Toward a Theory of the Evolution of the Global Political Economy: Competition between Liberal and Coordinated Market Economies

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Abstract

Political economists from Smith (1776) to Marx (1859) have long explored how wealth is created and distributed within and between nations. More recently, Acemoglu (2012) and Piketty (2013) have focused on the role of institutions and capital growth rates respectively to explain this. I integrate these into my exploration of how different *forms* of advanced political economy *function*, create *performance* differentials and co-evolve with the *environment* (Piepenbrock, 2009). To explore how capital and labour function in different forms of political economy, I use Hall and Soskice's (2001) typology of liberal and coordinated market economies – LMEs and CMEs. To explore the evolution of the political-economic-ecological interactions, I use *The Limits to Growth* (Meadows et al., 1972) and bounded rationality (Simon, 1957). I numerically simulate the nonlinear dynamic behaviour of constrained competition between LMEs and CMEs via coupled differential equations of multi-predator-prey interactions (Lotka, 1925; Volterra, 1926) which generate overshoot (Forrester, 1971), limit cycles (Goodwin, 1967) and chaos (Sterman, 1989). Capital and labour enable and constrain growth *endogenously*, while the environment does so *exogenously*. While LMEs outperform CMEs in the shorter term, the converse is true in the longer term, with LMEs maximising capital wealth and *efficiency* and CMEs maximising labour wealth and *equity*.[2]

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[1] The author wrote this as a 17-year-old high school student at Eton College in the UK, where he won a John Maynard Keynes prize (where Keynes was a student). He is a student member of the *System Dynamics Society,* a member of the Young Scholars Initiative of the *Institute for New Economic Thinking* and a Fellow of the *International Institute for Strategic Leadership.* He has received support for this research which is discussed in the Acknowledgements.
[2] Word Count: 7,169 (excluding footnotes, figures, references, acknowledgements and appendices).

1. The Evolution of the Global Political Economy

*"Traditionally **economics** has ignored **politics**,*
*but understanding politics is **crucial** for explaining **world inequality**."*[3]

*"The history of the **distribution of wealth** has always been deeply **political**,*
*and it cannot be reduced to purely **economic** mechanisms."*[4]

In attempting to model the evolution of the political economy, I stand on the shoulders of giants – both classical and modern. From *The Wealth of Nations*[5] to *Why Nations Fail*[6], and from *Das Kapital*[7] to *Capital in the 21st Century*[8], there is a rich history and re-emergence of intellectual thought in the field. In this paper I will explore some of the key problems in the field, and ultimately endeavour to incorporate them into a comprehensive model of the evolution of the global political economy.

The political economy can be characterized via the institutional paradigm (North, 1991). Institutions are the rules which enable and constrain function in both the polity (e.g. governments) and the economy (e.g. markets). Institutions have been demonstrated to enable economic development (Acemoglu, Johnson and Robinson, 2005), while others posit that development enables institutions (Chang, 2011).

*'The **institutionalist** paradigm focuses upon… an **holistic** and **evolutionary** view of*
*the **structure-behaviour-performance** of the **economy**…*
*in **interdependence** or **cumulative causation**."*[9]

Researchers have long posited typologies for forms of advanced capitalism (Esping-Anderson, 1990; Hall and Soskice, 2001; Piepenbrock, 2009; Acemoglu, Robinson and Verdier, 2017). The typology used in this paper is 'varieties of capitalism' (VoC), which range from Liberal Market Economies (LMEs) like the US and UK, to Coordinated Market Economies (CMEs) like Japan and Germany (Hall and Soskice, 2001). LMEs have institutional architectures which are narrow in space and time, i.e. they focus on the individual over short time periods. CMEs, on the other hand, have institutional architectures which are broad in space and time, i.e. they focus on the collective over longer time periods. Capital in LMEs is 'impatient' and seeks to maximise returns to shareholders in the short term, while in CMEs it is relatively more 'patient' and seeks to maximise returns to a broader set of stakeholders in the long term.[10] Labour in LMEs is concerned with 'flexibility' while in CMEs it is concerned with 'commitment'.

VoC's institutions reinforce each other as 'strategic complementarities' (Milgrom and Roberts, 1995).[11] For example, LMEs' impatient capital reinforces the need and ability to have flexibility in the labour markets, while CMEs' patient capital reinforces the need and ability to have commitment to the labour markets.[12] The varieties of capitalism framework is summarized in Figure 1 below.

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[3] Acemoglu, D. and Robinson, J. (2012).
[4] Piketty, T. (2013).
[5] Smith, A. (1776).
[6] Acemoglu, D. and Robinson, J. (2012).
[7] Marx, K. (1867).
[8] Piketty, T. (2013).
[9] Samuels, W.J. (1976). pg. 41.
[10] Piepenbrock, T. (2009).
[11] In a 'strategic complementarity', doing more of one activity, increases the value of doing more of another activity, i.e. they mutually reinforce each other. See Bulow, Geanakoplos, and Klemperer (1985).
[12] An example of 'flexibility' in labour markets is the ability to hire / fire quickly as market conditions dictate. An example of 'commitment' in labour markets is guaranteeing 'jobs for life' in return for continuous productivity improvements.

Figure 1: Varieties of Capitalism Framework[13]

Criteria	Liberal Market Economies	Coordinated Market Economies
National Examples	US, UK	Japan, Germany
Coordination Mechanism	Competitive Markets	Oligopolistic Relations
Direction of Influence	Bottom-up	Top-down
Equilibrium Mechanism	Supply and Demand	Strategic Interactions
Institutional Mechanism	Ensuring Competition	Sanctioning Defectors
Inter-firm Relations	Competitive	Collaborative
Spatial Boundaries	Individual	Community
Temporal Boundaries	Short-term	Long-term
Economic Focus	Efficiency	Equity
Income Distribution	Unequal (high Gini)	Equal (low Gini)
Innovation Type	Radical (Product)	Incremental (Process)
Capital Type	'Impatient'	'Patient'
Labour Strategy	Flexibility (short-term)	Commitment (long-term)
Unionisation Rate	Low	High
Wage Bargaining	Firm-level	Industry-level
Labour Skills	General	Specific
Education/Training	Formal, General	Industry-specific Apprentices
Legal Contracts	Complete, Formal	Incomplete, Informal
Government Policies	Deregulation, Lower Taxes	Regulation, Higher Taxes

Political economy researchers have long been concerned with the evolutionary trajectories of these varieties of capitalism (Streek and Thelen, 2005; Hall and Thelen, 2009). A growing body of research has posited the systematic liberalization of both LMEs and CMEs (Streek, 2009; Howell, 2003). This paper attempts to shed light on that debate, by exploring competition between varieties of capitalism as a means of driving the co-evolution of the political-economic ecosystem.[14]

*"**Comparative political economists** have become deeply interested in processes of **institutional change**, and especially in those taking place in response to… '**globalization**'. We have portrayed the political economy as an **institutional ecology** in which… the process of institutional change as one of mutual adjustment, inflected by **distributive concerns**..."*[15]

Leading contemporary political economy researchers - economists such as Acemoglu and political scientists such as Hall and Thelen - have generated compelling qualitative models, but have also called for comprehensive or formal modelling as the 'Holy Grail' of political economy research:

*"The framework we outlined was largely verbal rather than **mathematical**.
Constructing **formal models** incorporating and extending these ideas
is the **most important task ahead**… the **full model** has not been developed yet.
We believe that better, empirically more realistic theoretical frameworks
in the future will take us closer to this **Holy Grail**… of **political economy research**."*[16]

[13] Based on Hall and Soskice (2001) and adapted by Wikipedia: 'Varieties of Capitalism'. Note that blue is used to represent Capital and LMEs and red is used to represent Labour and CMEs throughout.
[14] Either institutional inertia constrains varieties of capitalism to remain in their current forms, or there is a free flow of economies between varieties of capitalism (e.g. as newly industrialised economies enter global trade).
[15] Hall and Thelen (2009), pp. 7 and 27.
[16] Acemoglu, D., Johnson, S. and Robinson, J.A. (2005). pp. 463-464.

2. Nonlinear Dynamic Simulation Model of the Political Economy

*"Not only in research but in the everyday world of **politics** and **economics**, we would all be better off if more people realised that **simple nonlinear systems do not** necessarily **possess simple dynamical properties**."*[17]

At around the time that Jay Forrester was creating the field of System Dynamics at MIT (Forrester, 1956, 1958, 1961), heterodox economists were also using systems of linear and nonlinear ordinary differential equations to model the dynamics of the economy either explicitly or implicitly (Kalecki, 1934, 1939, 1943, 1954; Myrdal[18], 1944; Boulding, 1948; Goodwin, 1947, 1949, 1951; Phillips, 1950, 1953; Tustin, 1953).

*"There is widespread agreement that it is necessary to introduce into **economics** both **dynamical relations** and general **interdependence**."*
*"…the one **omnipresent, incontestable dynamic** fact in **economics** – the necessity to have both **stocks and flows** of goods."*[19]

*"There has been an increasing use in **economic theory** of mathematical models, usually in the form of **difference equations**, sometimes of **differential equations**, for investigating the implications of **systems of hypotheses**."*[20]

In spite of this ground-breaking work, mainstream 'neoclassical' economics has not generally embraced such approaches and some appeared rather hostile to the new approach (e.g. Nordhaus, 1973, 1992) as they run counter to the prevailing epistemological and/or methodological orthodoxy (Radzicki, 1990).

In spite of the orthodox neoclassical economic ambivalence or antipathy for such methods, researchers have noted the potential synergies between System Dynamics and heterodox economics schools including institutional economics (Radzicki, 1988, 1990, 2003, 2004, 2005, 2007; Radzicki and Sterman, 1994), as well as between System Dynamics and classical economics (Saeed, 2005, 2020), both of which are central to the political economy. System Dynamics is therefore a potentially effective method for computer simulation-based 'pattern modelling' (Radzicki, 1988; Wilber and Harrison, 1978) especially in the political economy (Frey, 1978).

In order to explore how varies of capitalism evolve, I have built a System Dynamics model to begin to capture the underlying feedback causal mechanisms and simulate their dynamic behaviour.[21] The model is an abstract conceptual model, not an operational model. The 11th order system of nonlinear ordinary differential equations comprises four submodels or subsystems: the core capital-labour subsystem (Marx 1867; Kalecki, 1934; Goodwin, 1967), the investment-transfer behavioural decision rule subsystems (Simon, 1957, 1969, 1979, 1982, 1984), the carrying capacity subsystem (Forrester, 1971; Meadows et al., 1972, 1994 and 2004), and the global trade subsystem (Ricardo, 1817).

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[17] May, R. (1976), pg. 467.
[18] Nobel Prize-winning economist, Gunnar Myrdal's 'Circular Cumulative Causation' model (1944) is an example of the links between institutional economics and System Dynamics.
[19] Goodwin, R. (1947), pg. 181; and Goodwin, R. (1951), pg. 3.
[20] Phillips, W. (1950), pg. 283.
[21] For reproducibility (Rahmandad and Sterman, 2012), the model equations are presented in the Appendix.

The model parameters were estimated using the varieties of capitalism data (Hall and Soskice, 2001). The system of difference equations was solved numerically and simulated in continuous time.[22]

Regarding the level of abstraction of the model and the precision in specifying the model in this paper, Forrester (2013) offers insights:

*"The model I am working on is **generic**.*
*By **changing parameters**, it could be tailored to represent a **wide range of specific countries**. The model generates the **major modes of behavior** that are seen in **real economies** and addresses many of the **controversies** that have arisen in the **economic literature**.*
*Such a model can apply to most **industrial nations**,*
*and can even be interpreted as applying to the **developed world**."*[23]

I will next describe and test the primary submodels, building confidence in the structure and behaviour of each, before integrating them into the full model of the political economy.

2.1 Capital-Labour Submodel

*"Society is more and more splitting up into **two great hostile camps**,*
*into two great classes directly facing each other - **bourgeoisie** and **proletariat**."*[24]

Political economists from Marx (1867) to Kalecki (1933) to Goodwin (1967) have long conceived of the symbiotic class-struggle between the two primary factors of production: capital and labour.[25]

*"This inherent **conflict and complementarity** of **workers** and **capitalists** is typical of **symbiosis**."*[26]

Capital-share and labour-share of the wealth of the economy, was long-believed to be a stable concept[27], however in recent decades, labour-share of the wealth of the economy has begun to decline[28]. This research endeavours to explore the causes of such instabilities and resulting inequalities (Piketty, 2013).

