Notes on Macroeconomic Modelling from a Promise Theory Viewpoint

As an application of Promise Theory

N.B.- this is a part-time 'work in rather slow progress', subject to change, comments are welcome

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Abstract

See how to use promise theory — sketching out how to make a link between micro and macro economic modelling.

Contents

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1 Introduction

Macroeconomics is the story we hear on the business news; its central concepts (GDP, employment, inflation, interest rates, stock markets, etc) ring like the familiar slogans of a branding campaign, but remain mysterious to many. *Microeconomics* is our day to day experience of paying for things with money, and the moral compasses of wages, purchases, debts, and consumerism to guide us. The link between the two, however, is mysterious, highly politicized, and filled with riddles.

When there is unemployment, scarecity, or prices rise, we blame 'The Economy', but what is this capitalized economy, pun or no pun? Is it the macroeconomy, or is our personal microeconomy to blame? What do broad sociological changes like employment have to do with how much interest we should have to pay on a mortgage? Our personal experience of economic trouble might be that of not having enough money to pay bills, but does that view scale to the level of a nation state, or the globe, or could politicians simply print more money?

Many of the narratives we have about economics come from experiences that are not directly relevant to the matters where we hope to apply them. Economists too seem to suffer frmo an inability to separate the mechanics of the economy from its intended purpose. That purpose is deeply political, so we could never fully separate the machinations of money from policy. Nevertheless, these notes are an attempt to understand the independent influences and where they can and cannot be separated—to underline some of the implications of muddling concepts, and see where the current narratives are flawed.

1.1 Politics and economics

As creatures of purpose and intent, politics and moral justice play a large role in our ideas and perceptions about the economy. For some, economics should describe a system supposed to be for the benefit of society; for others, it has become a detached and impersonal game of accumulation, to be mastered by 'winners', like a video game for social status. Economists themselves have frequently sided with political positions, and shaped their conclusions with deliberate political slants, bending the theory to fit their opinions rather than facts [1, 2], only later to be uncovered [3, 4].

Western society is designed for those with money: those with plenty do not need to emcumber themselves too much with matters of society and justice, because they can operate with a high degree of autonomy. Social and legal structures are needed mainly by those who are not of independent means, who experience a less well-functioning society, and naturally search for answers in its founding principles. If we don't have money, then someone else must have it, which leads to questions of equality and justice. We are suspicious of a system that leads to too much inequality.

1.2 The labour mythology

Our received view of personal wealth is that it is a product of work. This belief persists in the developed world, in spite of plenty of evidence to the contrary, and seems to be a hangover from the largely bygone era of subsistence living. Although working for money brings transfers some regular amounts of money from employer to employee, or from customer to seller, modern studies have shown that, in the developed world, at least, significant wealth cannot easily be earned as the product of individual work, rather it is accumulated as 'capital' over generations, often fortuitously, passed on through family dynasties by inheritance, and amplified by rent collection [5]. Thus the ability to grow one's wealth significantly depends on what 'rentable' assets one has. Such rentable assets are what are known as 'capital'.

1.3 People and institutions

Whatever 'The Economy' might be to any one of us, it impacts on the lives of the ordinary and the extraordinary alike. In practice, what governments estimate is 'national average output', aggregated for the entire country, one year at a time. This makes for interesting statistics on social progress, but it has little to do with any person's experiences.

Governments and central banks often imply that their decisions and actions can 'fix' the economy when it seems to go awry (as if by sheer political will), but fix which view of the economy and for whom? These are questions we need to ask. If the macroeconomy is about an average condition for everyone, then it actually refers to no one. The verdict is that such political interventions are often haphazard, and have often been misguided, egged on by politically partial advisors [4, 6–8].

The twentieth century has seen periods of financial turmoil, which have wreaked hovoc on nations and regions across the world: some of these worsened as a result of interventions by such public and private institutions, while others were successfully abated. Politicians generally took credit for perceived successes, and deflected attention onto others when they experienced failures[1].

1.4 Dynamical systems and Promise Theory

Any system of variables (information) defines a so-called 'dynamical system' as it evolves over time. Econonomic activity clearly falls into this category. Certain universal principles are therefore applicable to the economy, as they are necessary for the functioning of its system. We shall examine these through the language of Promise Theory, and scaling. For example, an influence within a network of interacting parties (agents), which occurs on one timescale, will see a response to that influence on some other timescale, and so on. It might not be immediate.

Running an economy is thus not necessarily like driving a car, steering a path, but sometimes it can be like planting a seed and waiting for it to grow. *Timescales* are a critical component in any dynamical picture, and must therefore absolutely be the concern of economic matters. Everything from 'can we pay bills on time?' to 'how quickly is average prosperity growing?' involves timescales. Time appears in the intervals between work and wages and bills and payments, in a microeconomic picture, but it has been almost entirely forgotten in the mainstream descriptions of macroeconomics, replaced instead with mysterious average 'rates' that seem to apply to entire average nations not to any individual person or firm.

In previous work [9], promise theory was used to deseribe money's role as a technology. These notes attempt to extend that picture to include the intentional and planned use of money, which is how we define economics. Promise theory is a useful framework because it allows us to combine desciptions of intent with actual dynamical behaviours, in a way that other frameworks gloss over. This is important, because many approach economics as if it were only a question of politics (assuming that we can have what we decide), while others treat the economy as an inevitable force of nature. The truth is surely somewhere in between, as it is for all dynamical systems.

2 Models

Accounting for the flows of information, in a system of variables (which provides what we mean by a 'physics' viewpoint), tells us that *macroscopic* or large scale phenomena are compositions of processes involving *microscopic* or small scale degrees of freedom. This means large scale behaviours are constrained to behave as aggregates of small scale activity. However, this does not mean that macroscopic phenomena are a trivial generalization of microscopic phenomena. Macroscopic conditions may act, conversely, as slowly varying or even stable 'boundary conditions' that hem in microscopic behaviours.

The extent of the coupling between scales, depends on the strength of interactions, with both strong and weak coupling regimes possible. If there is very strong coupling, systems are known to exhibit chaotic behaviour, making predictions difficult and unstable. Since there is no causal story for predicting details from the top down, a bottom-up analysis is the best approach we know. Our larger goal, from a social justics pespective, should be to understand the impact of macroscopic conditions on microscopic humans.

[1] Since capitalist industrial times in the Western world, there has been a picture of Capitalists (Land Owners) and Workers, Haves and Have-nots, or Right and Left. This has persisted, even as the status of social groups changed markedly after the two world wars [5, 6]. The the Left, everything is political and about injustice of the workers' plight, while for the Right everything is righteous and about the belief in entitlement. Today, it seems little political progress has occurred, but strides have been made in understanding and even in running the economy, were it not for the distortions of vested political interests.

2.1 Characteristics of micro- and macroeconomics

Microeconomics is a kinetic theory of the economy, ballistic and transactional, with payments for goods and services firing back and forth like billards or particle physics. The analogy to physics is a matter of trivial accounting, simple and measurable. But what about the macroeconomy? As the economic studies developed, during the industrial revolution, its philosophers went to some lengths to model the capitalist macroeconomy on the successes of the macroscopic physics of the day, namely the equilibrium thermodynamics of heat engines. This was an intentional design, based on 'physics envy', and it persists today [10].

What turned out to be missing from both physics and economics were essential arguments about *scale* and *indeterminism*, i.e. the role of large number approximations and loss of distinct information about a system (entropy). It was during the twentieth century that the role of *indeterminism* or *uncertainty* was given proper credence, in physics, but this did not percolate into economics. Keynes was apparently the first to point to the need to take uncertainty and indeterminism seriously [11, 12], but his work was only partially heeded and later misrepresented for decades [3].

2.2 Scale mismatches in modelling

Mismatches of scale are a constant dilemma for the description and governance of systems. We witness how characterizations, laws, regulations, and policy set for the average case fail to address the needs of individual cases. When one treats all cases in aggregation, the result may apply to none, and average concerns risk riding roughshod over individual concerns.

This is an inherent conflict of interest in the scaling of semantics. In those cases where semantics are of such importance, one has to address them on a case by case basis, by brute force.

