LocalIncome} - \text{ProdExtExpense} \)
Initial value: 0

Flow: HHExternalIncome
Formula: ExtInc

Flow: NDE
Formula: limitMax(ConsumeNDE, MaxNDE)
Description: Non-Discretionary External expenditure

Flow: NDL
Formula: limitMax(ConsumeNDL, MaxNDL)
Description: Non-Discretionary Local expenditure

Flow: DE
Formula: limitMax(ConsumeDE, MaxDE)
Description: Discretionary External expenditure

Flow: DL
Formula: limitMax(ConsumeDL, MaxDL)
Description: Discretionary Local expenditure

Flow: LocalIncome
Formula: limitMax((\text{WagesPaid} + \text{AnnualOwnersDividend}), \text{MaxLocalIncome})

Flow: ProdExtExpense
Formula: limitMax((\text{ProducerSales} \times \text{ImportFraction}), \text{MaxProdExp})

Flow: ProdExternalIncome
Formula: ProdExportSales - Rationing

Dynamic Variable: MaxNDE
Formula: HouseholdMoney / 0.01923

Dynamic Variable: MaxNDL
Formula: HouseholdMoney / 0.01923

Dynamic Variable: MaxDL
Appendix

Formula: HouseholdMoney / 0.01923
Dynamic Variable: MaxDE
Formula: HouseholdMoney / 0.01923
Dynamic Variable: MaxProdExp
Formula: ProducerMoney / 0.01923
Dynamic Variable: MaxLocalIncome
Formula: ProducerMoney / 0.01923

**MCC subsystem**

Parameter: ProportionInitiate
Value: 0.5
Description: By definition 50% of transactions are purchases and 50% are reciprocal sales.

Dynamic Variable: PotentialMCCDemand
Formula: max(0, (NominalCapacityLimit - CashDemand))
Description: Potential MCC demand is a function of capacity limits.

Dynamic Variable: PerceivedSpareCapacity
Formula: smooth(RandomVar * PotentialMCCDemand, 0.25)
Description: Perceived spare capacity is a smoothed function of spare capacity and a random variable.

Event: TimeStepEvent
Action: RandomVar = triangularAV(0.9, 0.1, NoiseSeed);
Description: This is a discrete event in the model whereby each month a stochastically random variable is generated based on a triangular distribution with a mean of 0.9 and a variability of 0.1. Its purpose is to approximate a stochastic perception of spare capacity.

Variable: RandomVar
Initial value: 0.9
Description: Monthly variety based on random distribution.

Parameter: CreditorDelayParameter
Value: 0.08333
Description: delay represents the typical target holding period of the creditor before spending.

Parameter: EmployeeDelayParameter
Value: 0.25
Description: delay represents the typical target holding period of the employee before spending.

Stock: SMEDebtorsMCC
Formula \( d(SMEDebtorsMCC)/dt = \) ClosingPurchase + EmployeeSpendMCC – InitiatingPurchase
Initial value 0
Description Debtors are grouped as those who initiate sales.

Stock: SMECreditorsMCC
Formula \( d(SMECreditorsMCC)/dt = \) InitialSale – ClosingPurchase – PayEmployeeMCC
Initial value 0
Description Creditors are grouped as those who initially sell.

Stock: EmployeeMCC
Formula \( d(EmployeeMCC)/dt = \) PayEmployeeMCC – EmployeeSpendMCC
Initial value 0

Flow: InitiatingPurchase
Formula smooth((PerceivedSpareCapacity * ProportionInitiate),0.08333)
Description Initial purchases are driven as a smoothed function of perceived excess capacity.

Flow: InitialSale
Formula InitiatingPurchase
Description Sales reciprocate the purchase.

Flow: ClosingPurchase
Formula limitMax(smooth3((InitialSale - PayEmployeeMCC), CreditorDelayParameter), MaxCP)
Description As no long-term holdings of MCC are desired, what is not paid to employees is spent after a smoothing delay.

Flow: PayEmployeeMCC
Formula limitMax ((MCCFraction * WagesPaid * EmployeeMCCPreference), MaxPE)
Description Employees are paid a fraction of wages (based on given preference) in MCC.

Flow: EmployeeSpendMCC
Formula limitMax((smooth3(PayEmployeeMCC, EmployeeDelayParameter)), MaxES)
Description Employees treat MCC pay as to be spent with given delay.