*"While the **distribution** of aggregate income between **capital** and **labor** was a central element of **Marx's economics**, it has been largely ignored by **neo-classical economists**.*
*A major reason for the lack of interest in the **distribution** of income between the two factors comes from the commonly accepted view that it is **fixed**."*[29]

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[22] The simulations were run on Vensim PLE and used Runge (1895), Kutta (1901) 4th order integration.
[23] Forrester, J.W. (2013), pg. 30.
[24] Marx, K. and Engels, F., (1848).
[25] Minsky (1982, 1986) and Keen (1995) have proposed a more sophisticated model including a third banking class, which will be discussed in the 'Further Research' section of this paper.
[26] Goodwin, R. (1967), pg. 55.
[27] Keynes, J.M., (1939, pg. 48) referred to this as: "*one of the most surprising, yet best-established facts in the whole range of economic statistics.*"
[28] OECD, 2012, pg. 109: "*During the past three decades, the share of national income represented by wages, salaries and benefits – the labour share – has declined in nearly all OECD countries*."
[29] Brada, J.C. (2013), pp. 333, 334.

2.1.1 Primary State Variable: Wealth[30]

Taking my cue from the original political economists (or 'classical' economists) like Adam Smith who focused his efforts on *An Inquiry into the Nature and Causes of the Wealth of Nations* (1776), the central state variable of the model is 'wealth', broadly conceived.

> *"The great object of the* ***political economy*** *of every country*
> *is to increase the* ***riches*** *and* ***power*** *of that country."*[31]

Wealth is a stock, which is accounted for on a balance sheet, while income is a flow, which is accounted for on an income statement.[32] As a stock, wealth is an abstract measure which includes material and immaterial factors that can be created and destroyed and is therefore not necessarily conserved. Wealth can be conceived as assets of a variety of types, representing capital (both physical and financial[33] capital) and labour (both human and consumer capital) as shown in Figure 2 below.[34]

Figure 2: Multidimensional Conception of Wealth

	Capital Wealth	**Labour Wealth**
'Paper' Economy **Factors of Circulation**[35]	Financial Capital[36]	Consumer Capital[37]
'Real' Economy **Factors of Production**[38]	Physical Capital[39]	Human Capital[40]

> *"...by* ***economic growth*** *we should mean* ***growth in wealth*** *- which is the social worth of an economy's entire* ***stock of capital assets*** *- not* ***growth in GDP****..."*[41]

The units of measurement of the value of wealth is money, for example in US dollars.

> *"That* ***wealth*** *consists in* ***money****, or in gold and silver, is a popular notion which naturally arises from the double function of money, as the instrument of* ***commerce****, and as the measure of* ***value****."*[42]

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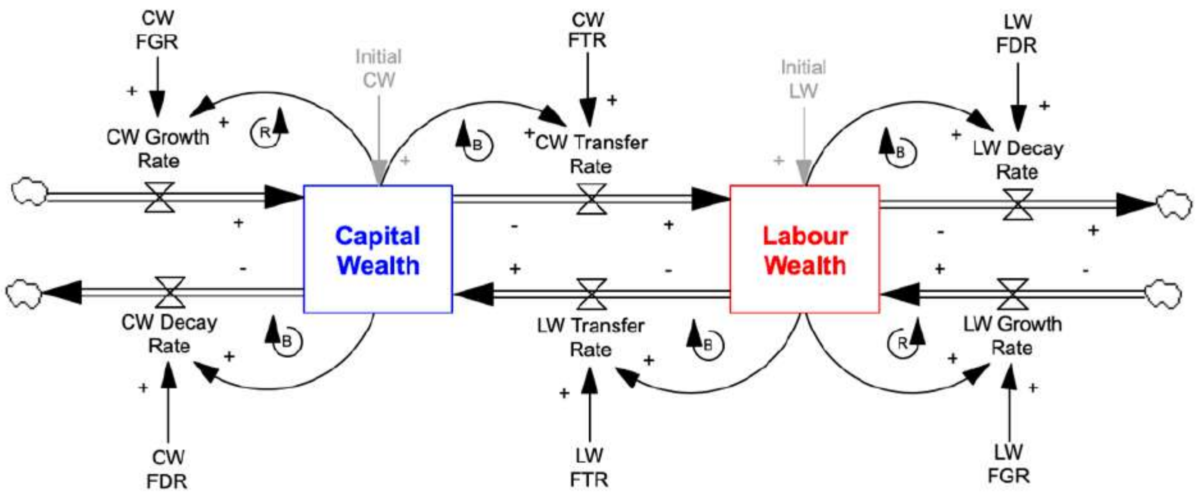
[30] For simplicity and clarity, the model developed herein assumes equal populations between varieties of capitalism. Therefore, Wealth and Wealth per Capita can be used interchangeably in the analysis of the model. For a qualitative (not a quantitative) empirical comparison between varieties of capitalism, Wealth per Capita should be used.
[31] Smith, A. (1776), book II, chapter V.
[32] The value of all stocks is simply the accumulation (i.e. net present value) of discounted cash flows.
[33] Wealth of the capitalist class and banking class are aggregated in this current model. Further developments of the model would disaggregate this state variable and explicitly model the effects of debt (Minsky, 1982, 1986; Keen 1995).
[34] Formally, an economy's wealth W(t), can be defined as follows: $W(t) = \Sigma_i[P_i(t)K_i(t)]$, where $K_i(t)$ is the economy's stock of asset i at time t, and $P_i(t)$ is its shadow price (Dasgupta, 2014, pg. 20).
[35] Similar to the 'superstructure' in Karl Marx's (1859) 'economic base-superstructure' concept.
[36] Adam Smith (1776, book II, chapter I) referred to this as 'circulating' capital. Karl Marx (1867, chapter IV) referred to this as 'Money-Commodity-Money (M-C-M)' or 'Money-Money (M-M)'. Money used as 'financial' capital can be seen as an institution in Marx's 'superstructure' concept.
[37] Karl Marx (1867, chapter IV) referred to this as 'Commodity-Money-Commodity (C-M-C)'. This can be seen as money used to purchase commodities or savings that has not been converted into investment. Money used as 'consumer' capital can be seen as an institution in Marx's 'superstructure' concept.
[38] Similar to the 'economic base' in Karl Marx's (1859) 'economic base-superstructure' concept.
[39] Adam Smith (1776, book II, chapter I) referred to this as 'fixed' capital (e.g. productive assets, like factories).
[40] This can be derived from the net present value of the expected discounted cash flow of future output of a labourer.
[41] Dasgupta, P., 2014, pg. 18.
[42] Smith, A. (1776), Book IV, pg. II.

2.1.2 Capital-Labour Core Structure

The core of the model of the evolution of the political economy is therefore the capital-labour submodel as shown in Figure 3 below.

Figure 3: Capital-Labour Submodel Basic Structure



The structure focuses on two stocks: capital wealth and labour wealth.[43] The flows capture both the bidirectional flow of wealth between the stocks as well as the flows in and out of the system.[44] Instead of taking a neoclassical economic view of capital and labour as operational factors of production in a Cobb-Douglas production function[45], this more generalised and abstract formulation of capital and labour *wealth* presents a complementary view, which enables the systematic flow of the state variable throughout the political-economic system. What is undoubtedly lost in operational precision in defining rate variables, is hopefully gained in high-level systemic insights into global dynamic patterns of the behaviour of macro-political economies.

Moving clockwise through the flows from the top left in Figure 3, the inflow of wealth into capital wealth (i.e. the Capital Wealth Growth Rate) is governed by reinforcing feedback based on investment.[46] The outflow from capital wealth to labour wealth (i.e. the Capital Wealth Transfer Rate) is controlled by balancing feedback which can include a number of (re)distributive mechanisms.[47] The outflow from labour wealth (i.e. the Labour Wealth Decay Rate) is controlled by balancing feedback which can include various forms of human capital depreciation.

The inflow of wealth into labour wealth (i.e. the Labour Wealth Growth Rate) is governed by reinforcing feedback based for example on population growth.[48] The outflow from labour wealth to capital wealth (i.e. the Labour Wealth Transfer Rate) is controlled by balancing feedback which can

[43] The wealth stocks measure 'value' in money, for example in US dollars. Note that this is a more conceptual formulation than found in the Classical economists' models of Smith, Ricardo and Marx (Saeed, 2005, 2020).

[44] The stocks do not represent people or classes of society (e.g. capitalists and labourers). In this formulation, a labourer earning labour wealth, who invests any surplus wealth, can then also earn capital wealth.

[45] A simple form of the equation is: $Y = AL^{\beta}K^{\alpha}$. Cobb and Douglas (1928).

[46] This includes mechanisms such as reinvested profits as well as rate of return on investment (Saeed, 2005, 2020). This mechanism also captures capital productivity, as well as the growth in money supply. Examples of this behaviour can be found in the Harrod (1939) and Domar (1946) model, the Solow (1956) and Swan (1956) model, the Ramsey (1928), Cass (1965) and Koopmans (1965) model, and the Romer (1986) model.

[47] This includes mechanisms such as wages for labour, a capital tax, etc. Note that unlike an SIR epidemic model (Sterman, 2000) or a Bass diffusion model (Bass, 1969), this model does not have reinforcing feedback in the flow between stocks which accelerates transfer.

[48] This includes mechanisms such as net birth rates or immigration. This mechanism also captures labour productivity.

include consumption[49] and moving savings to investment.[50] The outflow from capital wealth (i.e. the Capital Wealth Decay Rate) is controlled by balancing feedback which can include forms of depreciation of capital assets.

Note that each flow currently aggregates both *quantity* and *quality* (e.g. productivity) factors. For example, the Capital Wealth Growth Rate captures *quantity* (e.g. return on investment), as well as *quality* (e.g. capital productivity). The Labour Wealth Growth Rate captures *quantity* (e.g. population), as well as *quality* (e.g. labour productivity). The Wealth Transfer Rates capture changes in *quantity*, as well as in *quality* (e.g. total factor productivity, TFP) through capital-labour synergies.

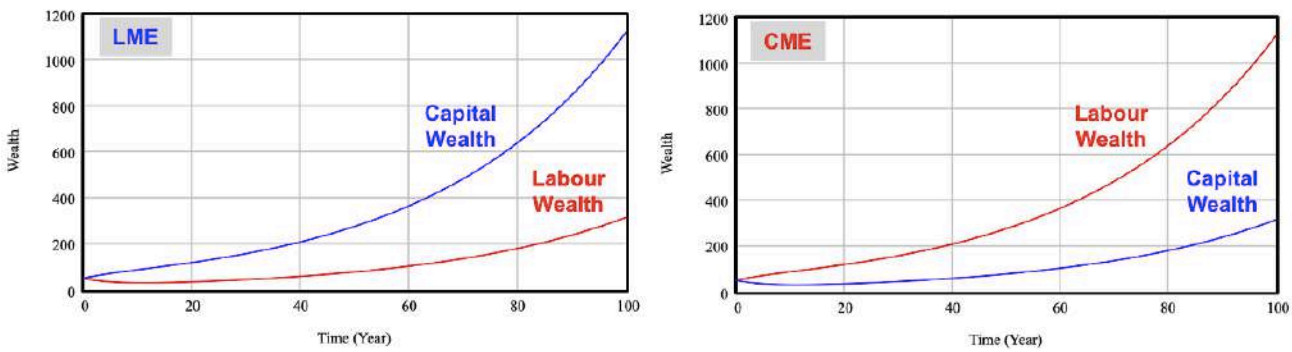
The model is parameterised to capture two orthogonal varieties of capitalism, those which focus on capital as a factor of production (i.e. LMEs) and those that focus on labour as a factor of production (i.e. CMEs) as shown in Figure 4 below. Note how the parameters are symmetric, which matches the logic of each variety of capitalism.

Figure 4: General Parameters for Theoretical Archetypal Varieties of Capitalism

General Structural Parameters	Liberal Market Economies	Coordinated Market Economies
Initial Capital Wealth (CW_0)	50	50
Initial Labour Wealth (LW_0)	50	50
Capital Wealth Fractional Growth Rate (CW FGR)	0.1	0.05
Capital Wealth Fractional Transfer Rate (CW FTR)	0.05	0.1
Labour Wealth Fractional Decay Rate (LW FDR)	0.1	0.05
Labour Wealth Fractional Growth Rate (LW FGR)	0.05	0.1
Labour Wealth Fractional Transfer Rate (LW FTR)	0.1	0.05
Capital Wealth Fractional Decay Rate (CW FDR)	0.05	0.1

As can be seen in Figure 5 below, the models are symmetric and exhibit exponential growth,[51] with the dominant wealth stocks inverted: Capital Wealth for LMEs and Labour Wealth for CMEs.