2.3 Smooth and cyclic (long term) behaviours

Based on the Newtonian tradition, economists studying macroeconomic models used smooth differentiable functions to model changes in aggregate variables, assuming the kind of stability that was the basis for the engines of the industrial revolution. As one might expect, this had some success in describing large scale aggregate behaviours on timescales at which changes to averages could be considered smooth (years and decades).

One macroeconomic phenomenon, which has been modelled in this way, is the cycles of 'boom and bust' in capitalist economies. During a boom the economy grows, jobs are plentiful and the market brings profits to investors. In a bust the economy shrinks, people lose their jobs, and investors lose money. Economic models, such as Goodwin models, and their extensions as 'Minsky models' by Keen [13] and followers [14, 15], are differential formulations of economic cycles in a closed network. These cycles of employment, earnings, consumption, capital investment, and rent collection, compete with one another to bring about cycles of 'boom and bust', though the reasons for such cycles are not without some controversy.

The behaviours of the macroeconomy on large and long scales is interesting, but not very practical, since human lives focus on payments and transactions day by day, not decade by decade. Moreover, the sudden catastrophes of the financial crises in the 70s, 80s, 90s, 2000s, etc, were all more sudden than this, and their causes were in no way represented or diagnosable by the models. If we are to approach an improved understanding of the transactional and abrupt changes in economic systems, in the same way that physics took on such phenomena, then economics must also embrace techniques that do not exclude them by design.

2.4 Semantic spacetime view of the macroeconomy

The accounts of economics by Minsky are paricularly useful as a basis for describing a multiscaled view of economic activity [3]. His descriptions are both detailed in capturing real world details, and focus on the mechanics rather than the politics of phenomena. Using promise theory to analyse Minksy's decomposition of the macroeconomy [6] may help to reveal some of the structural dependencies, and potential failure modes, of our present day economic structures.

Despite the elimination of small scale semantics from present day models of the macroeconomy, the economy is not so large, over daily human timescales, that semantics are unimportant, so a scaled promise theoretic view is appropriate. It seems plausible that we can identify a network of economic activity as a kind of semantic spacetime [16–18], and even as a cognitive system (whose sensory apparatuses are yet to be defined).

2.5 Transactions as monetary promises

Promise theory asks us to consider: who and what are the key agents in a network of interactions, and what promises do they make to one another?

- Agents at a microscopic level could be individual persons, households or firms, interacting amongst themselves.
- Agents at the macro level may include nation states, governments, and central banks. The promises macroscopic agents make at the macro level cannot directly or immediately influence microscopic scales (just as weather does not directly change people's behaviours to any large extent under normal conditions), except as an effective (non-linear) boundary condition; but, with a powerful information technology, multi-scale agents could self-govern by detailed balance, i.e. by brute force (like a Maxwell's daemon) countering every debt with a payment.

In aggregation, agents may accumulate into certain classes, playing particular roles, but we should be cautious about inferring smooth statistical properties to these bulk quantities, as remarked in section 4.

2.6 Intermediate agents and exchanges

Agents, working together in clusters, may use intermediaries to delegate the keeping of promises (see the delivery problem in [19]). The agents involved in monetary interaction promises are often only the subject of transactions. It is increasingly rare for them to be involved in the transacting of money. The subjects of payments are now more commonly only conditional dependencies parameterizing payments. Apart from cash, money never comes into contact with people or institutions. Banks or other currency hubs mediate in making payments, because money is now almost entirely pure information.

Money flows through intermediaries, which are the transactors of currency. In keeping with [9], we call these *accounts*. In the capitalist economy these usually belong to banks. Banks form hubs. Recently decentralized currencies, based on 'blockchain' technology, have been experimented with. In this case, the blockchain acts as a kind of bank, often with a limited array of functions compared to private and national banks.

Money moves from account to account, through the monetary network, conditional on the account holder's (A_i) authorization:

$$\text{Account}_1 \xrightarrow{+\mu|A_i} \text{Account}_2 \tag{1}$$

Occasionally cash might be exchanged, in which case there are no account holders, and individual holders H_i are involved:

$$H_1 \xrightarrow{+\mu} \blacksquare\, H_2. \tag{2}$$

Ownership is permantly decoupled from monetary matters, as described in [9]. Tying ownership to payment requires a significant legal and cultural framework.

3 The languages of scale: semantics and dynamics

The language of economics conceals many details that are taken for granted, and thus requires some explanation. On finding its nomenclature, economicists have semanticized concepts that a physicist might have rendered separate by a more impartial reference to scales.

Semantics relate to the *context* in which processes appear [18], and these are chosen within a human narrative. The human concept of 'meaning' effectively maps to a 'context' in which promised outcomes play a role. Typically we design such that:

Semantics describe issues or modular concerns, placing a ring around an issue, or the marking of a contextual positioning, by virtue of its promised role or identity.

Dynamics describe an approximate continuity of changes along a quantitative trend, pertaining to the same chosen issue.

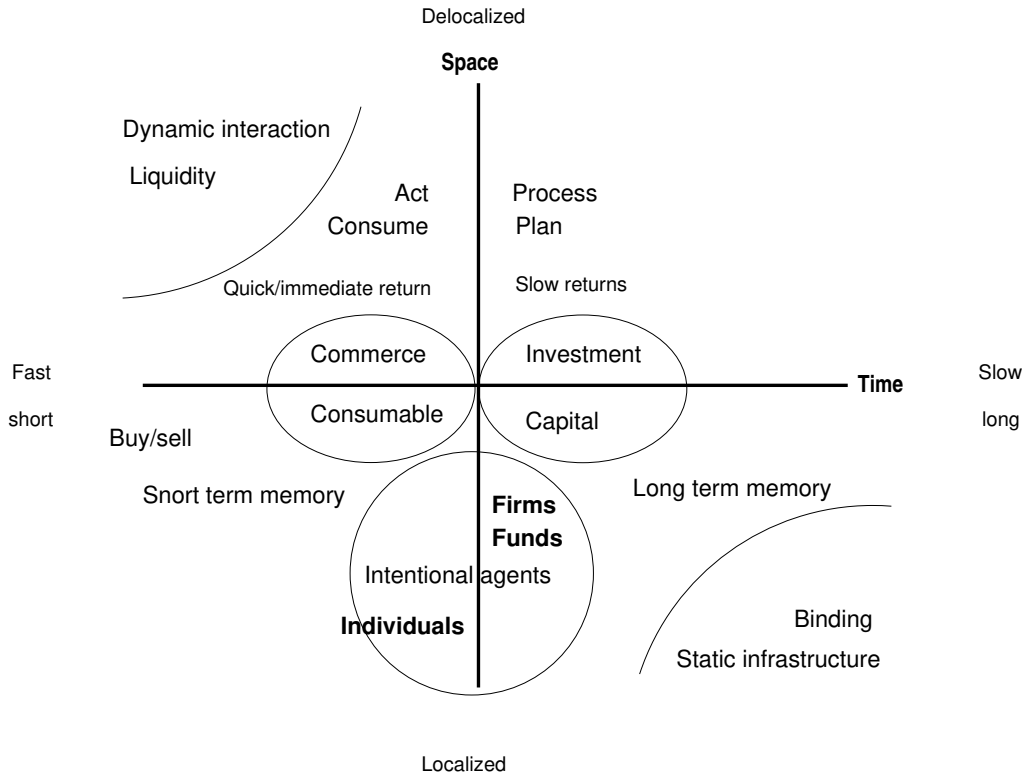

Figure 1: The interaction scales for economic processes can be organized by spacetime scales. The traditional separation into capital investment and commodity consumption is not significantly different in semantics, but different in timescale.

3.1 Interaction scales

Figure 1 attempts to show how the separation of concerns in economic semantics broadly follows implicit space-time scales, where space refers to aggregation of instances, and time refers to accumulation of duration.

The scaling of payments from micro to macro levels involves a change of perspective:

$$\text{transactions} \xrightarrow{\text{aggregation}} \text{flows} \xrightarrow{\text{duration}} \text{investments} \tag{3}$$

$$\text{things} \xrightarrow{\text{duration of promise}} \text{capital} \tag{4}$$

Thus, economists will speak of spending and investment (which a physicist might call fast and slow spending, or short term and long term money interactions). Economists speak of commodity goods and capital, where a physicist might only note the timescale over which these goods are held and are used up. Capital items (long term goods) tend to be more expensive purchases, and they tend to be usable for processes that can lead to (rent collection or manufacturing), whereas consumer goods tend to be eaten or used quickly (and although they fuel all our activity, we choose not to see them as wealth creating).