Dynamic Variable: MaxCP
Formula SMECreditorsMCC / 0.01923

Dynamic Variable: MaxPE
Formula SMECreditorsMCC / 0.01923

Dynamic Variable: MaxES
Formula EmployeeMCC / 0.01923
**Consumer Policy**
Parameter: ExtInc  
Value 50 (shocked in experiments)

Parameter: HHExpDelay  
Value 0.25

Parameter: WlthPerceptionDelay  
Value 0.25

Parameter: TargetWealthIncomeRatio  
Value 1

Parameter: NDE_demand  
Value 30

Parameter: NDL_demand  
Value 33

Parameter: AdjustmentTime  
Value 2.5

Parameter: RelocalisationDrive  
Value 1

Dynamic Variable: DE_DemandFraction  
**Formula**  
\[(\text{DE\_DemandFractionLookUp(DisposablePPAsPerCentDiscretionary)}) \times \text{RelocalisationDrive}\]

Dynamic Variable: DisposablePPAsPerCentDiscretionary  
**Formula**  
\[\text{DisposablePurchasingPower} \div (\text{NDE\_demand} + \text{NDL\_demand})\]

Lookup Table: DE_DemandFractionLookUp  
<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>0.1</td>
<td>1.0</td>
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<tr>
<td>0.2</td>
<td>0.9</td>
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<tr>
<td>0.3</td>
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<tr>
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<td>0.6</td>
</tr>
<tr>
<td>2.0</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Dynamic Variable: TotalGBPIncome  
**Formula**  
\[\text{LocalIncome} + \text{HHExternalIncome}\]
Dynamic Variable: PerceivedIncome
Formula \( \text{smooth3(TotalGBPIncome,HHExpDelay)} \)

Dynamic Variable: PerceivedPurchasingPower
Formula \( \text{PerceivedIncome + PerceivedWealth} \)

Dynamic Variable: NDLPurchasingPower
Formula \( \max(((\text{PerceivedPurchasingPower} - \text{NDE_demand}) \times \text{NDEDemandMet}), 0) \)

Dynamic Variable: NDE_Expenditure
Formula \( \text{NDE_demand} \)

Dynamic Variable: NDEDemandMet
Formula \( \text{NDE} \geq \text{NDE_demand} ? 1 : 0 \)

Dynamic Variable: NDL_Expenditure
Formula \( \text{NDL_demand} \times \text{NDEDemandMet} \)

Dynamic Variable: NDLDemMet
Formula \( \text{NDL} \geq \text{NDL_demand} ? 1 : 0 \)

Dynamic Variable: DisposablePurchasingPower
Formula \( \max(((\text{NDLPurchasingPower} - \text{NDL_demand}) \times \text{NDLDemMet}), 0) \)

Dynamic Variable: TargetWealth
Formula \( \text{PerceivedIncome} \times \text{TargetWealthIncomeRatio} \)

Dynamic Variable: PerceivedWealth
Formula \( \text{smooth3(HouseholdMoney, WlthPerceptionDelay)} \)

Dynamic Variable: PerceivedWealthShortfall
Formula \( \text{TargetWealth} - \text{PerceivedWealth} \)

Dynamic Variable: TargetSaving
Formula \( \text{PerceivedWealthShortfall} / \text{AdjustmentTime} \)

Dynamic Variable: ActualSaving
Formula \( \text{TargetSaving} > 0 ? \text{TargetSaving} \times \text{NDLDemMet} : 0 \)

Dynamic Variable: DiscretionaryConsumption
Formula \( \begin{align*} (\text{DisposablePurchasingPower} - \text{ActualSaving}) \geq 0 & \? \ (\text{DisposablePurchasingPower} - \text{ActualSaving}) : 0 \end{align*} \)

Dynamic Variable: ConsumeDE
Formula \( \text{DE_DemandFraction} \times \text{DiscretionaryConsumption} \)

Dynamic Variable: DL_DemandFraction
Appendix

Formula 1 - DE_DemandFraction

Dynamic Variable: ConsumeDL
Formula DL_DemandFraction * DiscretionaryConsumption

**Producer Policy**

Parameter: ProdExportSales
Value 23

Parameter: ImportFraction
Value 0.3

Parameter: LabourProductivity1
Value 10

Dynamic Variable: MCCDemand
Formula InitiatingPurchase + ClosingPurchase + EmployeeSpendMCC