Figure 5: Basic Capital-Labour Submodel Dynamic Behaviour



[49] Note that currently 'consumption' implies domestic consumption. Later the model will involve another outflow which captures foreign consumption via international trade.
[50] Note that Labour Wealth can flow into Capital Wealth as labourers can invest their surplus wealth, making them both labourers as well as capitalists.
[51] As the net inflows and net outflows to/from outside the model are equal, one might expect the total system is in dynamic equilibrium. However, the system grows exponentially as there is a net flow between the stocks towards the stock (Capital Wealth for LMEs, Labour Wealth for CMEs) experiencing a net inflow from outside of the model.

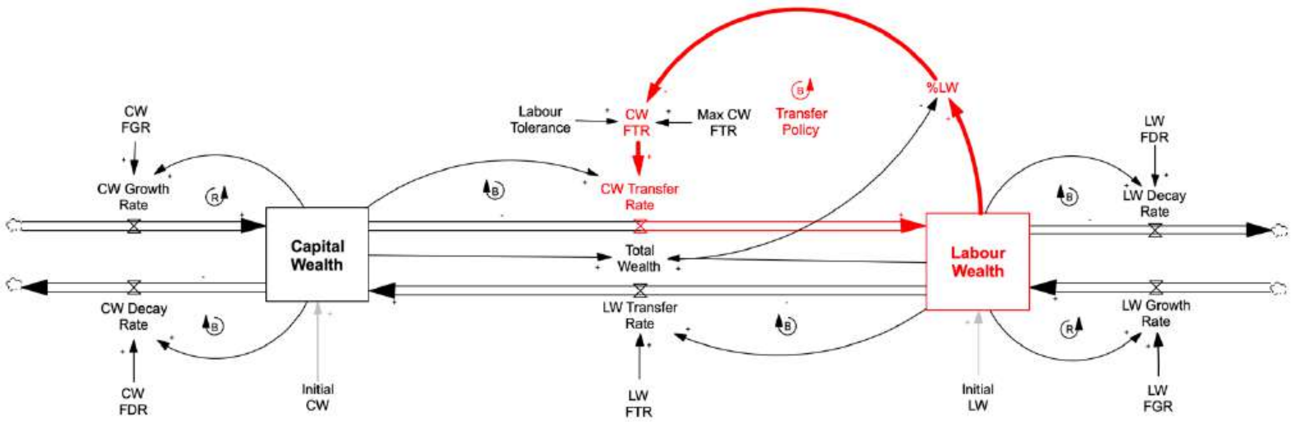
2.1.3 Wealth Creation and Wealth Transfer Policies

This portion of the Capital-Labour submodel contains balancing feedback structures on the inflows of both Capital and Labour Wealth to capture the policies used by capitalists and labourers.

The Capital-Labour submodel incorporates elements of behavioural decision theory based on Nobel Prize-winning economist, Herbert Simon's (1957, 1969, 1979, 1982, 1984) 'bounded rationality'.[52]

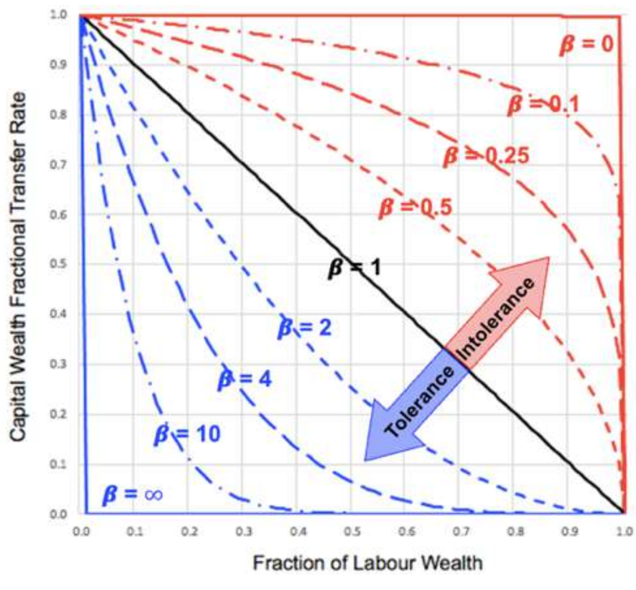
The wealth transfer policy is modelled as a balancing feedback structure on the inflow of Labour Wealth to capture the policies used to control Capital Wealth as shown in red in Figure 6 below.

Figure 6: Capital-Labour Submodel Structure with Wealth *Transfer* Policy



The model also captures the nonlinear behavioural decision variable of labour 'tolerance' β as shown in Figure 7 below. β expresses the nonlinear relationship between the % Labour Wealth and the Capital Wealth Fractional Transfer Rate (CW FTR). The more tolerant labour is in transferring wealth from capital, the higher the value of β.

Figure 7: Nonlinear Labour Tolerance Functions[53]



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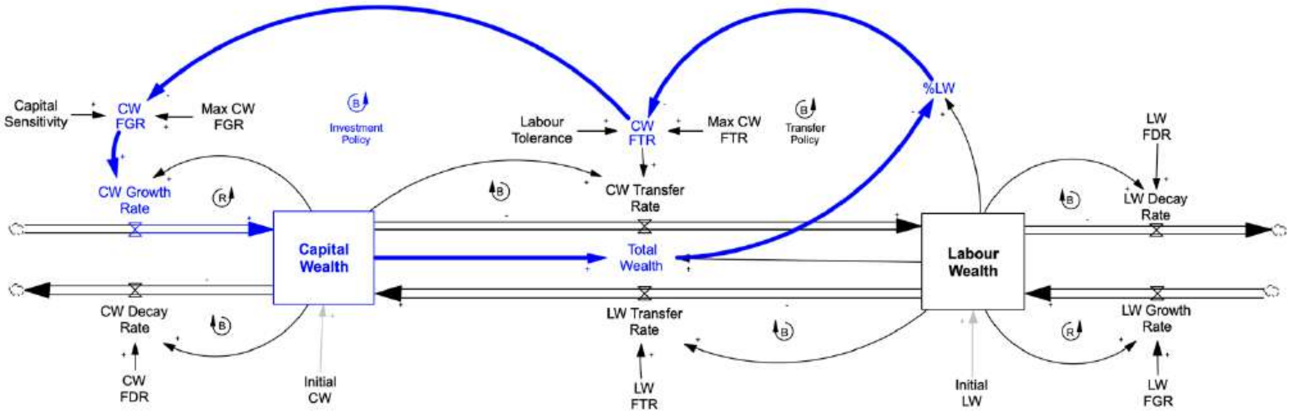
[52] The introduction of micro-level behavioural decision rules addresses the so-called 'Lucas Critique' after Nobel Prize-winning economist, Robert Lucas' (1976) called for bringing microeconomic behaviour into macroeconomic modelling.

[53] CW FTR = $(\text{CW FTR})_{\text{Max}}(1 - \%\,\text{LW})^{\beta}$.

The wealth generation policy is modelled as balancing feedback on the inflow of Capital Wealth as shown in blue in Figure 8 below.

Figure 8: Capital-Labour Submodel Structure with *Investment* Policy



The model also captures the nonlinear behavioural decision variable of capital 'sensitivity' α as shown in Figure 9 below. α expresses the nonlinear relationship between the Capital Wealth Fractional Transfer Rate (CW FTR) and the Capital Wealth Fractional Growth Rate (CW FGR). The more sensitive capital is in reacting to labour's transferring wealth from capital, the higher the value of α.

*"The logic for low capital taxes is powerful: the **supply of capital** is **highly elastic**."*[54]

Figure 9: Nonlinear Capital Sensitivity Functions[55]

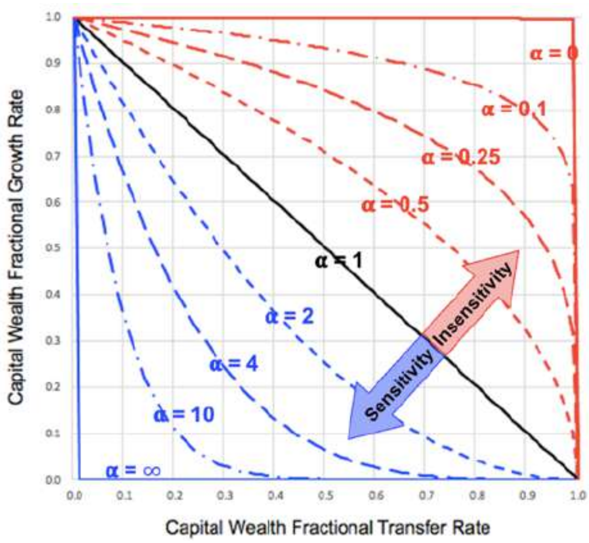


Figure 10 below summarises the estimation of internal policy parameters which capture the strategic complementarities of each variety of capitalism.[56] For LMEs, capital is relatively 'sensitive' (i.e. it reduces investment in the face of tax), while labour is 'tolerant' (i.e. it is more forgiving in the redistribution of wealth). For CMEs, capital is relatively 'insensitive' (i.e. it maintains investment in the face of tax) while labour is relatively 'intolerant' (i.e. it redistributes wealth early).

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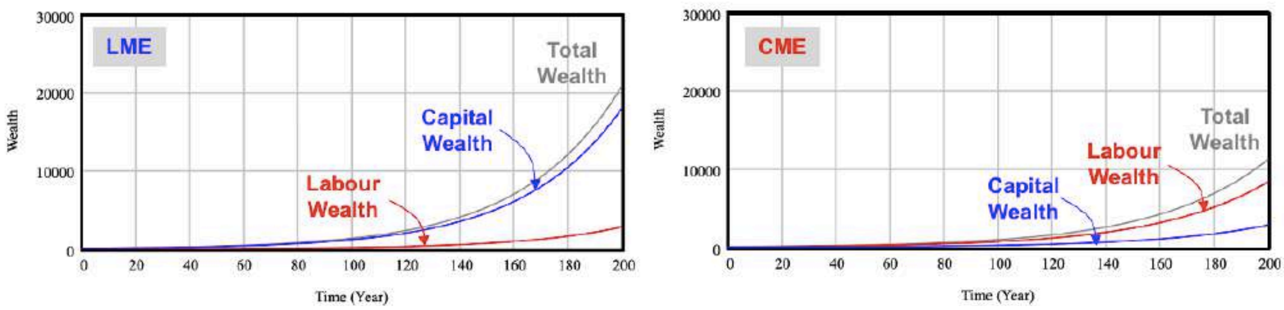
[54] Mankiw, et al. (2009), pg. 168. This suggests that for LMEs α is larger than for CMEs.
[55] $CW\ FGR = (CW\ FGR)_{Max}\,(1 - CW\ FTR)^{\alpha}$
[56] Future empirical research would estimate these parameters econometrically.

Figure 10: Internal Policy Parameters for Theoretical Archetypal Varieties of Capitalism

Internal Policy Parameters	Liberal Market Economies	Coordinated Market Economies
Capital Sensitivity (α)	4	0.25
Labour Tolerance (β)	4	0.25

Figure 11 below shows the policy behaviour of LMEs (left) and CMEs (right). LMEs achieve efficiency (i.e. higher total wealth) at the expense of equity, while CMEs achieve equity at the expense of efficiency. Note that Labour Wealth in CMEs is greater than in LMEs in spite of lower total wealth. In the absence of a carrying capacity, LMEs outperform CMEs in Total Wealth and Capital Wealth, while CMEs outperform LMEs in Labour Wealth and equity (or minimisation of inequality). The tax and investment policies have the effect of slowing growth via the addition of two balancing feedbacks.