Economists refer to marginal quantities, when meaning derivatives with respect to its parametric variable. Scale free marginal increases have the form

$$\frac{dX}{X}. \tag{5}$$

The semantic nomenclature in economics, like many technical jargons, feels arbitrary, and forces us to remember the semantics rather than intuit their meanings from simpler concepts like time and space that are familar. As fields mature, semantic separations of concerns tend to be replaced by a unified picture, in which distinctions are described in relative terms (by measure in duration or size).

- The term liquidity is used to mean how easily something can change hands, by analogy to flow. The terms free or bonded are used in natural sciences. Money might be viewed as being locked into a purchase, as if it were a chemical compound waiting to be released by some suitable reaction (the analogy is not important, but the scaling is). Cash is free to be spent and is thus liquid.

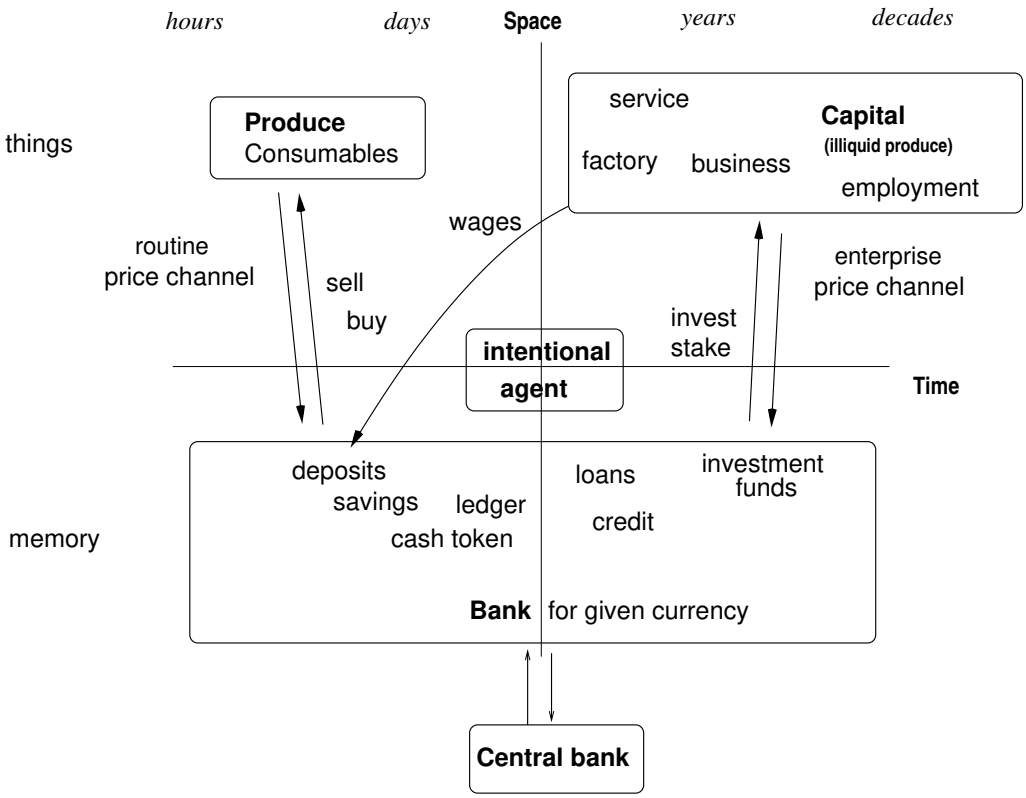

Figure 2: The flow of money in the economy does not pass through humans, except for cash transactions (which are increasingly uncommon for all but small daily exchanges). Humans are only conditional authorizers of transactions that happen between different ledgers. The connection between money and property is quite tenuous, and cannot be maintained naturally without the machinery of legal convention.

- The main thing distinguishing the terms *capital* from *commodity goods* is a timescale for the keeping of its promises. Capital is an illiquid asset, whose resale price decays slowly, perhaps after appreciating in a specialist market, while a commodity's life cycle is short and liquid, with therefore little opportunity for resale. Luxury goods lie somewhere in between these cases: if not immediately consumed, they might be resold (other than wholesale/retail distribution).
- A return on investment (ROI) is an amount of rents or profits that can be extracted from a capital asset. This is different from what the immediate resale value might be. So what is the profit potential of a property would come from renting out the property, or from holding on to the property in a rising market.

3.2 Money flows as information channels (distinguished by semantic labels)

A flow of money is the term used to describe a channel for many transactions, along which information about payments flows? This is a vague definition: what distribution of promises, agents, or assets contributes to a channel of exchange or flow? Different promises in the distribution may have different semantics, and may fail to be kept in different ways. This will affect the discrete time outcomes of an economic system, in a potentially discontinuous way, so it has to be addressed as part of definitions of scale.

The language of information theory is more appropriate than the language of fluid dynamics, but the language of flow is in common use. Each transaction attaches to certain semantics according to the viewpoints of the agents involved. Economic theory does not usually caer about these interpretational details, however. It is concerned mainly with the amounts, or with 'balance of payments'. This is similar to what we do in physics when looking at energy accounting.

The important role of semantics is similar to that of 'kinds of interaction' in the physical sciences (also called types of force): certain kinds of agent can have certain kinds of interactions with other agents. In promise theory language, which we can use for both cases, we would say that certain agents makes kinds of promises that enable interactions to happen with outcomes that depend on the kind of interaction.

To microeconomic agents, a payment reflects a particular purchase or payment of a particular debt. The semantics are crucial to maintaining context and separation of concerns. No one would argue that, when a rich hieress pays a million dollars into the bank, that all other account holders' debts are suddenly paid off. Amounts are labelled by the payer and the payee, by underlying promise semantics.

The aggregation of promised monetary flows is schematic, and should not distract anyone into the lazy belief that there is any determinism involved. Minksy's characterizations are both comprehensive and honest in this regard, and I shall not try to reproduce them here—only issue a warning that the effects of individuals on the aggregates should remains to be described in detail, and we should make no a priori assumptions about their decoupling. Indeed, economic agents in a variety of roles are of all sizes, and their impact on the bulk quantities may be insignificant or dominant.

3.3 Sources, sinks, and relays

Sources and sinks of money are banks and garbage dumps.

Money may be redistributed by banks, governments, stealing, etc..

Interest is a convention (a rent) paids as an incentive to attract funds in a particular direction.

3.4 Generating wealth: wages, employment, and finance

Of the legacies we have inherited from the origins of the capitalist economy is the narrative that wealth is a result of work. This is a simplistic and quite misleading view, but one that remains the stubborn view of ordinary folk whose lives have been dominated by work. While this may change in the coming decades, due to automation, our normal lives have come to be dominated by the culture of 'work to live'.

There are approximately three sources of money for agents in an economy:

Exchange Agents (people, firms, etc) offer service or goods in exchange for money. This does not create money. This may include rents on property held, and wages for work.

Gifts Agents give money as gifts, inheritance, or come upon it by providence.

Finance Agents may borrow money from a lender. If the lender is an authorized bank, this results in new money being created [9].

Money changes hands in these transaction types, and work only enters as a 'norm' that happens to dominate the lives of many people in the developed world.

- A nominal wage is the rate of pay employees are compensated. If you're paid $15.00 per hour, your nominal wage is $15.00 per hour. The most important thing to know about a nominal wage is that it is not adjusted for inflation. Nominal wages are the wages received by a worker in the form of money. Therefore, nominal wages are also called money wages.
- So-called real wages are adjusted for inflation, in the following sense. Real wages can be defined as the amount of goods and services that a worker purchases from his/her nominal wages. Therefore, real wages are the purchasing power of nominal wages.
- Labour supply is assumed to depend on the ratio of wages to prices, in gross average terms.
- Other benefits for workers may be given 'in kind'. Money is only one medium of exchange for promises kept. The ability for people to fulfil their promises to pay in contracts and bills, etc, increases when they have more money. But other factors might come into play to prevent or allow equivalent promises to be kept. Payment in kind is one example.