Dynamic Variable: CashDemand
Formula DL + NDL + ProdExternalIncome

Dynamic Variable: Demand
Formula CashDemand + MCCDemand

Dynamic Variable: ProducerSales
Formula Demand <= NominalCapacityLimit ? Demand : NominalCapacityLimit

Dynamic Variable: NominalCapacityLimit
Formula (TotalLabourForceHours * LabourProductivity1) + delay(ProdExtExpense, 0.25)

Dynamic Variable: Rationing
Formula Demand <= NominalCapacityLimit ? 0 : (Demand - NominalCapacityLimit)

Dynamic Variable: ProducerNetIncome
Formula ProducerSales - ProdExtExpense

Dynamic Variable: ProdPerceivedIncome
Formula smooth3(ProducerNetIncome, ProdExpDelay)

Dynamic Variable: NominalLabourDemand
Formula ProdPerceivedIncome

Dynamic Variable: AnnualOwnersDividend
Formula ProducerMoney

**Employment submodel**
Parameter: LabourProductivity
Value 10

Parameter: HiringTime
Value 0.08333

Parameter: WageRate
Value 10

Parameter: WorkingPopulation
Value 2.5

Parameter: HoursPerWorker
Value 2

Parameter: EmployeeMCCPreference
Value 0 shocked in experiment.
Description Exogenously given parameter indicating an employee preference for payment.

Dynamic Variable: LabourDemandHours
Formula  \( \frac{\text{NominalLabourDemand}}{\text{LabourProductivity}} \)

Dynamic Variable: EmploymentGap
Formula  \( \text{LabourDemandHours} - \text{LabourHours} \)

Flow: Hiring
Formula  \( \text{limitMax}(\text{EmploymentGap} / \text{HiringTime}, \text{MaxHireRate}) \)

Stock: LabourHours
Formula  \( \frac{d(\text{LabourHours})}{dt} = \text{Hiring} \)
Initial value 0

Stock: UnemployedLabourHours
Formula  \( \frac{d(\text{UnemployedLabourHours})}{dt} = -\text{Hiring} \)
Initial value \( \text{TotalLabourForceHours} \)

Dynamic Variable: MaxHireRate
Formula  \( \text{UnemployedLabourHours} / \text{HiringTime} \)

Stock: UnemployedLabourHours
Equation mode Classic
Initial value \( \text{TotalLabourForceHours} \)

Dynamic Variable: TotalLabourForceHours
Formula  \( \text{WorkingPopulation} * \text{HoursPerWorker} \)

Dynamic Variable: UnemploymentRate
Formula  \( (\text{UnemployedLabourHours} / \text{TotalLabourForceHours}) * 100 \)
Dynamic Variable: WagesPaid
Formula: LabourHours * WageRate

Dynamic Variable: MCCFraction
Formula: zidz(MCCDemand, Demand)
Description: MCC demand as a fraction of demand (excluding division by zero at runtime).
A.10 LGC Model equations

**Monetary submodel**

Stock: HouseholdMoney  
Formula \( \frac{d(\text{HouseholdMoney})}{dt} = \text{LocalIncome} + \text{HHExternalIncome} - \text{DE} - \text{NDL} - \text{DL} - \text{NDE} \)  
Initial value 0

Stock: ProducerMoney  
Formula \( \frac{d(\text{ProducerMoney})}{dt} = \text{ProducerExternalIncome} + \text{NDL} + \text{DL} - \text{LocalIncome} - \text{ProdExtExpense} \)  
Initial value 0

Flow: HHExternalIncome  
Formula ExtInc

Flow: NDE  
Formula limitMax(ConsumeNDE, MaxNDE)  
Description Non-Discretionary External expenditure

Flow: NDL  
Formula limitMax(ConsumeNDL, MaxNDL)  
Description Non-Discretionary Local expenditure

Flow: DE  
Formula limitMax(ConsumeDE, MaxDE)  
Description Discretionary External expenditure

Flow: DL  
Formula limitMax(ConsumeDL, MaxDL)  
Description Discretionary Local expenditure

Flow: LocalIncome  
Formula limitMax((WagesPaid + AnnualOwnersDividend), MaxLocalIncome)