Figure 11: Dynamic Behaviour of Wealth *Creation* (Investment) and Transfer (Tax) Policies



2.1.4 Constant Exogenous Carrying Capacity

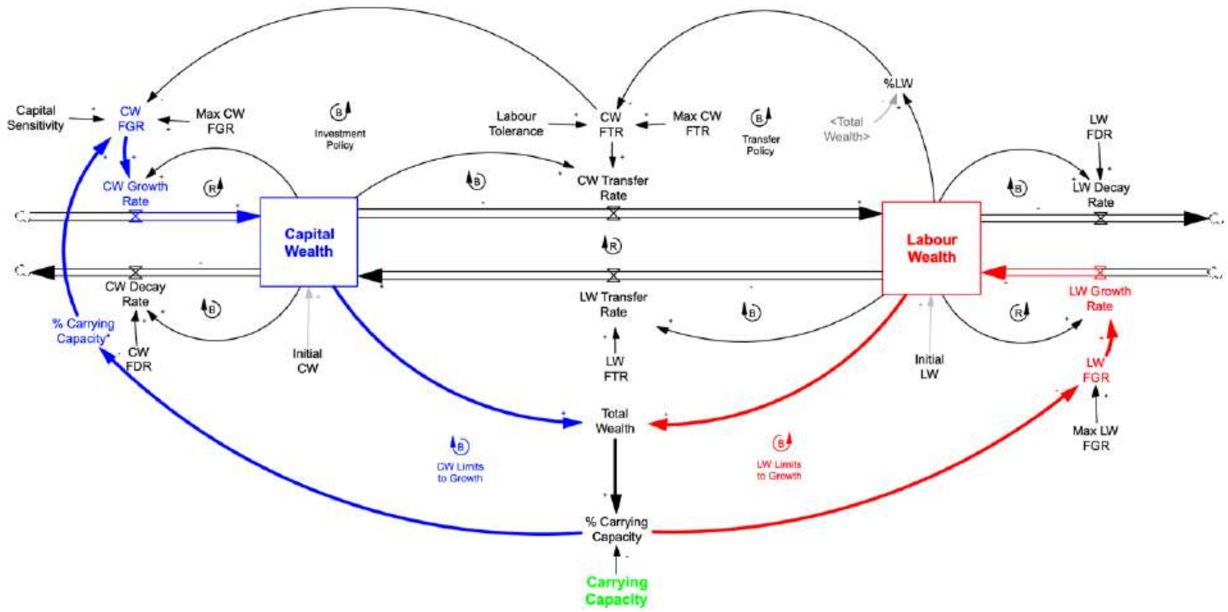
*"Anyone who believes that **exponential growth** can go on forever in a **finite world** is either a **madman** or an **economist**."*[57]

Political economists ranging from Malthus (1798) to Pareto (1906)[58] to Keynes (1937) have long acknowledged limits to growth in human activity.[59] While Malthus may have focused on the mechanism of food production being a constraining factor, the general principle applies.

This portion of the Capital-Labour submodel incorporates a carrying capacity of the system which constrains infinite growth of wealth in a system having finite resources.[60] It contains two main balancing feedback structures applied to capital wealth and to labour wealth, respectively, as shown in Figure 12 below. The counterclockwise balancing feedback acting on the inflow to capital wealth is shown in blue. The clockwise balancing feedback acting on the inflow to labour wealth is shown in red.

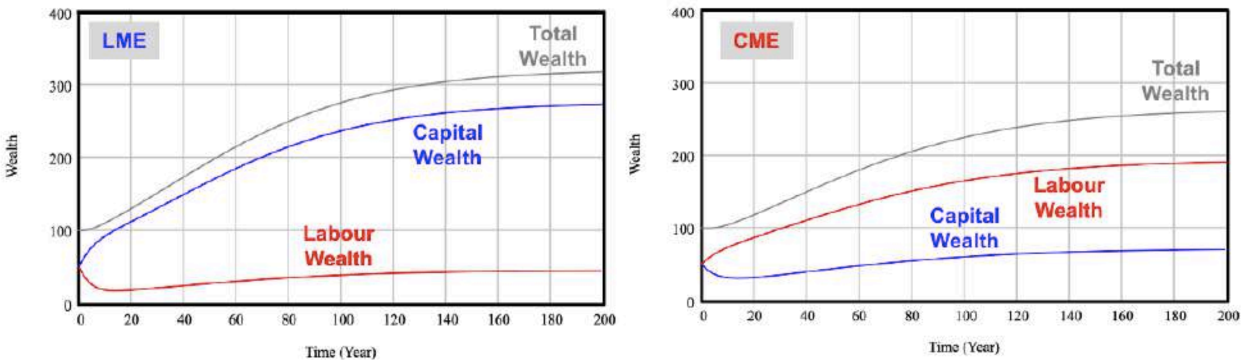
[57] Attributed to Kenneth E. Boulding, the late, British evolutionary economist.
[58] Pareto discussed population growth in the UK reaching one person per square metre (1906, pg. 207).
[59] Saeed (2005, 2020) formally modelled with System Dynamics classical economists' informal models of limits to growth.
[60] Note that 'carrying capacity' is typically defined in terms of the amount of a given species (e.g. humans) the ecosystem can support. As the primary state variable of this research is wealth, the notion of carrying capacity herein is defined in terms of the amount of wealth of a given species, the ecosystem can support. Operationally for humanity, this means the total population times the wealth per capita. In this way, wealth and the carrying capacity of wealth can be compared.

Figure 12: Model with Constant Carrying Capacity Structure



A generic parameterisation of the Capital-Labour with Carrying Capacity submodel indicates logistic growth of the total wealth (shown in grey) of the economy towards the theoretical carrying capacity (which will be developed later) as shown in Figure 13 below.

Figure 13: Behaviour of the Model with Constant Carrying Capacity[61]



The exponential growth seen in the previous submodels is now logistic growth constrained by the carrying capacity. Capital Wealth ultimately dominates and is maximised in LMEs (left) while Labour Wealth is maximised in CMEs (right). LMEs maximise *efficiency* or Total Wealth (left), while CMEs maximise Capital-Labour *equity* (right). CMEs exist further below the Carrying Capacity limits.

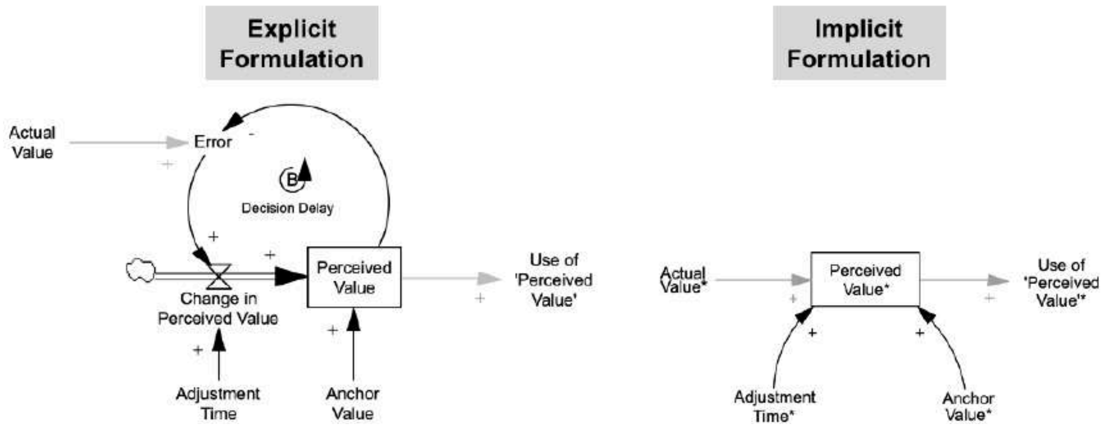
The reinforcing feedback driving the initial exponential growth comes from two sources: growth in capital wealth (quantity as well as quality or productivity) and growth in labour wealth (quantity as well as quality or productivity). The balancing feedback causing goal-seeking behaviour in the second half of the simulation comes primarily from carrying capacity acting on the capital and labour stocks.

[61] CC = 1,000. Note that because of the outflows to the system (CW Decay Rate and LW Decay Rate), neither LME nor CME reaches 1,000 as some wealth is lost exogenously. In the case with exogenous losses, this is analogous to a drain in the bathtub in which a floating mechanism rises and turns off the faucet until the rate of inflow equals the rate of outflow in the drain, creating dynamic equilibrium.

2.1.5 Decision Delay Submodels

The key decisions made in the Capital-Labour submodel are captured in the Decision Delay submodels which introduce decision delays into the system (Sterman, 2000) based on Nobel Prize-winning economist, Herbert Simon's (1957, 1969, 1979, 1982, 1984) concept of 'bounded rationality'. A generic example of the structure is shown on the left of Figure 14 below, where the input of the 'Actual Value' of a variable is mediated by a stock of 'Perceived Values', which is updated by balancing feedback to produce a delayed 'Use of Perceived Value' output. The 'Adjustment Time' defines the speed with which the inertia in the stock is dissipated. For visual clarity and simplicity, the model uses an implicit formulation of the information delay, which captures the stock, flow and feedback internally, without showing them in the diagram, as shown on the right of Figure 14 below.[62]

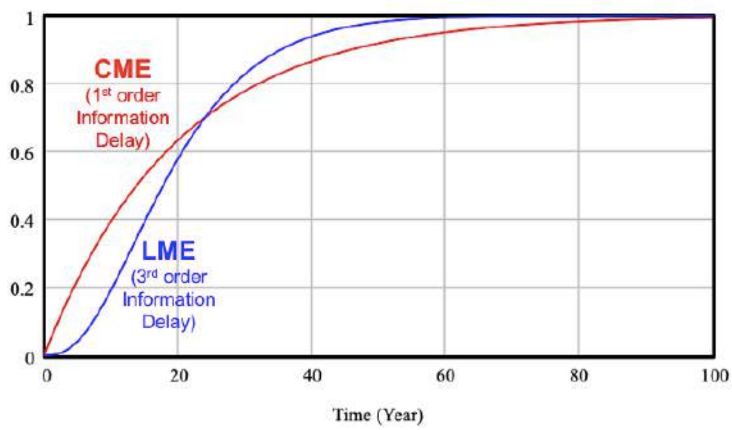
Figure 14: Generic Decision Delay Submodels



LMEs, which wait more and respond quicker, are modelled with a third order decision delay, while CMEs, which respond immediately and more gradually, are modelled with a first order decision delay.

As shown in Figure 15 below, the behaviour of balancing feedback on an inflow is goal-seeking behaviour for the first order delay and logistic behaviour for the third order delay.[63]

Figure 15: Dynamic Behaviour of Decision Delays on Perceived Values[64]



[62] The software package, Vensim, uses a 'Delay1I' function for a first order information delay (used for CMEs) and a 'Delay3I' function for a third-order information delay (used for LMEs).

[63] Econometricists use a similar discrete-time geometric Koyck lag (Koyck, 1954).

[64] Actual Value = 1; Anchor Value = 0; Adjustment Time = 20 years.

There are four balancing feedbacks in which the Decision Delay submodels are used in the Capital-Labour submodel: two applying to Capital Wealth and two applying to Labour Wealth. Capital and labour must each make two decisions: one regarding the policy of interacting with the other, and one regarding the policy of interacting with the carrying capacity as shown in Figure 16 below.

Figure 16: Capital-Labour Submodel Structure with Decision Delay Submodels

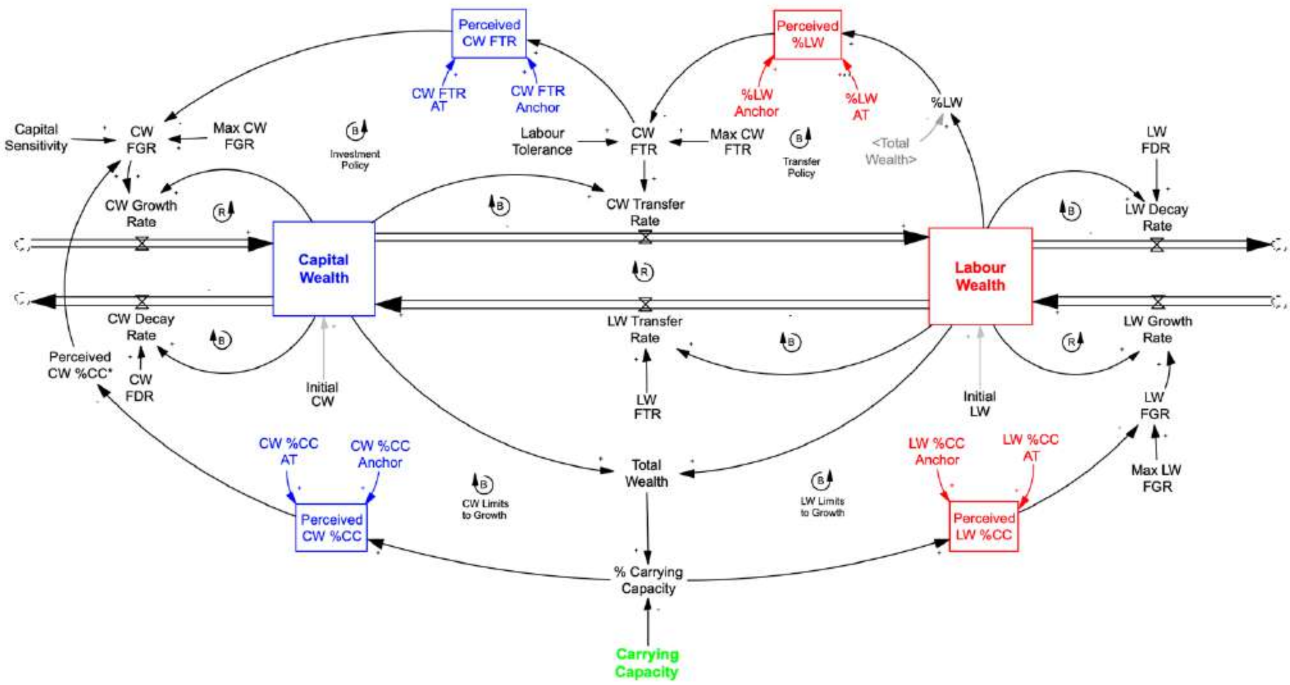


Figure 17 below summarises the estimation of behavioural decision parameters for each variety of capitalism.[65]