3.5 Assets and substitutes

Assets or things T may be real (ownable things) or imaginary (deeds or records of intent). Bonds and bitcoins...

Assets make certain functional promises, else we wouldn't value them. For every asset there may be a number of 'substitute assets' which make some of the same promises, but not all. If there is sufficient overlap, an agent might promise to accept a substitute in place of T.

3.6 Inflation

There are two kinds of inflation [3]:

- Wages rise at a slower rate than prices (on average), but they keep pace in a more or less linear fashion.
- Rising prices induce rising wages, etc in an unstable spiral of positive feedback.

Investment imparts an inflationary push...relative wage rates reflect market demands

Purchasing power may not change if one good rises and another falls in price. The net result is the same, so there is an aggregation over individuals

Even in a world with collective bargaining, wage increases have to be ratified by financing.

In a simple model, grossmoney profits in the production of goods for consumption rise when total wages in investment goods production rises, and fall when they fall.

The sudden failure to keep promises might there for be the result of many causes. Contacts cab be broken, with short and long term consequences.

> In an economy with complex corporate and government stucture that now exists, the course of money wages is not the triggering factor in inflation. Inflation is, first of all, the result of financing too many claims on the supply of consumer goods–such as occurs in wartime, or a the result of a drought–or any expansion of incomes that will be available to finance the demand for consumer goods, without any concomitant increase in supply, will lead to rising prices.

In other words, bidding for prices, like in the housing market.

In the Philips and Phelps-Brown, Samuelson and Solow account of wages and employment, increase in wages leads to a decrease in employment (at constant....?)

This plays on assumptions about what employers think are their future prospects, and therefore requires some time-based speculation

- A key set of dimensionless ratios, for economic behaviour, are the ratios of an agent's wages relative to the prices of things it considers buying may provide an approximation the tendency to spend.
- Inflation: prices may increase if supply in a thing (or close alternatives) is short. e.g. housing market. Inflation is a slow process, compared to buying and selling.
- Big government can redistribute money, but its intentions can also focus and amplify intent, concentrating demand for something. This government programmes can lead to inflation, by making certain assets scarce.
- The semantics of any large coherent influence, by a large company or a government can skew the price profile of the economy.
- Institutions like firms and government increase the lifetime of agents by spanning multiple human lifetimes, and taking on an independent purpose. Large insitutions are needed to carry out large projects, as these are the only ones that can raise sufficient financing.
- A lender of last resort is under no obligation to sell its bonds to banks, so it has some measure of power of life and death over institutions.
- The normal functioning of a capitalist economy is that debts are repaid by the rents earned from capital assets. The source of the tenant's money is borrowing by the tenant, or wages (which are rents on the capital assets of the company).
- Capital is similar to a bond, in that it promises future income.
- If money is instantiated by banks along with debt, and that money is repaid with interest, how does the money supply increase to accomodate inflation and interest? More and more assets are created, and refinancing, and bond instruments have to finance these assets. Thus the debts echoes have to be held in this memory of bonds and refinancing. Inflation may gradually erode debt. So no one really repays everything: money moves around, but as much money as is needed to keep the flow of things remains in circulation.
- An important aspect of this is perishability of assets. What effect does depreciation and obsalescence have?
- In a non-capitalist economy, the state is owns everything and rations are provided. How is the money supply controlled? How can it expand and shrink to encompass demand and supply?

4 Differential models of the economy

Following a tradition from Newtonian physical systems, economic dynamics are modelled using differential rate equations. This could be criticized as choosing models to fit the tools, rather than vice versa. The scales over which smooth differentiable functions can be defined for economics suggest that such models might describe changes over the past several decades, rather than the coming weeks. So, while they have some interest for the purpose of seeing patterns and cycles in the long term economy, given certain assumptions of invariance, differential models have probably little role to play in predicting the daily concerns of ordinary economic participants.

4.1 Goodwin models

Goodwin first tried to model the interaction between consumption and investment scenario (a so-called class struggle model) in a simple local 'mean field theory' at the macroeconomic level, in order to investigate the normal modes of oscillation between investment in capital and consumption of consumables, and their stable equilibrium states of these modes. The result was a set of coupled differential equations, based on the assumption of exponential growth of population and output [21]. The model has since been extended to account for the effects of debt highlighted by Minksy [3, 7, 14, 22][2].

In a Goodwin model, one looks for 'monolithic' characterizations of the economy: i.e. single variables that summarize the totality of microscopic behaviours. This approach has worked well for the study of cities, where broad universalities have been discovered across a range of scales [23, 24]. The advantage of this is that one can explore the generic aspects of the major flows. The disadvantage is that the result says nothing about the experiences of any single agent, at any scale, within the model. Society is treated as a ball on a string.

The methodology thus consists of formulating a small set of coupled oscillator equations, and searching for the stable normal modes of those coupled oscillators. For stability analyses, one can search for the attractors, and Lyapunov exponents, in a way that is not practical in a microscopic model. Interpreting the equations in the context of the real economy is a matter of some speculation, however, given the low level of detail in such a mean field approach.

4.2 Model of a single currency economy

The parameters in a model are generally chosen to represent a single imaginary nation state, with a closed economy. Modelling a world of interacting nation states is possible in principle, but would shift the focus towards even less relevant variables. A loss of detail is a limitation of a mean field theory, but universal scaling laws may mean that such details are not important to the universal characteristics of the model on average. Dynamically, this means that the network of interacting scales is truncated arbitrarily. The impact is hard to assess without trial and error. Some evidence of the universality of basic phenomena ecxhibited by the models comes from [14, 15]. It is highly plausible that agent-based modelling could supply further evidence with much more detail. Agent-based models are more complex, but more realistic, and offer great potential to gain a detailed insight into the effects on very specific agents within a society.

Minsky's point was that, as a dynamical feedback network, the economy is basically unstable. A semblance of stability can be maintained by timely corrections as a matter of public policy, on a timescale at which the system remains almost linear. This is essentially like making frequent course corrections to a spacecraft trajectory as it passes close to unexpected gravitational bodies. If the corrections are timely, a stable trajectory is maintained. If one waits too long, the craft may be lost forever. The question we have not yet answered for economics seems be: what precisely are those key timescales in an economy?

4.3 Quantities

Another disadvantage of a macrolevel model, in which one deals with a highly aggregated picture, through composite variables is lies in the ambiguity of interpretation. Common terms like 'capital', 'investment', 'consumption', 'employment', etc., are used as though they have unambiguous meanings, but different authors define these aggregate quantities differently. The relationship between labour and production is also somewhat naive in the age of increasing automation.

A promise theory approach, in which agents are referred to by functional role rather than '(un)employed', 'investor', etc. is best replaced by the extent to which those functions exist amongst a multi-role population. Some nation states may be vulnerable to an absence of certain roles. It is well known that the culture of investment is

[2] Although Minsky never formalize his ideas as a dynamical model, in the traditional manner of differential equations, Keen did so [13] and others have expanded on these models, e.g. [14, 15].

	HOUSEHOLDS	FIRMS		BANKS	SUM
Balance Sheet					
Capital stock		$+pK$			$+pK$
Inventory		$+cV$			$+cV$
Deposits	$+M$ also $+D$			$-M$	also $-D$ 0
Loans		$-D$ also $-L$		$+D$ also $+L$	0
Sum (net worth)	X_h	X_f		X_b	X
Transactions		current	capital		
Consumption	$-pC_h$	$+pC$		$-pC_b$	0
Capital Investment		$+pI_k$	$-pI_k$		0
Change in Inventory		$+c\dot{V}$	$-c\dot{V}$		0
Accounting memo [GDP]		$[Y_n]$			
Wages	$+W$	$-W$			0
Depreciation		$-p\delta K$	$+p\delta K$		0
Interest on deposits	$+r_m M$			$-r_m M$	0
Interest on loans		$-rD$		$+rD$	0
Profits		$-\Pi$	$+\Pi$		0
Financial Balances	S_h	0	$S_f - p(I_k - \delta K) - c\dot{V}$	S_b	0
Flow of Funds					
Change in Capital Stock		$+p(I_k - \delta K)$			$+p(I_k - \delta K)$
Change in Inventory		$+c\dot{V}$			$+c\dot{V}$
Change in Deposits	$+\dot{M}$			$-\dot{M}$	0
Change in Loans		$-\dot{D}$		$+\dot{D}$	0
Column sum	S_h	S_f		S_b	$pI_k + c\dot{V}$
Change in net worth	$\dot{X}_h = S_h$	$\dot{X}_f = S_f + \dot{p}K + \dot{c}V$		$\dot{X}_b = S_b$	$\dot{X}$

Table 1: Balance sheet and transactions flows, cited directly from [15]. Note that the authors changed notation for deposits and loans between [14] and [15], leading to some unfortunate confusion over use of 'D'.

very different in different geographical regions, leading to international cooperation and investment across borders. Such matters can only be simulated through stand-in variables in an aggregate approach.