Flow: ProdExtExpense  
Formula limitMax((ProducerSales * ImportFraction), MaxProdExp)

Flow: ProdExternalIncome  
Formula ProdExportSales - Rationing

Dynamic Variable: MaxNDE  
Formula HouseholdMoney / 0.01923

Dynamic Variable: MaxNDL  
Formula HouseholdMoney / 0.01923

Dynamic Variable: MaxDL
Appendix

Formula  HouseholdMoney / 0.01923

Dynamic Variable: MaxDE
Formula  HouseholdMoney / 0.01923

Dynamic Variable: MaxProdExp
Formula  ProducerMoney / 0.01923

Dynamic Variable: MaxLocalIncome
Formula  ProducerMoney / 0.01923

LGC submodel

Parameter: HhLGTaxRate
Value 0.3

Parameter: ProdLGTaxRate
Value 0.3

Parameter: LocalGovSpend
Value 0 shocked in experiment

Dynamic Variable: HhTaxDemand
Formula  LGTaxRate * IncomeLG

Dynamic Variable: ProdTaxDemand
Formula  ProdLGTaxRate * ConsumeLG

Dynamic Variable: BudgetDeficit
Formula  LGSpend - HouseTaxLG - ProducerTaxLG

Stock: HouseholdLGMoney
Formula  \(d(HouseholdLGMoney)\)/dt = IncomeLG – HouseTaxLG – ConsumeLG
Initial value  0

Stock: ProducerLGMoney
Formula  \(d(ProducerLGMoney)\)/dt = LGSpend + ConsumeLG – IncomeLG - ProducerTaxLG
Initial value  0

Stock: LGMoneyLiability
Formula  \(d(LGMoneyCirculation)\)/dt = PrintLGMoney – DestroyLGMoney
Initial value  0
Description  The value of LGC in circulation (Note, the liability this represents in double-entry terms is not presented).

Flow: PrintLGMoney
Formula  BudgetDeficit > 0 ? BudgetDeficit : 0
Description As in Functional Finance, the decision to print money is based on the tax and spend parameters creating a budget deficit or surplus.

Flow: DestroyLGMoney
Formula \( \text{BudgetDeficit} \leq 0 \ ? \ (\text{BudgetDeficit} \times -1): 0 \)

Flow: LGSpend
Formula \( \text{LocalGovSpend} \)

Flow: IncomeLG
Formula \( \text{limitMax}((\text{WagesPaid} \times \text{FractionLGC}), \text{MaxIncomeLG}) \)

Flow: ConsumeLG
Formula \( \text{limitMax}((\text{ConsumptionLG}, \text{MaxConsumeLG}) \)

Flow: HouseTaxLG
Formula \( \text{limitMax}((\text{HhTaxDemand}, \text{MaxHouseTaxLG}) \)

Flow: ProducerTaxLG
Formula \( \text{limitMax}((\text{ProdTaxDemand}, \text{MaxProdTax}) \)

Dynamic Variable: MaxHouseTaxLG
Formula \( \text{HouseholdLGMoney} / 0.01923 \)

Dynamic Variable: MaxConsumeLG
Formula \( \text{HouseholdLGMoney} / 0.01923 \)

Dynamic Variable: MaxIncomeLG
Formula \( \text{ProducerLGMoney} / 0.01923 \)

Dynamic Variable: MaxProdTax
Formula \( \text{ProducerLGMoney} / 0.01923 \)

**Consumer Policy**

Parameter: ExtInc
Value 50 shocked in experiments.
Description Wages from external employers, Pensions, Benefits

Parameter: HHExpDelay
Value 0.25

Parameter: WlthPerceptionDelay
Value 0.25

Parameter: TargetWealthIncomeRatio
Value 1

Parameter: NDE_demand
Value 30
Parameter: NDL_demand
Value 33

Parameter: AdjustmentTime
Value 2.5

Parameter: LGWlthDelay
Value 0.25

Parameter: AT_LGMoney
Value 0.25

Parameter: IncomeLGDelay
Value 0.08333

Parameter: RelocalisationDrive
Value 1

Dynamic Variable: DE_DemandFraction
Formula
\[(DE\_DemandFractionLookUp(\text{DisposablePPAsPerCentDiscretionary})) \times \text{RelocalisationDrive}\]