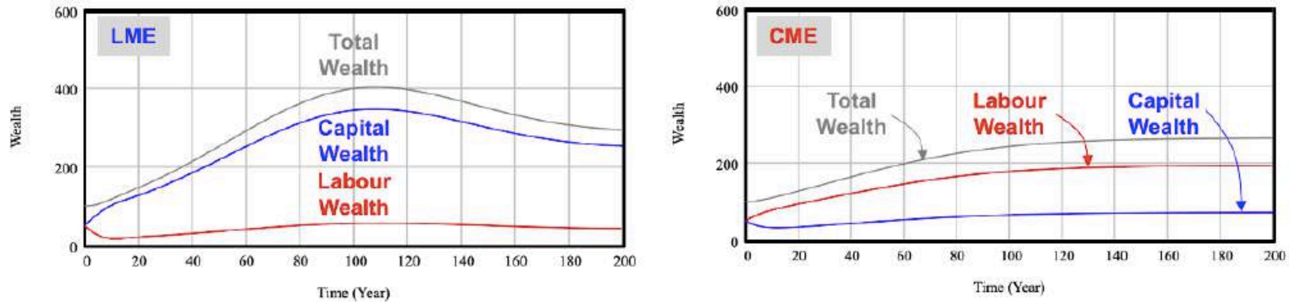
Figure 17: Behavioural Decision Parameters for Archetypal Varieties of Capitalism

Behavioural Decision Parameters	Liberal Market Economies	Coordinated Market Economies
Capital Wealth Fractional Transfer Rate (CW FTR) Anchor[66]	0.003	0.04
Capital Wealth Fractional Transfer Rate (CW FTR) Adjust. Time	2	4
% Labour Wealth (% LW) Anchor[67]	0.5	0.5
% Labour Wealth (% LW) Adjustment Time	4	2
Capital Wealth % Carrying Capacity (CW %CC) Anchor[68]	0.05	0.05
Capital Wealth % Carrying Capacity (CW %CC) Adjustment Time	40	20
Labour Wealth % Carrying Capacity (LW %CC) Anchor[69]	0.05	0.05
Labour Wealth % Carrying Capacity (LW %CC) Adjustment Time	20	10

The dynamic behaviour indicates logistic growth with overshoot and oscillation of the total wealth of the economy as shown in Figure 18 below.

65 Future empirical research would estimate these parameters econometrically.
66 Parameters chosen based on CW FTR_0 values.
67 Parameters chosen based on LW_0/CW_0 values.
68 Parameters chosen based on CW_0/CC_0 values.
69 Parameters chosen based on LW_0/CC_0 values.

Figure 18: Behaviour of Model with Constant Carrying Capacity and Decision Delays



Once again, Capital Wealth ultimately dominates and is maximised in LMEs (left) while Labour Wealth is maximised in CMEs (right). Despite the presence of a carrying capacity, LMEs maximise *efficiency* or Total Wealth (left), while CMEs maximise Capital-Labour *equity* (right).

2.2 Effects of Variable Carrying Capacity

Instead of assuming that the global carrying capacity is constant, the model captures the interaction between economic activity and the (re)generation and degradation/erosion of the carrying capacity.

System Dynamics formed the basis of the controversial *The Limits to Growth* literature (Forrester, 1971; Meadows et al, 1972, 1994, 2004; Randers, 2012), which explored how human economic activity interacts with finite global constraints and how human activity can act to erode the very systems that supports it. The conclusions of the model drew criticism from some economists (Nordhaus, 1973), but not all, like Nobel Prize-winning economist, Jan Tinbergen:

> *"We can all learn some lessons from this book, especially **we economists**.*
> *It shows that… possibilities… **are limited**, more so than some economists think.*
> *As **economists** we must be grateful to these authors for showing us where*
> *the present path of human development threatens to **exceed the limits**…"*[70]

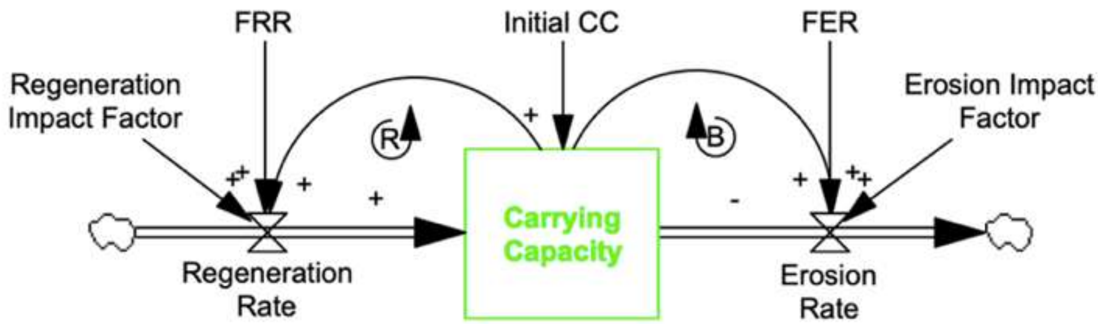
2.2.1 Variable Carrying Capacity Submodel

The Carrying Capacity (CC) of the global economic system is represented as a stock. The inflow is a Regeneration Rate, which is governed by the Fractional Regeneration Rate (FRR) inherent in the natural processes (e.g. growth of plants and animals) as well as a Regeneration Impact Factor (RIF), which captures the human impact (e.g. of planning trees, etc.). The inflow has reinforcing feedback. The Carrying Capacity can therefore be increased by a combination of natural and human activity.

The outflow is an Erosion Rate, which is governed by the Fractional Erosion Rate (FER) inherent in the natural processes (e.g. death of plants and animals) as well as by an Erosion Impact Factor (EIF), which captures human impact (e.g. consuming non-renewables). The outflow has balancing feedback. The Carrying Capacity can therefore be decreased by a combination of natural and human activity.
The variable Carrying Capacity submodel is shown in Figure 19 below.

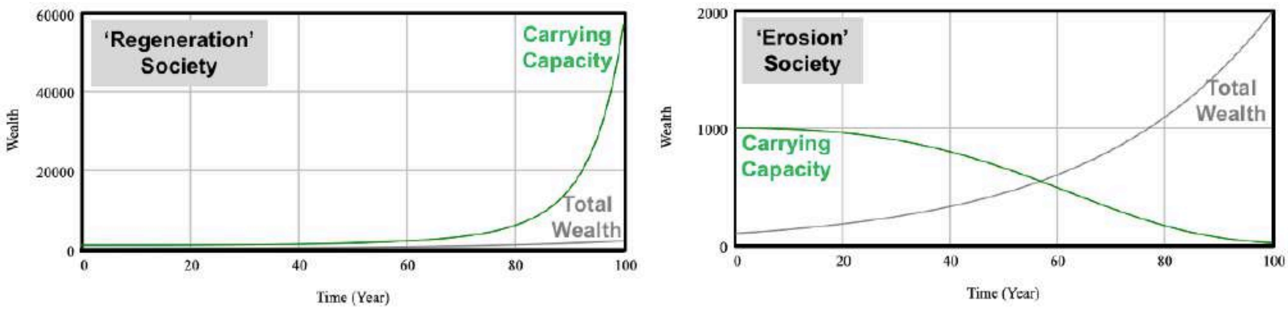
[70] Nobel Prize winner, Jan Tinbergen, in the preface to *Beyond the Limits* (Meadows, et al.., 1992, pg. xii).

Figure 19: Variable Carrying Capacity Submodel Structure[71]



The dynamic behaviour of the Carrying Capacity submodel is shown in Figure 20 below. Here, a simple model of the global economy (in grey) is assumed to grow exponentially. Depending upon the parameters used for the Regeneration Impact Factor and the Erosion Impact Factor, the Carrying Capacity (in green) can either grow exponentially (left) or decay (right).

Figure 20: Behaviour of the Carrying Capacity Submodel[72]



The Carrying Capacity is parameterised to show how human activity impacts both Regeneration and Erosion, along with the 'natural' processes of Regeneration and Erosion as shown in Figure 21 below.[73]

Figure 21: Parameterisation of the Carrying Capacity

Carrying Capacity Parameters	Base Case
Carrying Capacity (CC)	1,000
Fractional Regeneration Rate (FRR)	0.01
Fractional Erosion Rate (FER)	0.01
Regeneration Impact Factor (RIF)	0.5
Erosion Impact Factor (EIF)	1.0

Modelling the political economy in the absence of constraints leads to unrealistic behaviour, namely capital always dominates labour and LMEs always dominate CMEs. Modelling limits to growth is not only realistic, but it has the potential to expose interesting behaviour as each variety of capitalism is now exposed to environments which favour and harm each of them: LMEs outperform CMEs in high growth environments, while CMEs outperform LMEs in low growth environments.

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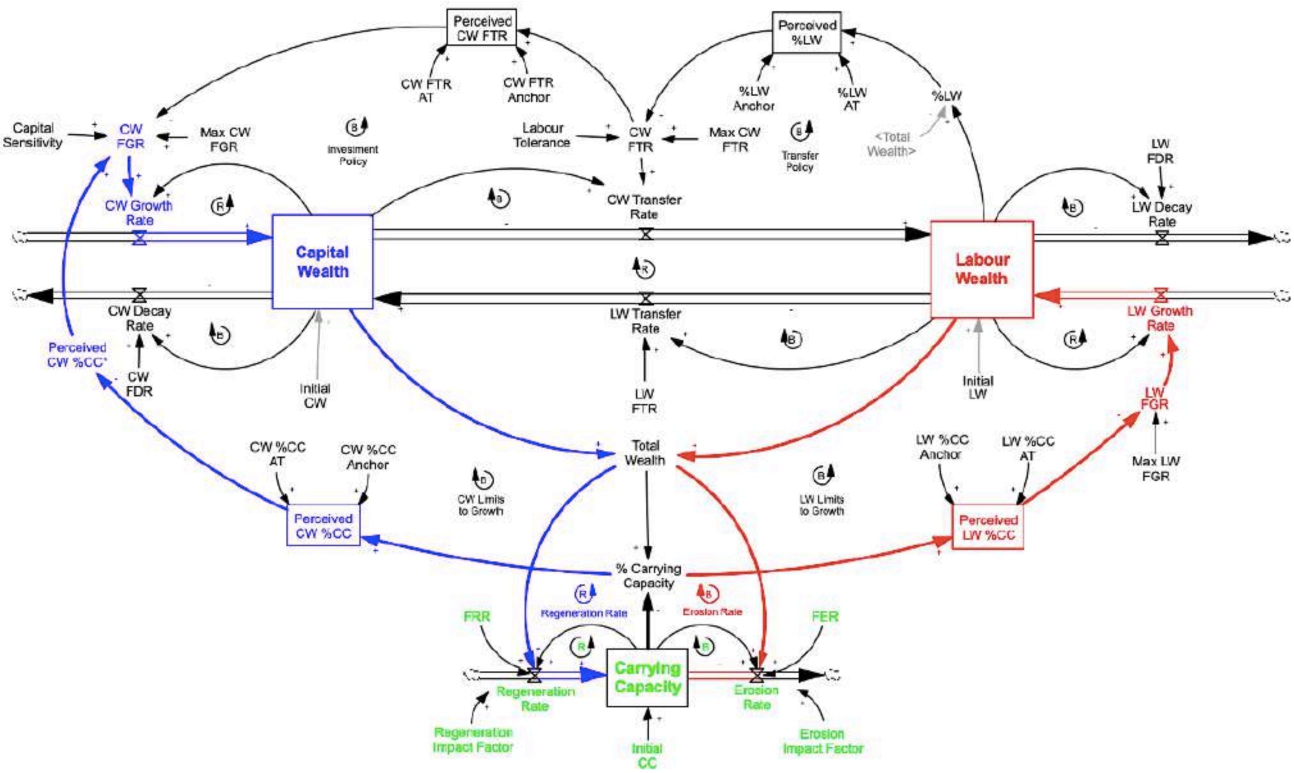
71 See Appendix 3 for the formulation of the Regeneration Rate and the Erosion Rate.
72 CC_0 = 1,000; FRR = FER = 0.01. TW_0 = 100; FGR = 0.03. Left: RIF = 1.0, EIF = 0.5. Right: RIF = 0.5, EIF = 1.0.
73 While it is possible to vary the parameters of the Carrying Capacity further to generate limit cycles and chaotic behaviour, this will be done later once international competition between Varieties of Capitalism is introduced.