Table 1 shows a balance sheet of monetary exchanges used in Grasselli and Huu's version of a Goodwin model. This version contains extensions to explore the role of savings, inflation, and debt. I've picked their version of the models for their neat presentation.

4.4 The normal modes

Authors characterize the normal modes of these equations variously [14, 15, 21], both in terms of equilibrium attractors and monetary exchange flows. Flow characterizations focus on the two main competing loops of the Goodwin model and whether one dominates over the other. When investment in new capital dominates, wages must fall and consumption may falter, leading to a deflationary spiral of falling demand. On the other hand, when investment is insufficient, there is insufficient capital for expansion, and there may be insufficient production to meet demand, leading to higher prices and inflation.

- Good equilibria in which there is finite debt, positive wages and positive employment.
- Bad equilibria in which there is infinite debt, wages fall to zero, and employment the same, in some combination.

The assumptions are that there is a single unform market, with no expicit dependencies, only a single level of price and wage inflation, and all companies are represented by this singular average behaviour. Money cannot be created or destroyed, so the models do not model the changes in money supply. The benefits of the models are the relative simplicity, controllability of parameters to explore the solution space, and conduciveness to differential modelling. The downsides are the over simplification of the key variables, and the assumption that everything produced gets spent or reinvested like a Kirchoff electric circuit. The models one describes apply to everyone and yet to no one, and their idealization places their effects on a timescale of years that is too long to be of relevance to individuals in society. For an individual, one can go from riches to rags overnight.

GH	YBY	SK	Dimensions	Meaning/Semantics
N	N_w	N	$[1]$	Population
ℓ	N_w	L	$[1]$	Workforce $\propto e^{\beta t}$
λ	λ_w	$\lambda = L/N$	$[1]$	employment level/rate
p	P	-	$[\mu]$	Price level $\propto e^{\gamma t}$
a	θ_w	a	$[1]$	Productivity per population $\propto e^{\alpha t}$
W	W	W	$[\mu/t]$	Wages
Y	Y	Y	$[\mu/t]$	Agent output
Π	R	Π	$[\mu/t]$	Return on Investment / Profit
C	C	-	$[\mu/t]$	Consumer consumption
I	I	I?	$[\mu/t]$	Capital Investment rate
K	-	K	$[\mu]$	Capital held
pI	B	-	$[\mu/t]$	Inter-agent trading/purchases
L	-	D	$[\mu]$	Debt level (loan) of agent
D	-	-	$[\mu]$	Bank deposits of agent
r	-	r	$[1]$	Interest rate
$w = W/\ell$	w	$w = W/L$	$[\mu]$	wage level per capita
$\Phi(\lambda) = \dot{w}/w$	-	$w(\lambda) = \dot{w}/w$	$[t^{-1}]$	wage rate

Table 2: Some literature conventional notations compared. In this paper, we follow the notations of GH [14, 15].

Grasselli and Huu [14, 15] have generalized the models to include a number of other parameters such as inventory accumulation and market speculation, and have studies which assumptions are stable to changes of assumption. They some additional variables, and have a reader-friendly presentation of their model, with attention to mathematical correctness. They consider derivatives $\dot{M}, \dot{D}, \dot{V}, \dot{a}, \dot{N}, \dot{p}$, i.e. the growth rates of deposits, debt, inventory, productive output, population, and price levels.

I shall use the notation of Grasselli and Huu (GH)[3], as well at my own notation from [9].

4.5 Model timescales

To understand the limits of validity for these equations, we need to understand to what extend these time derivatives represent actual changes in an economy.

- Timescale of transactions (B2C) (days, months).
- Timescale of accounting (B2B) (days, months).
- Timescale of responses and defaults (days, months, years).

Detailed balance conditions that would accommodate smooth continuity of a differential equation may be achieved in one of two ways: by parallel (spacelike) ensemble aggregation, or by serial (timelike) ensemble stability. The latter case takes longer to achieve, and the former case requires a larger system to absorb fluctuations. Thus the differential macromodels aim their sights at a world of large long-lived corporations.

Grasselli and Huu consider price variations and inventories on top of Keen's model and show that not only debt crises can destabilize economic flows, but also voluntary or imposed hoarding, such as by lack of demand, may lead to collapse of wage share and unemployment. So a recession may also be caused by too many unwanted commodities.

They also effectively show that a lack of money supply, in the face of rising prices can lead to falling employment with or without a debt crisis.

4.6 Limits of differential models

What could be missing from a differential equation model? By definition, a differential model cannot properly represent catastrophes [25] and discontinuous changes in a well-behaved manner. However, all failure modes in a network are sudden and catastrophic. For example, the failure of one agent causes a cascade of dependent failures.

Differential equations are based on the assumption of sampling the system in small increments Δt. To some extent, the relative sampling rates are adjustable by scale coupling constants in the equations. However, there is an

[3]There is some poor typography in [13], and GH consider a more general case with greater lucidity.

underlying assumption of smooth continuity, which obvious empirical experience tells us cannot be a good guide to anyone's experience of the economy.

Discontinuities abound, whether by sudden changes in interest rates, price changes, the start of new businesses, and the death of others, accidents, weather conditions like hurricane events or cold spells that increase heating costs, or personal tragedies, winning the lottery, etc. None of these effects can easily be argued within the framework of a differential Goodwin model. We are limited to regimes in which we can argue:

$$\frac{\Delta t}{T} \quad \to \quad 0 \tag{6}$$

Implying either:

$$T \quad \to \quad \infty \tag{7}$$

$$\Delta t \quad \to \quad 0 \tag{8}$$

Since cash flows are usually computed say monthly or quarterly basis for most businesses, then this is the sampling rate of a trend that could be captured by an aggregate differential model. So, whether appealing to the Nyquist frequency of the sampling rate, or to general physical handwaving, one would expect $T \gg \Delta t$, say by an order of magnitude. This indicates that any changes represented by a dt or a d/dt would be on the timescale of years, not shorter. Thus, a differential model could never capture the sudden catatrophe of crack propagation in a metal or the sudden failure of the banking system by end of month bankruptcy.

A further delay in the action of the equations comes from real-life *hysteresis*. Because of the normal periodic accounting, the response to failures is likely to be delayed by at least an accounting period. There is thus natural inertial lag in the system, which depends on the particular practices of an agent that depends on another. The main argument for discounting hysteresis is that bulk time-based interference smooths out such effects. This means that one has to be dealing with a diversified portfolio of equivalent interactions, in which there is no fixed time correlation. This suggests only economies of above a certain size will be modelled well by a Goodwin model.

4.7 Inventory, savings, and rationing

Accumulation of a buffer against the unexpected, whether in manpower, money savings, or production inventory is the way all systems become resilient to external perturbations. In a network, any agent, which accumulates savings or hoards money, effectively takes money out of circulation, potentially impeding future trade. This is a main reason why wealth inequality is a problem.

- Governments or central banks can withdraw excess money delierately in order to discourage spending. Unlike wartime rationing of specific goods, according to supply, this blunt instrument has little power to distinguish behaviours that are good or bad for society as a whole. Taxation, rent-collection, or through the expiry of fixed term contracts, especially finanical products allow powerful agents to accumulate money that then cannot be used by others to get access to their network dependency needs.