Dynamic Variable: DisposablePPAsPerCentDiscretionary
Formula \[\text{DisposablePurchasingPower} / (\text{NDE\_demand} + \text{NDL\_demand})\]

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<td>0.5</td>
<td>0.7</td>
</tr>
<tr>
<td>0.6</td>
<td>0.65</td>
</tr>
<tr>
<td>0.8</td>
<td>0.61</td>
</tr>
<tr>
<td>1.0</td>
<td>0.6</td>
</tr>
<tr>
<td>2.0</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Dynamic Variable: TotalGBPIncome
Formula \[\text{LocalIncome} + \text{HHExternalIncome}\]

Dynamic Variable: PerceivedIncome
Formula \[\text{smooth3}(\text{TotalGBPIncome}, \text{HHExpDelay})\]

Dynamic Variable: PerceivedPurchasingPower
Formula \[\text{PerceivedIncome} + \text{PerceivedWealth}\]

Dynamic Variable: NDLPurchasingPower
Appendix

Formula \( \max(((\text{PerceivedPurchasingPower} - \text{NDE\_demand}) \times \text{NDEDemandMet}),0) \)

Dynamic Variable: NDE\_Expenditure
Formula \( \text{NDE\_demand} \)

Dynamic Variable: NDEDemandMet
Formula \( \text{NDE} \geq \text{NDE\_demand} ? 1 : 0 \)

Dynamic Variable: NDL\_Expenditure
Formula \( \text{NDL\_demand} \times \text{NDEDemandMet} \)

Dynamic Variable: NDLDemMet
Formula \( \text{NDL} \geq \text{NDL\_demand} ? 1 : 0 \)

Dynamic Variable: DisposablePurchasingPower
Formula \( \max(((\text{NDLPurchasingPower} - \text{NDL\_demand}) \times \text{NDLDemMet}),0) \)

Dynamic Variable: TargetWealth
Formula \( \text{PerceivedIncome} \times \text{TargetWealthIncomeRatio} \)

Dynamic Variable: PerceivedWealth
Formula \( \text{smooth3}(\text{HouseholdMoney}, \text{WlthPerceptionDelay}) \)

Dynamic Variable: PerceivedWealthShortfall
Formula \( \text{TargetWealth} - \text{PerceivedWealth} \)

Dynamic Variable: TargetSaving
Formula \( \frac{\text{PerceivedWealthShortfall}}{\text{AdjustmentTime}} \)

Dynamic Variable: ActualSaving
Formula \( \text{TargetSaving} > 0 ? \text{TargetSaving} \times \text{NDLDemMet}: 0 \)

Dynamic Variable: DiscretionaryConsumption
Formula \( \text{(DisposablePurchasingPower} - \text{ActualSaving}) \geq 0 ? \text{(DisposablePurchasingPower} - \text{ActualSaving}) : 0 \)

Dynamic Variable: ConsumeDE
Formula \( \text{DE\_DemandFraction} \times \text{DiscretionaryConsumption} \)

Dynamic Variable: DL\_DemandFraction
Formula \( 1 - \text{DE\_DemandFraction} \)

Dynamic Variable: ConsumeDL
Formula \( \text{DL\_DemandFraction} \times \text{DiscretionaryConsumption} \)

Dynamic Variable: TargetLGMoney
Formula \( \text{HhTaxDemand} \)

Dynamic Variable: LGWealthShortfall
Formula \[ \text{TargetLGMoney} - \text{smooth3} (\text{HouseholdLGMoney}, \text{LGWlthDelay}) \]

Dynamic Variable: LGSaving
Formula \[ \frac{\text{LGWealthShortfall}}{\text{AT_LGMoney}} \]

Dynamic Variable: ConsumptionLG
Formula \[ \max \left( \text{smooth3} (\text{IncomeLG}, \text{IncomeLGDelay}) - \text{LGSaving}, 0 \right) \]

**Producer Policy**

Parameter: ProdExportSales
Value 23

Parameter: ImportFraction
Value 0.3

Parameter: LabourProductivity1
Value 10

Parameter: ProdExpDelay
Value 0.25

Dynamic Variable: LGCDemand
Formula \[ \text{ConsumeLG} + \text{LGSpend} \]

Dynamic Variable: CashDemand
Formula \[ \text{DL} + \text{ProdExternalIncome} + \text{NDL} \]