2.2.2 Varieties of Capitalism separately under Variable Carrying Capacity

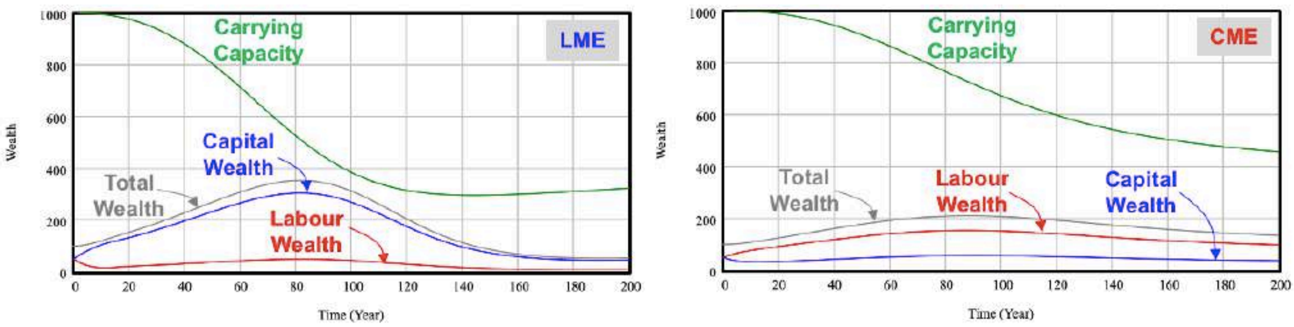
Figure 22 below incorporates the Carrying Capacity submodel into the Capital-Labour submodel.

Figure 22: Capital-Labour Submodel with Variable Carrying Capacity Submodel



The behaviour of the Capital-Labour submodel with variable Carrying Capacity is shown in Figure 23. On the left, the model has been parameterized for LMEs and on the right for CMEs.

Figure 23: Behaviour of Varieties of Capitalism under Variable Carrying Capacity



Note that while both LMEs and CMEs overshoot and collapse by degrading the Carrying Capacity, LMEs degrade the CC more.[74] While LMEs achieve greater peak *efficiency* (i.e. Total Wealth) and greater peak Capital Wealth than CMEs, CMEs achieve greater peak Labour Wealth and *equity* than LMEs. Note also that by the year 120, CMEs also have higher Total Wealth than LMEs.

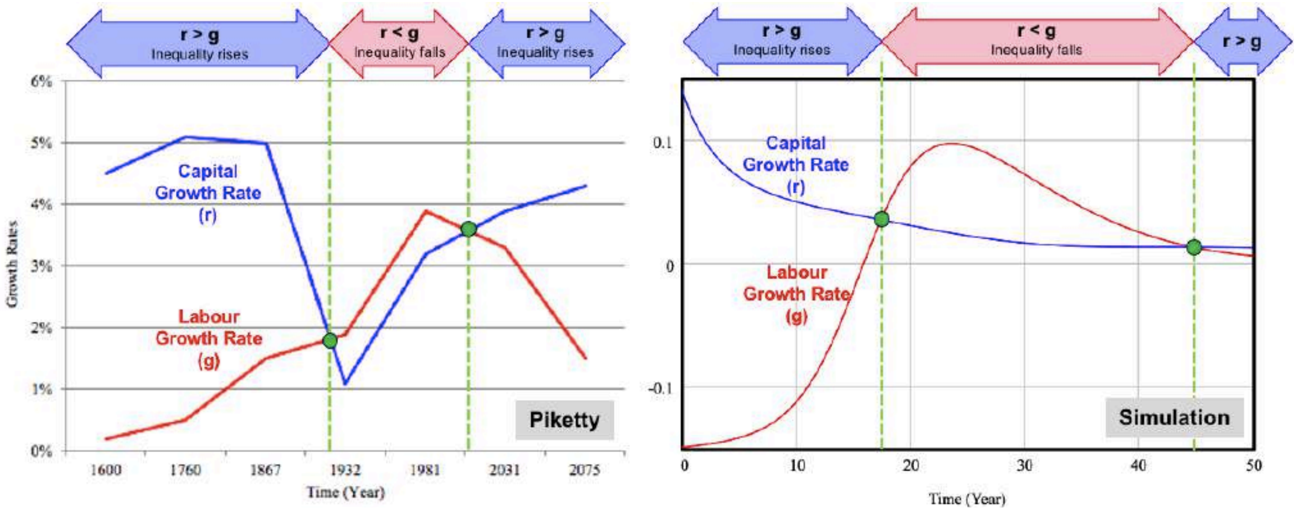
[74] Brander and Taylor (1998) also used nonlinear dynamic simulation modelling to demonstrate overshoot and collapse.

2.2.3 Piketty's Inequality

"Once constituted, ***capital reproduces itself faster than output increases****.*
The past devours the future."[75]

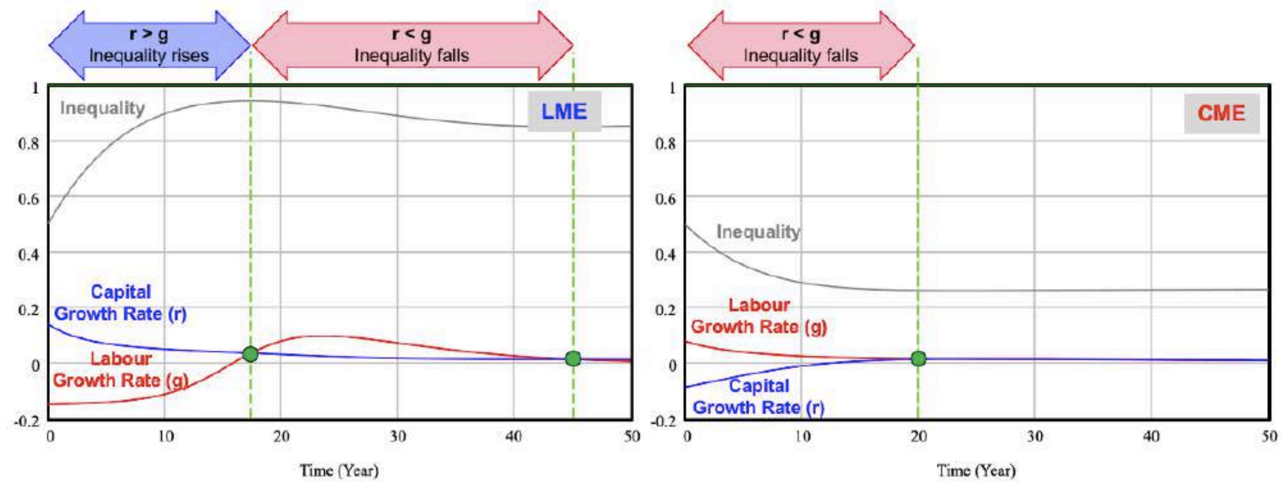
Piketty (2013) empirically demonstrated using international data sets over long periods of time that inequality occurs when the growth rate in capital, r exceeds the growth rate in output, g. The model structure captures Piketty's hypothesis, with the behaviour indicating regions of inequality, characterised by where r > g as shown in Figure 24 below.

Figure 24: Dynamic Behaviour of Piketty's Inequality[76]



As can be seen in Figure 25 below, LMEs (left) exhibit rising and higher inequality than CMEs (right).

Figure 25: Comparing LME and CME Inequality[77]



[75] Piketty, T. (2013).
[76] Data on left from Piketty, T. (2013), pg. 356.
[77] Capital Growth Rate, r = the % change in Capital Wealth. Labour Growth Rate, g = the %change in Labour Wealth. Inequality is defined as % Capital Wealth. To see the effects of r and g on inequality, %LW AT = two times the base case.

2.3 Competition between Varieties of Capitalism via International Trade

*"The different progress of **opulence** in **different ages and nations**, has given occasion to **two different systems of political economy**, with regard to **enriching the people**."*[78]

Adam Smith wrote of two different systems of political economy in *The Wealth of Nations* (1776). The present model similarly characterises two different systems of political economy but takes as its point of departure those in *Varieties of Capitalism* (Hall and Soskice, 2001), namely LMEs and CMEs.[79]

The model captures these varieties of capitalism by parameterising LMEs and CMEs in accordance with Hall and Soskice (2001) and captures their interaction via international trade.[80]

*"It is possible to **connect together two of the models**…*
*to deal with the multiplier relationships **between the incomes of two countries**…"*[81]

Instead of wealth remaining within a domestic political economy, trade allows wealth to flow between political economies, with *absolute* advantage (Smith, 1776) or *comparative* advantage (Ricardo, 1817) working to redistribute wealth. The global economy, being larger than any domestic economy, has the potential to both grow (and shrink) the wealth of a nation depending upon its competitiveness.

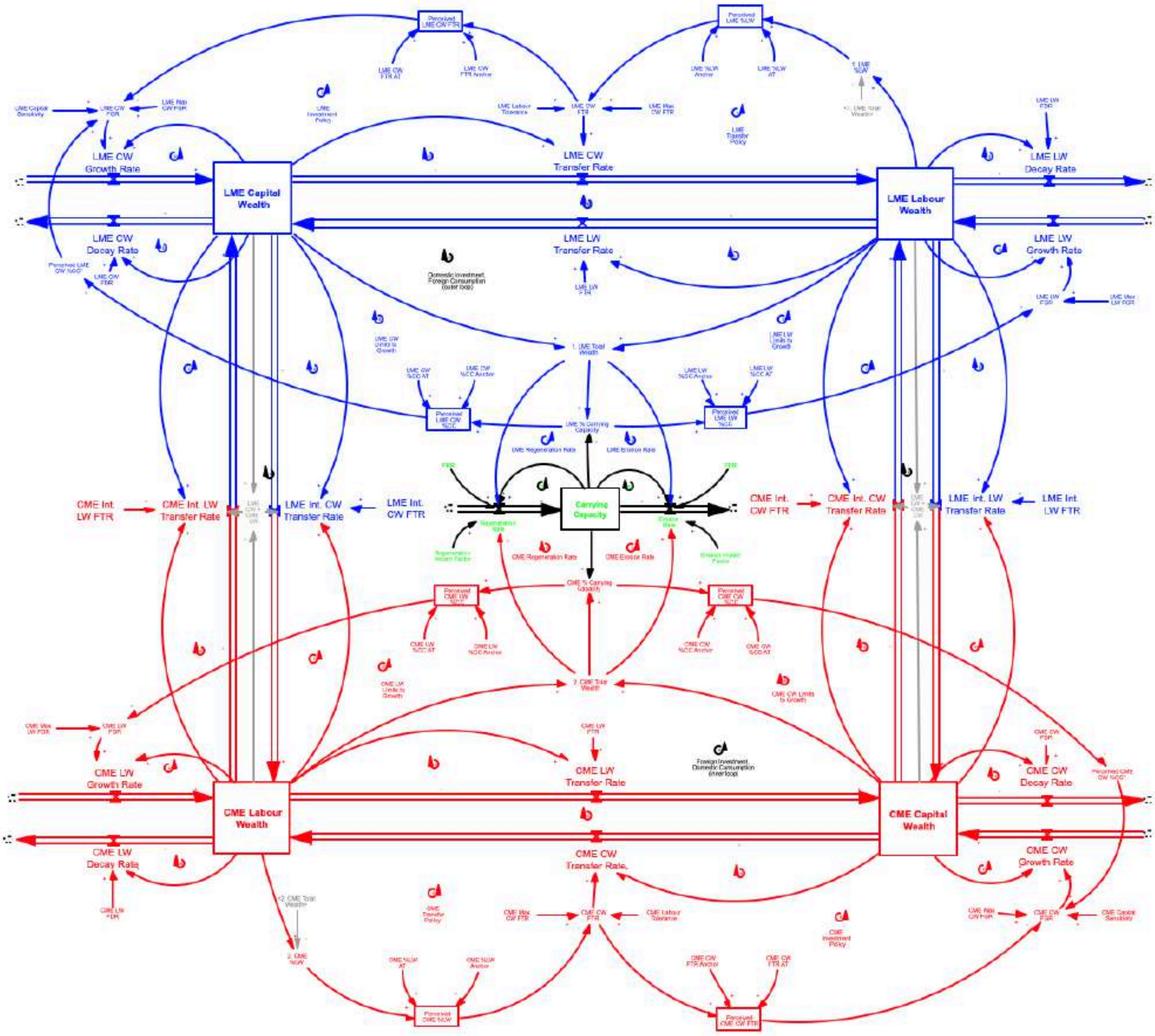
Competition is modelled via international trade, which captures Labour Wealth of one political economy flowing to and from the Capital Wealth stock of the competitor political economy, as well as the Capital Wealth of one political economy flowing to and from the Labour Wealth stock of the competitor political economy.