- A singular central bank is thus the ultimate source and sink for money supply. Each currency must have such an entity to control its supply, in a capitalist system, but other agents may still be able to compete with monetary policy by holding and releasing large amounts of money. This is a weakness of a system based only on a single currency. In a system of microcurrencies, a system more akin to wartime rationing, flow controls could be applied to specific functions—with the potential for both helpful and harmful interventions[4].

- Only the central bank has the ability (in principle) to create or destroy money without liabilty. Hoarding of money is radically different from hoarding of goods, because money is the universal proxy for transferance. If every agent could be assured a buffer of funds to cover immediate liabilties, and no agent was allowed to build up too large a hoard, the economy could be regulated more effectively.

- It is fear of losing access to a fair share that leads agents to save and to hoard. Agents might hoard in order to artificially inflate prices by manifacturing scarcity. Again, if this were regulated, ill effects could be avoided. In orinciple society could easily be reengineered to work on different assumptions, given the vast increase in brute force ability to manage information in the modern era.

[4] In either case, money can be used as an effective weapon. A single currency is a weapon of mass destruction, and little selective power. A microcurrency can be a smart silver bullet.

- Instead of giving cash, one could be awarded a licence to spend or buy goods of different kinds. Fair distribution could be based on a different level of competition, in which users compete for right of access by argument and judgement (like a grant mechanism). This could lead to an overwhelming bureaucracy unless that too were regulated.

5 A promise approach (non-local response with discrete transitions)

A differential formulation based on network-wide aggregates, accumulated over an implicit timescale, has a number of weaknesses. It idealizes many of the measures and assumes that there will be no accumulation, buffering, or memory function to monetary exchanges. All these features point to an implicit timescale that is much longer than individual payments. My guess is therefore that a differential model could only apply over a timescale of several years, not over months or less. This means that macroeconomic modelling holds no interest for individual agents, whether humans, households, or small to medium sized businesses. It can only be a coarse approximation of the long term effects of generic microscopic actions that are made in response to decisions and actions of individuals, firms, and institutions of government.

Some key promise types involved in social cooperation:

- Ownership (persistent)
- Membership of an organization of entity (composition and merger)
- Rent or interest payment (repeated)
- Sales price
- Acceptance of sale (one off per item, or repeated relationship)
- Wage levels, employment contracts
- Lending terms, offered and accepted
- Double entry book-keeping?
- How states assess taxation.

If persistent goods change hands over time, their market price can change up or down too due to appreciation or depreciation.

5.1 Multiscale network approach

Promise theory allows us to understand the scales of any network of agents, and thus offers a bridge between views based on sudden interventions, like policy changes, environmental circumstances, and the slow, broad aggregate measures that refer to the mythical 'economy' we hear about on the new.

The attempt to build a causal model that makes the links from micro to macroeconomics has acquired a bad reputation, in some circles, because of the attention afforded to 'demand curves' and the attempt to extrapolate from a Robinson Crusoe economy to a society (see a discussion in [7]). However, that extrapolation was only based on wishful thinking, not on a mathematical model or formal reasoning, and it seems frankly one of the more bizarre fabrications of economic reasoning.

The microstructure of any economy must have the form of a network, formed by voluntary relationships of varying durations, each cemented by the binding of various promises. Some influences are non-voluntary, such as the 'exogenous' effects of weather and resource starvation. These promises have a wide range of types. Promise theory describes the scaling of agent-like structures, in hierarchies and flat ensembles [16, 17, 26]. The economy may then be seen as a superposition of multiple sparse networks labelled by these types, that interconnect through dependencies. Such conditional dependencies of promises are the link that can transmute one kind of promise into another, forming a broadly percolating network:

$$A \xrightarrow{X|Y_1,Y_2} A' \tag{9}$$

e.g. if I am promised Y_1 and Y_2, I can promise X. The linkage through dependencies is both the source of all component assembly, and commoditization of component construction, to ascend the evolutionary complexity ladder by combination and recombination. It is the also the source of its fragility.

Dependencies are the mechanism that causes errors, failures, and faults to propagate. They imply strong coupling, with brittle transmission of failures. Failed promises propagate at the rate at which the promise binding is relied upon (i.e. the source information is sampled, in information language). Since each agent may keep an inventory (a memory buffer) of what it promises (or what it relies on), agents can be self-sufficient or autonomous for a finite duration.

Example 1 *If a garage stops promising fuel, a car can still drive for many miles before this dependency on fuel affects its ability to promise transportation. Conversely, electric lighting has no buffer for electricity, so ist dependence on its power source is strong and immediate, leading to instantaneous fault transmission.*

This tells us that short timescales are a critical part of an economic model, just as debts and repayment schedules incur artificial costs through interest, delays might lead to degradation (e.g. food in a freezer is ruined after a few hours if it loses power). Any default on a time limit is a sudden event that can begin the propagation of a fatal crack in an unstable system.

Example 2 *There is a connection to smart spaces, as defined in [26], where we have access to economic scaling data, thanks to the ingenious research of West and Bettencourt and collaborators. Suhc data allow one to see how aggregation affects certain relationships in the presence of dependencies, and gain some insight into the percolation thesholds of promises. This, in turn, makes a connection to more general network science [27].*

Promise theory allows us to make the connection between the mean field quantities and their underlying elementary sources. Contrasting with a differential continuum approximation, a promise network will be a fundamentally discrete transactional system, that could be used as a blueprint for a cellular automaton or agent-based model.

5.2 Elementary agents and superagents

Some important elementary agents, in a promise model, include the following symbols (see figure 3):

AGENT SYMBOL	DESCRIPTION
$A_i \in \{H, T, E, \ldots\}$	A generic agent
$H_i \in \{\overline{H}, \tilde{H}\}$	Humans or households. – $\overline{H}_i$ (stable residential) – $\tilde{H}_i$ (transient visitors, e.g. tourists)
E_k	Business or government entities
B_j	Banks, which are authorized to create money for lending
T_a	Thing category superagent (goods and services for exchange)
$M(T_a)$	A market superagent for thing category T_a

Grasselli and Huu point out implicitly that, rather than considering individual humans as the relevant agents, the minor superagent of 'household' is a more relevant unit for consumption, as a household is, almost by definition, a unit of shared resources. One exception, which cannot be easily be modelled in the differential model is the transitory appearance of migrants, such as tourists. In a city, like my own city of Oslo, the number of vistors in a year outnumbers the number of stable residents, so it would be a mistake to discount them.

- Monetary exchanges are written as $\pm\mu$, as in reference [9]. Note that the sign refers to give and receive, not to the sign of the amount. All amounts are assumed to be positive.
- Total balance of savings or holdings H_μ of an agent are denoted by:

$$H_i \xrightarrow{H_\mu} * \tag{10}$$

$$B_j \xrightarrow{H_\mu} * \tag{11}$$

$$E_k \xrightarrow{H_\mu} * \tag{12}$$

  Without the ability to build up a buffer, agents would not be able to weather the shocks and unexpected circumstances of the real world. A differential model cannot represent such realities, but these are the very events that may lead to collapses. They are directly analgous to the stress concentrations that are instrumental in material fatigue and crack propagation in mechanical failure.