Dynamic Variable: Demand
Formula \[ \text{CashDemand} + \text{LGCDemand} \]

Dynamic Variable: ProducerSales
Formula \[ \text{Demand} \leq \text{NominalCapacityLimit} \ ? \ \text{Demand} : \ \text{NominalCapacityLimit} \]

Dynamic Variable: NominalCapacityLimit
Formula \[ (\text{TotalLabourForceHours} \times \text{LabourProductivity1}) + \text{delay} (\text{ProdExtExpense}, 0.25) \]

Dynamic Variable: Rationing
Formula \[ \text{Demand} \leq \text{NominalCapacityLimit} \ ? \ 0 : (\text{Demand} - \text{NominalCapacityLimit}) \]

Dynamic Variable: ProducerNetIncome
Formula \[ \text{ProducerSales} - \text{ProdExtExpense} \]

Dynamic Variable: ProdPerceivedIncome
Formula \[ \text{smooth3} (\text{ProducerNetIncome}, \text{ProdExpDelay}) \]

Dynamic Variable: NominalLabourDemand
Appendix

<table>
<thead>
<tr>
<th>Description</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pounds total</td>
<td>ProdPerceivedIncome</td>
</tr>
</tbody>
</table>

Dynamic Variable: AnnualOwnersDividend
Formula: ProducerMoney

**Employment submodel**

Parameter: LabourProductivity
Value: 10

Parameter: HiringTime
Value: 0.08333

Parameter: WageRate
Value: 10

Parameter: WorkingPopulation
Value: 2.5

Parameter: HoursPerWorker
Value: 2

Dynamic Variable: LabourDemandHours
Formula: \((\text{NominalLabourDemand} / \text{LabourProductivity})\)

Dynamic Variable: EmploymentGap
Formula: \((\text{LabourDemandHours} - \text{LabourHours})\)

Flow: Hiring
Formula: \(\text{limitMax((EmploymentGap / HiringTime), MaxHireRate)}\)

Stock: LabourHours
Formula: \(\frac{d(\text{LabourHours})}{dt} = \text{Hiring}\)
Initial value: 0

Stock: UnemployedLabourHours
Formula: \(\frac{d(\text{UnemployedLabourHours})}{dt} = -\text{Hiring}\)
Initial value: TotalLabourForceHours

Dynamic Variable: MaxHireRate
Formula: \(\text{UnemployedLabourHours} / \text{HiringTime}\)

Stock: UnemployedLabourHours
Equation mode: Classic
Initial value: TotalLabourForceHours

Dynamic Variable: TotalLabourForceHours
Formula: \(\text{WorkingPopulation} \times \text{HoursPerWorker}\)
Dynamic Variable: UnemploymentRate
Formula \( \frac{\text{UnemployedLabourHours}}{\text{TotalLabourForceHours}} \times 100 \)

Dynamic Variable: WagesPaid
Formula \( \text{LabourHours} \times \text{WageRate} \)

Dynamic Variable: FractionLGC
Formula \( \text{zidz(LGCDemand, CashDemand)} \)
Description Fraction of wages paid in LGC (no division by zero).

Dynamic Variable: CashWages
Formula \( \text{WagesPaid} - \text{IncomeLG} \)
References


Centre for Towns (2017) Launch Briefing. Available at: https://www.centrefortowns.org/reports.


Hickel, J. (2018) 'The great challenge of the 21st century is learning to consume less. This is how we can do it'. *World Economic Forum*, [Online]. Available at: https://www.weforum.org/agenda/2018/05/our-future-depends-on-consuming-less-for-a-better-world.


MacLean, J. P. (1900 [2008]) *An Historical Account of the Settlements of Scotch Highlanders in America*. Glasgow: John Mackay.


Radzicki, M. J. (2003a) 'Mr. Hamilton, Mr. Forrester, and a Foundation for Evolutionary Economics'. *Journal of Economic Issues (Association for Evolutionary Economics)*, 37 (1). pp 133-173.


Selgin, G. (2017) 'The Folly that is "Local" Currency'. _Alt-M, Ideas for an Alternative Monetary Future_, [Online]. Available at: https://www.alt-m.org/2017/01/06/the-folly-that-is-local-currency/.


WIR Bank (2018) 'About Us'. [Online]. Available at: https://www.wir.ch/ueber-wir/wer-und-was-ist-wir/.