*"When two **sectors of an economy** are **interdependent** in some way (coupled, we may say),*
*then it is quite **inadmissible** to discuss the one sector **assuming the other unchanged**.*
What we should say is that each sector depends on all the others,
*but then the problem becomes really **unmanageable**.*
*Actually progress in the understanding of any subject comes through **abstraction**,*
*i.e., finding out what can be **ignored** and what cannot."*[82]

The integrated model of the political economy captures the symbiotic dynamics between capital and labour within varieties of capitalism (taking into consideration behavioural decision theory), as well as between varieties of capitalism competing in international trade under limits to growth as shown in Figure 26 below.[83]

[78] Smith, A. (1776), pg. 1 of Book IV.
[79] The typology used for this model was originally derived from 'modular' and 'integral' forms (Piepenbrock, T., 2009). It was subsequently developed and applied to the political economy (Piepenbrock, G., 2020a, 2020b, 2020c, 2020d).
[80] In Figure 26, the blue text indicates the LME Capital-Labour submodel and the red text indicates the CME Capital-Labour submodel.
[81] Phillips, W. (1950), pg. 305.
[82] Goodwin, R. (1947), pg. 181.
[83] Although presentation of the full model violates the 'gazinta' or 'spaghetti diagram' rule (Rahmandad and Sterman, 2012, pg. 398), it is shown simply to visualize the totality and macrostructure of all submodels previously presented.

Figure 26: International Trade between Varieties of Capitalism under Limits to Growth



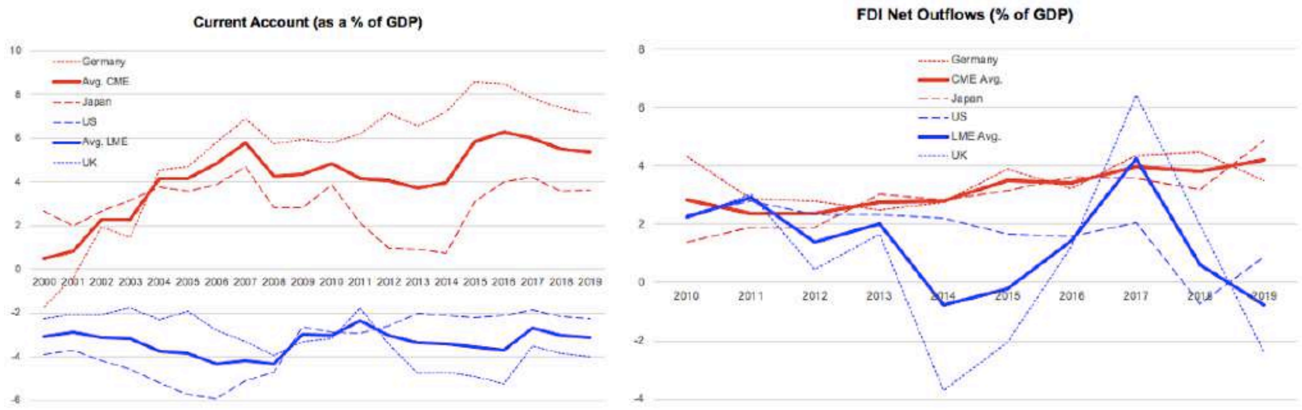
The outer loop describes the international flow of wealth from domestic LME Capitalists who pay domestic LME Labour, who then can purchase imported goods and services from foreign CME Capitalists, who pay their own domestic CME Labour, who can then purchase imported goods and services from foreign LME Capitalists. As wealth flows pass through Capitalists, they can take a profit before passing the residual wealth to Labour.

The inner loop describes the international flow of wealth from domestic LME Labour who purchase domestic goods and services from domestic LME Capitalists, who can set up foreign subsidiaries and pay foreign CME Labour, who purchase domestic goods and services from domestic CME Capitalists who can set up foreign subsidiaries and pay foreign LME Labour. As wealth flows pass through Labour, they can keep some as savings before passing the residual wealth to Capital.

Wealth can also arise from ownership of foreign assets and this is recorded as a flow from foreign Capital wealth into domestic Labour wealth. This income can then be converted from Labour wealth to Capital Wealth domestically, representing a re-investment of that source of foreign income. The more foreign assets a country owns, the greater the flow from foreign Capital wealth becomes.

As LMEs tend to run higher trade deficits than CMEs as shown in Figure 27 below, their International Labour Wealth Fractional Transfer Rates were estimated to be higher than CMEs.

Figure 27: Empirical Evidence for International Wealth Fractional Transfer Rates[84]



As CMEs tend to make larger Foreign Direct Investment as a percentage of their GDP than LMEs as shown above, their International Capital Wealth Fractional Transfer Rates were estimated to be higher than LMEs'.

The parameters used for competition via international trade presented in the simulations herein are shown in Figure 28 below.

Figure 28: Parameterisation of International Competition

International Trade Parameters	Liberal Market Economies	Coordinated Market Economies
International Capital Wealth Fractional Transfer Rate (ICW FTR)	0.05	0.1
International Labour Wealth Fractional Transfer Rate (ILW FTR)	0.1	0.05

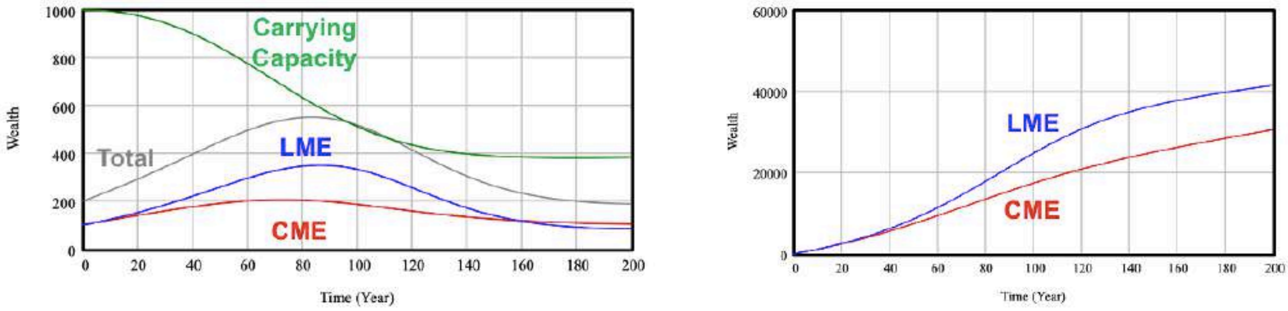
2.3.1 Overshoot and Collapse

Having described the structure of the International Trade submodel, the model was conceptually parameterized for LMEs and CMEs as shown in Appendix 2.[85]

The dynamic behaviour of competition between LMEs and CMEs under limits to growth is shown in Figure 29 below.

[84] Source: World Bank https://databank.worldbank.org/reports.aspx?source=2&series=BN.CAB.XOKA.GD.ZS
[85] For the full model, LME CW_0 = 80 and LME LW_0 = 20, and CME CW_0 = 20 and CME LW_0 = 80. This minor change from a 50:50 assumption simply reduces the time to reach equilibrium between capital and labour.

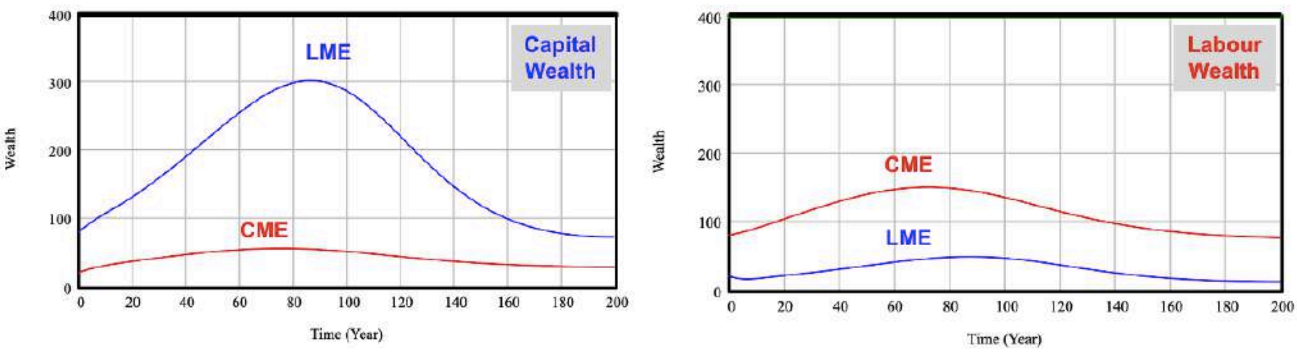
Figure 29: Overshoot and Collapse: Wealth (left) and Cumulative Wealth (right)[86]



Note that LMEs dominate CMEs when there are significant growth opportunities. However, when the Carrying Capacity is greatly reduced, CMEs begin to dominate LMEs.[87] In such low growth regimes, it is not clear that trade based on comparative advantage functions (Ricardo, 1817) as zero-sum competition can prevent the coordination required to see gains under comparative advantage.

The dynamic behaviour of the factors of production are disaggregated and shown in Figure 30 below.

Figure 30: Dynamic Behaviour of Capital and Labour Wealth *within* Varieties of Capitalism



Heterodox economist, Richard Goodwin, showed that the antagonistic yet symbiotic relationship between capital and labour can lead to oscillations (Goodwin, 1967; Weber, 2005; Rammelt, 2018), not unlike those found in predator-prey interactions (Lotka, 1925; Volterra, 1928) which complemented his previous work on limit cycles in the economy (Goodwin, 1949, 1951).

> *"It has long seemed to me that Volterra's problem of **symbiosis** of two populations – partly **complementary**, partly **hostile** – is helpful in the understanding of the **dynamical contradictions** of **capitalism**, especially when stated in a more or less **Marxian** form. This inherent **conflict** and **complementarity** of **workers** and **capitalists** is typical of **symbiosis**."*[88]

[86] Parameters are summarised in Appendix 2. Note that the Cumulative Wealth is measured in units of Dollar-Years.

[87] Piepenbrock, T. (2009) empirically observed this phenomenon and developed theory which explains this contingent behaviour.

[88] Goodwin, R. (1967), pg. 55.

2.3.2 Limit Cycles

LME-CME competition, interacting with a variable Carrying Capacity is equivalent to a predator-prey system (Lotka, 1925; Volterra, 1928). The core structure of this submodel can give rise to limit cycles (Goodwin, 1949, 1951; May 1972, 1976) under a specific range of parameters.[89]

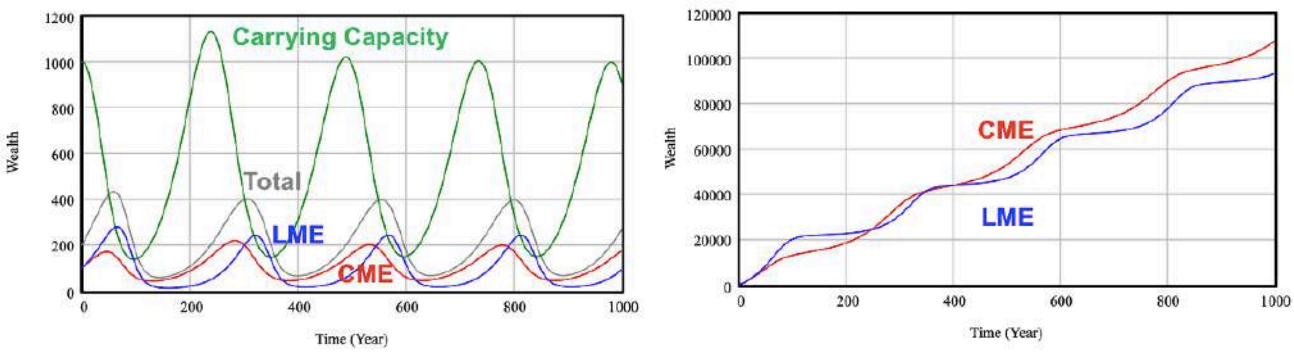
The model is now parameterized in order to explore the effects of a Carrying Capacity in which regeneration does not rely on human activity but on accelerated 'natural' processes, as shown in Figure 31 below. Increasing the Fractional Regeneration and Erosion Rates adds energy into the system, which pushes the dynamic behaviour of the world economy into a more unstable regime causing limit cycles.