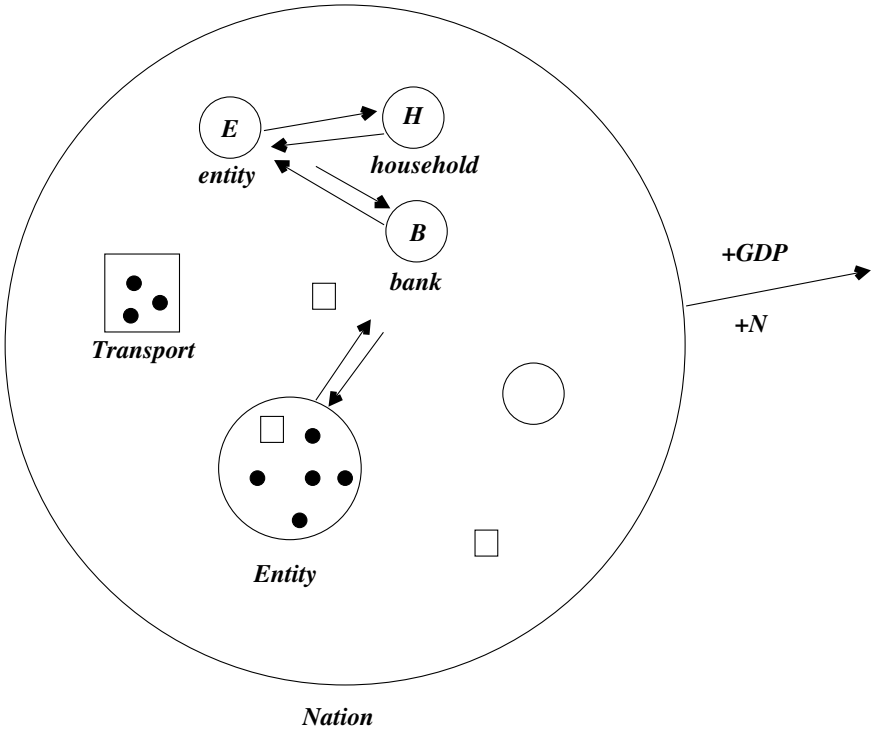

Figure 3: Agents and superagents in an economic network. The elementary or irreducible agents are taken to be humans (circles) and things (squares). Superagents formed from both include business entities, machinery, buildings, etc. Each superagent scale may make new promises, collectively. The greatest encapsulating scale is usually the nation state, which can only promise imports and exports, GDP, and population figures, etc.

- Banks, households, and business entities can all pay for goods and services and make investments to other business entities

$$H_i, B_j, E_k \xrightarrow{+\mu_S} E'_k \tag{13}$$

$$H_i, B_j, E_k \xrightarrow{+\mu_I} E'_k \tag{14}$$

  Buying and selling are not simple promises; they are quite complicated interactions. They are dependent on access to money however, so these transfer promises crop up as obstacles whenever a condition occurs such as:

$$H_i, B_j, E_k \xrightarrow{+\mu|(\mu<H)} E'_k \tag{15}$$

  to pay an amount μ if the agent has enough balance H. Note that such payments are stochastic events for small agents. Larger, more powerful agents, with sufficient pollitical muscle, are tolerated when they payroll payments to the end of a month. Most transactions, for individuals however, are immediate, and bankruptcy can happen more suddenly.

- Wages are payed to humans or households by business or government entities, if they have enough on their balance sheets:

$$E_k \xrightarrow{+W|(H_\mu>W)} H_i \tag{16}$$

  It is normal to assume that this depends on the human agent promising to work. However, this promise is currently debateable: it is possible to receive welfare support, and the matter of a basic universal income may also come into play. Gifts and inheritances may pass from human to human:

- Central banks B_C can promise loans L_C, for a price P_b and their central interest rate r_C for provate bank

lending:

$$B_C \xrightarrow{+r_C} B_j \tag{17}$$

$$B_C \xrightarrow{+(P_b=\mu_b)} B_j \tag{18}$$

$$B_C \xrightarrow{+b_C|(\mu_b=P_b)} B_j \tag{19}$$

and they may buy bonds and securities

- Independent banks B_j can promise bonds b, for a price P_b and their interest rate r_j:

$$B_j \xrightarrow{+r_C} * \tag{20}$$

$$B_j \xrightarrow{+(P_b=\mu_b)} * \tag{21}$$

$$B_j \xrightarrow{+b_C|(\mu_b=P_b)} * \tag{22}$$

  In practice, each such agreement could have its own interest rate, allowing banks to favour certain customers and penalize others.

5.3 Implicit dependencies of production of things

The size of the economic network is not constant. Somewhat like a biological network, the collections of agents and promises are constantly fluctuating. The total bulk has traditionally exhibited growth (assumed exponential in the Goodwin models), though more modern demographics show that the trend is changing in many parts of the world [28]. Growth depends implicitly on investment through infrastructure to support tooling, machinery, transportation, housing, etc. We can make this explicit, where applicable, in a promise model. Even population growth can't be supported without investment in housing, shopping, schools, etc. Define the dimensions of agent roles by:

$$N_H \equiv |H_i| \tag{23}$$

$$N_E \equiv |E_k| \tag{24}$$

$$N_T \equiv |T_\ell| \tag{25}$$

At the top level, a nation may be able to promise new humans and businesses, only conditionally on there being sufficient funds for investment. Informally, something like this:

$$\text{Nation} \xrightarrow{+\Delta N_H>0,+\Delta N_E>0,+\Delta N_T>0|\text{Investment}} * \tag{26}$$

Growth of the human population $N_H = |H_i|$, the business sector $|E_k|$, or the production of things $|T_\ell|$, in turn, may drive greater demand for consumption of consumables, assuming the things are not obsolete, which may lead to an increase in prices unless these are regulated by competition or by fiat. This leads to a web of dependency, like a food-web or food-chain.

Insufficient consumption, on the other hand, may implicitly lead to price collapse and a downward spiral of employment. The more detailed assumption is that insufficient consumption over time time interval means fewer sales, lower revenues, and strain in a company. This may be responded to be increasing prices to recover lost revenue, or lowering prices to encourage sales. How can we know the policy? In classical economics it would be assumed that competition would drive prices down. There is no causal reason for why this must happen. If human labour is the primary mechanism of production, then a price change could lead to unemployment, unless unions intervene.

With a machine based production, there would be a long term lag before loss of revenues of a whole company begin to affect the maintenance and running costs of machinery. Clearly the simplistic assumptions of the neo-classical models are based on an earlier age of monolithic industrialization, and need updating for a smaller-grained world.

5.4 Explicit dependencies

We can sketch out some of the promises. The superagent dimensions follow the pattern of sums over their constituents:

$$N_T = |T_\ell| = \sum_\ell 1, \text{where} \quad \ell = 1 \ldots |T_\ell| \tag{27}$$

$$\tag{28}$$

The prices (often erroneously called 'value') of these things is what the recipient is willing to pay for its promised function f_ℓ:

$$P_{\ell j} = v_j(A_j \xrightarrow{-f_\ell} T_\ell). \tag{29}$$

If there is a sufficient number of agents willing to buy at roughly similar prices, then the recipient agent may be replaced by a 'market', or a superagent of potential buyers who effectively promise a single price determined by competitive equilibrium, provided sufficient time has elapsed for such an equilibrium to settle.

The fraction of workers in employment, represented by quantities λ, L, N_w all depend on assessments of the sampling of number of agents who are in promise bindings of the form:

$$N_w = L = \alpha \left(\sum_i^N (H_i \xrightarrow{+s_i} E_k)(E_k \xrightarrow{-s_i} H_i) \right) \tag{30}$$

This depends on the cooperation of multiple agents and can collapse from any number of reasons.

Wages depend on the conditional promise:

$$E_k \xrightarrow{+w_{ki}|s_i} H_i \tag{31}$$

The interest rate is a promise by a central bank, which may propagate by voluntary cooperation. Let B_j be a bank agent, and C be the central bank (final tier lender):

$$CB \xrightarrow{+r} B_j \tag{32}$$

$$B_j \xrightarrow{-r} CB \tag{33}$$

$$B_j \xrightarrow{+r_j|r} H_i \tag{34}$$

The bank's promise may or may not depend explicitly on the central bank's rate, but I we add the conditionality as documentation of a potential influence.

.... many such promises, defining the boundaries of modular activity

5.5 Payments with dependencies

Investment appears as a semantically separate phenomenon in the capitalist narrative, but its effect is just a method for wealth redistribution to enable the overcoming of obstacles [9]. Whether investors get their money back or not, they do society a service, which is to keep money flowing by quenching a conditional dependency.

Regardless of their semantics, the core obstacles in payment are dependencies, which all have the form of promises conditional on a buffer of funds:

$$A \xrightarrow{+\mu_a|(\mu_a<H)} A' \tag{35}$$

When an agent is a hub, and has made many such promises, clearly the sum of promised amounts has to be less than the holdings, over the timescale of the payments:

$$H \geq \sum_a \mu_a \tag{36}$$

The fact that all such promises are functions of coarse grained time $\overline{\Delta t_a}$ indicates that we need to know the relevant timescales for all such interactions. Different microscopic promises will have different expectations in this regard. This opens up an uncertainty about when balances are checked and assessments of solvency are formed.

In the modern information age, we have the technology to compute balances and discover overdrawn accounts very quickly (much faster than payments can be made and verified); thus, we are vulernable to a lack of tolerance on the part of receivers. This intolerance propagates around the network, in unreasonable expectations escalate. If time timescales for repayments could be extended to longer and longer times, stability of the economy's functional interactions increases. As the timescale for repayment shrinks, local instabilty escalates to impossible levels.

SYMBOL	DESCRIPTION
$\mu(S, I)$	Money originating from sales or investment input
$\mu(W, D)$	Money originating from wages W or loan D

One can easily see in such a chain of dependencies, how the network effect can lead to sudden amplification of a crack in the economy. Suppose a large company relies on a small delivery agent, or power company, who cannot make its payments and is forced into bankruptcy. Deliveries stop, causing a problem for its clients, who are then subject to a stop of revenues, leading to goods not arriving, causing further problems. As society grinds to a halt, money becomes increasingly irrelevant because it cannot be spent.

5.6 Conditional promise dependencies

These are the localized weakpoints where a failure can occur. There are diffent kinds of agents that make promises.

$$A \in \{H_i, B_j, E_k, CB\} \tag{37}$$

The basic agent types are humans H_i, and organizational entities E_k , firms, and banks B_j, etc. An economic entity E_k or unit may be a single firm, all firms, or a nation etc. Timescales are determined by the ability to strokeep promises. If we have

$$A \xrightarrow{X|Y} A', \tag{38}$$

then the sampling rate for Y partially determines the change rate of X

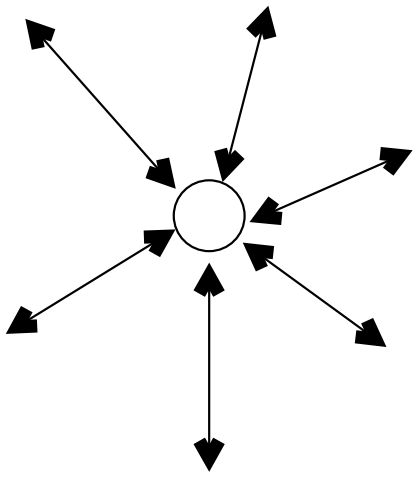

Figure 4: A hub agent is one that other agents depend on for their own promises, e.g. the post-office delivery servies. The failure of such a node can cripple the network.

Annealing of the network of conditionals is the way to avoid temporal or spatial catastrophes.
...
Show the connection between dependencies and instablities?

5.7 Supply and demand

Production supply depends on access to labour H or machinery M, as well as on money from sales earnings S or investment I:

$$H_i, E_k \xrightarrow{+T_\ell|H,M,\mu(S,I)} H_i', E_k' \tag{39}$$

Automation breaks this dependency on H, i.e. on employment, or the promise of wages W_{ki} from a company E_k to a human H_i:

$$\text{Employment} = \left| E_k \xrightarrow{+W_{ki}} H_i \right| \tag{40}$$

Demand for things (formally, a promise to make use of an offer) depends on agents having access to money, through wage earnings or loans:

$$H_i, E_k \xrightarrow{-T_\ell|\mu(W,L)} H_i', E_k' \tag{41}$$

These interactions can be described in more detail, as in the preliminary paper [9].

5.8 Automation of welfare, channelled influence, and economic continuity

For conservatives, the ideas of welfare is something of an anathema, but a network view of the economy highlghts that it might actually be a necessity to save an economy from collapse[5]. It is no different than a form of investment in economic stabilty, targeted at the microscopic personal level.

Redistribution of resources, including money, where there is insufficient supply to enable dependent continuity, is the mechanism (at any scale) performed by economic regulation. It is a policy matter. The mechanism is performed by central banks and by dole offices.

Because it is a policy matter, welfare has to be applied for, by a miserable and time consuming process that may be inconvenient for those who need it the most, e.g. the disabled and sick. An information society based on common ledgers can easily monitor the personal finances of individuals, en masse, and determine when assistance is needed. Funds could be allocated (possibly with semantic constraints on usage). This is one use of microcurrencies: not so much for earmakring for a particular purpose, but for excluding certain items, like luxury items or gambling.

Today, there is a stigma associated with welfare that we need to shake off, given the changes to manufacturing and labour. Free market pundits love the market freedom until its instabilties wreak havoc. Then handouts cannot come too soon, and considered 'investments'.

European attitudes to welfare are ironic: welfare at the personal level are quite common, but at the level have been frowned upon, especially in the Germanic tradition. This inattention to the macroeconomy may have held Europe back from the recovery after the credit crisis 2008-. If even some individuals do not have access to basic exchange money, the effect is to cut off the blood-supply to a limb of society (however small). The network feedback effect can be amplified into a larger problem because all such feedback loops are fickle and subject to a kind of weather of perferences.

Interest rates are the bluntest instrument, that attempt to coerce behaviour. Propaganda, marketing, and advertising are more fine grained attempts to exert influence over a 'free market' of 'autonomous' individuals. Ultimately a direct intervention by powerful forces (public or private) could be needed to correct an imbalance, as Minsky argued. The level of freedom of agents in a free market mythology is exaggerated so long as those agents are not truly self-sufficient in all aspects of their lives, like modern technologically enhanced hunter-gatherers. Civil society (with attendant specialization and cooperation across sufficient diversity) is thus, by definition, not a free market[6] .

TODO: show tha central bank and welfare are functionally equivalent at different scales?

6 2008 crisis

Several authors have claimed to foresee the debt crisis in 2008 by using differential Minsky models. The discussion by Keen is particularly interesting [7,29]. It is clear from the preceding remarks that what was predictable was only a set of conditions in which aggregate levels of debt and employment etc, could interact to create the conditions for such a collapse. The actual mechanism itself could not be foreseen, since all such details are abstracted away to entropy. It is analogous to predicting that when the force on a metal beam increases beyond a certain point, it will reach a critical level of stress. This determines a kind of probability for some kind of extreme event, but it cannot determine exactly how it will take place.

Predicting this general set of harsh conditions is what a macro model can achieve, but no such model could identify which companies or institutions would be most likely to fail. A network (promise) model could make that determination, by tracking the chains of dependencies. This is analogous to modelling an atomic or molecular structure in a metal alloy, and observing the presence of weak points, cracks that could be opened due to localized weaknesses. A single bank, contrained by a weak balance sheet could therefore precipitate a cascade failure, by being unable to pay its bills, triggering another failure and another, and so on. The Goodwin models cannot 'see' these failure modes, only calculate the bulk forces at work, assuming average properties of the whole. Promise Theory, on the other hand, has the capacity (with sufficient data) to predict exactly how such a failure might occur in a multiscale model.

Cellular automaton (agent) models are almost certain superior to this approach in every regard, except perhaps for the difficulty in submitting to a formal stabilty analysis.

[5] Friedman often made bizarre reversals in his reasoning, proving that policies he didn't like were natural and necessary, but always finding a way to twist the facts to his political views with predictable sleight of hand [1].

[6] Mono-towns are towns built around a single factory, like a mine or production plant. These were common in early industrial times. Some still exist in Siberia and many have fallen into disuse, as ghost towns, in the USA and the Russian federation. They collapse because they have too strong a dependency on a single agent source.

7 Summary

Thoughts

- The significance of Goodwin models goes beyond economic output and monetary flows. The feedback cycles have parallels in any flow in a closed network with several modes. Just as you can't have unregulated free markets, you can't have free movement of people, money, or any resource in a network without instability.
- Once a society starts to use money, it becomes hard to escape a connection between fair distribution and payment or debt. The exception lies with money lenders, who are authorized to create the money agents need to buy things, no matter where they may come from. Money enters circulation by political 'fiat' or by lending.

  Taxation or rent-collection can take 'liquid' money out of the economic network.
- Trust is follows money closely. You can't easily borrow money if you don't already have plenty, and can show a history of plenty. Similarly, you can't esily get work if you are not already working, or can show a history of working.

My speculation is that, because each new scale makes new promises, each scale needs to equilibrate on its own level, effectively requiring a separate 'heat reservoir' or separate currency. So instead of multiple horizontal currencies, one might have single currencies across single market scales, and different currencies would occur vertically, e.g. one for the household, one for local trading, and one for international transfers, etc. It remains to be seen if this makes sense.

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