Figure 31: Parameterisation of the Carrying Capacity to Produce Limit Cycles

Carrying Capacity Parameters	Base Case	Limit Cycle
Carrying Capacity (CC)	1,000	**1,000**
Fractional Regeneration Rate (FRR)	0.01	**0.03**
Fractional Erosion Rate (FER)	0.01	**0.03**
Regeneration Impact Factor (RIF)	0.5	**0.0**
Erosion Impact Factor (EIF)	1.0	**1.0**

As can be seen in Figure 32 below, the 'multi-predator-prey' model can exhibit limit cycles having a period of approximately 250 years. The peak Carrying Capacity equilibrates at 1,000 and the total peak wealth of society equilibrates at 400, which is twice the initial wealth. Note that LME peak wealth exceeds CME peak wealth, with both stabilizing at approximately 240 and 200 respectively.

Figure 32: Limit Cycles: Wealth (left) and Cumulative Wealth (right)[90]



The cumulative wealth of LMEs and CMEs are shown above, where a 'tortoise-hare' dynamic can be seen, in that LMEs take the early lead in wealth accumulation, whereas CMEs overtake them long-term.[91] CMEs appear to be better adapted to a slow/negative growth economic environment, due to their focus on Labour over Capital.[92]

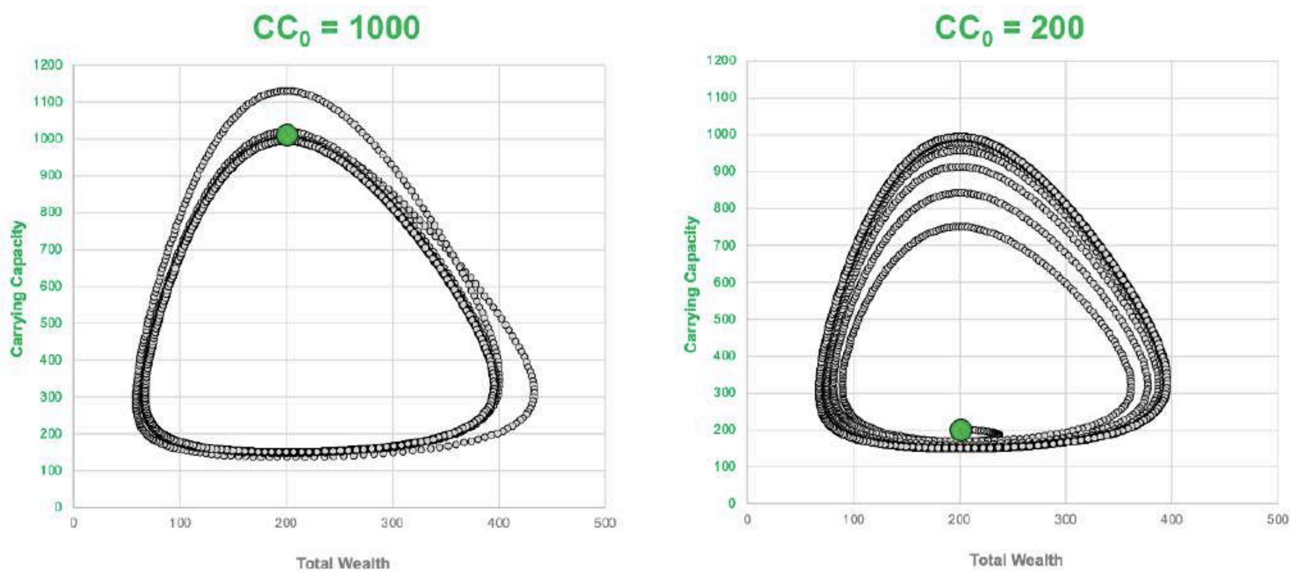
[89] A 'limit cycle' is a nonlinear self-sustained oscillation, presenting itself as an *isolated, closed* trajectory in phase space.
[90] Note that the Cumulative Wealth is measured in units of Dollar-Years.
[91] CMEs win the 'wealth race' after approximately the year 400. This is captured in the African proverb: *"If you want to go fast, go alone, if you want to go far, go together."*
[92] Piepenbrock, T. (2009).

This research begins to demonstrate that perhaps predictions of liberalisation of varieties of capitalism are premature as environmental constraints on growth may not be accelerating liberalisation, but act to do precisely the opposite.

*"Business cycles must be explained by essential **nonlinearities** in **economic relationships**…*
*it can be shown that we do find such a **stable limit cycle**.*
*…a **second-order nonlinear differential equation**… It may be easily **integrated**…*
*and the resulting **stable motion** is plotted in the **phase plane**…"*[93]

Phase plots of the system are shown in Figure 33 below. As can be seen, for the parameters chosen, the system settles quickly into a stable limit cycle, whether from above (on the left) or below (on the right). This system appears to be ergodic over the long term[94], as it is insensitive to initial conditions of Wealth and Carrying Capacity stocks. This further contextualises the 'ergodic hypothesis' in economics (Samuelson, 1968, 1969).

Figure 33: Phase Plots with Varying Initial Carrying Capacity[95]



The dynamic interaction between LMEs and CMEs is shown on the left in Figure 34 below. The orbit is not symmetric, with LMEs experiencing a wider range of growth and contraction than CMEs.

The figure on the right compares LMEs' and CMEs' markedly different limit cycle orbits with regard to the Carrying Capacity, with CMEs expanding into space which grows the Carrying Capacity, while LMEs constrain their own long-term growth by degrading Carrying Capacity.[96]

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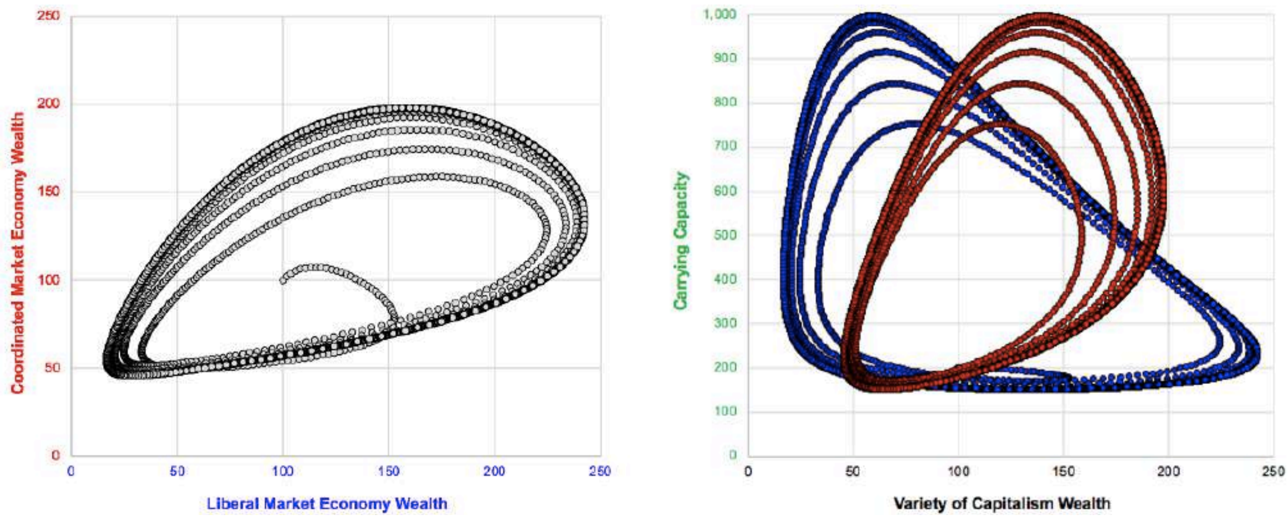
[93] Goodwin, R. (1949), pg. 185. The paper was presented orally in December 1948.
[94] However, as Keynes remarked (1923), *"In the long run, we're all dead."*
[95] In order to capture the long-run dynamics of the limit cycle, the model was run for 10,000 years. The green dots indicate the starting position for the clockwise trajectories.
[96] The shapes of the outer limits of the limit cycle orbits mimic Production Possibility Frontiers (PPFs) posited for LMEs and CMEs: convex away from the origin for LMEs and concave towards the origin for CMEs (Piepenbrock, G. 2020c).

Figure 34: Phase Plots Comparing LMEs and CMEs[97]



2.3.3 Deterministic Chaos

"The regimes of fluctuating steady-state behaviour, including ***chaos****,*
lie squarely in the middle of the realistic region of parameter space…
Chaos *is a steady-state phenomenon which manifests over* ***very long time frames****."*[98]

"A simulation was assumed to be ***chaotic*** *if the trajectory did not close after* ***100 orbits****."*[99]

The model can be parameterized to move beyond the limit cycle regime, into deterministic chaos (May, 1976, pg. 466; Sterman, 1989). The previous model is now parameterized so that the Fractional Regeneration Rate and the Fractional Erosion Rate of the Carrying Capacity are increased from 0.03 to 0.10 as shown in Figure 35 below.

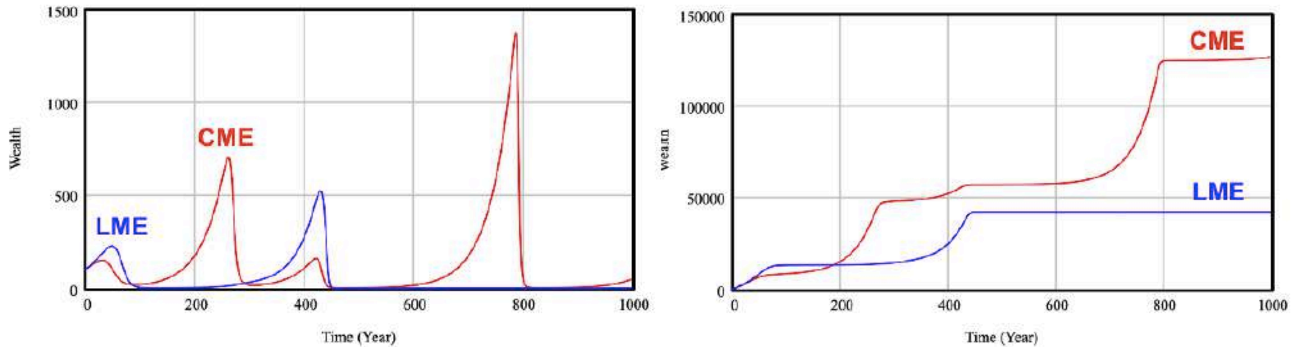
Figure 35: Parameterisation of the Carrying Capacity to Produce Chaos

Carrying Capacity Parameters	Base Case	Limit Cycle	Chaos
Carrying Capacity (CC)	1,000	1,000	**1,000**
Fractional Regeneration Rate (FRR)	0.01	0.03	**0.10**
Fractional Erosion Rate (FER)	0.01	0.03	**0.10**
Regeneration Impact Factor (RIF)	0.5	0.0	**0.0**
Erosion Impact Factor (EIF)	1.0	1.0	**1.0**

This parameterisation results in deterministic chaos having irregular periods and amplitudes as shown on the left in Figure 36 below. Note that for a wide range of parameters, given a long enough period of time, CME cumulative wealth exceeds LME cumulative wealth as shown on the right in Figure 36.

97 CC_0 = 200, generating limit cycles from below.
98 Sterman (1989), pg. 25.
99 Sterman (1989), pg. 22. Note that the trajectories did not close after 100 orbits, which took approximately 50,000 years, indicating chaos.

Figure 36: Deterministic Chaos: Wealth (left) and Cumulative Wealth (right)[100]



3. Discussion

3.1 Results

These results add to the literature which demonstrates the symbiotic nature of 'interspecies' competition between complementary forms of capitalism (Goodwin, 1967; Hall and Soskice, 2000; Piepenbrock, 2009; Acemoglu, Robinson and Verdier, 2017).

*"We have shown that, somewhat **paradoxically**, starting with similar initial conditions,*
*those that choose **cuddly capitalism**, though poorer, will be **better off***
*than those opting for **cutthroat capitalism**.*
*This configuration is an equilibrium all the same, because **cutthroat capitalists** cannot switch to*
***cuddly capitalism** without having a large impact on **world growth**,*
*which would ultimately **reduce their own welfare**."*[101]

The 'species' of economic actors emerge from the mathematical dynamics of the ecosystems. Evolutionary strategies of 'r-strategists' and 'K-strategists' (MacArthur and Wilson, 1967) are derived from the ecological differential equations: 'r' is the fractional growth rate, and 'K' is the carrying capacity. Sociologists (Brittain and Freeman, 1980; Brittain, 1994) and evolutionary economists (Piepenbrock, T., 2009) have applied this framework to organizational and economic environments.[102]

"An ***'opportunist'*** or ***r-strategist*** is a species with a ***high*** maximal intrinsic rate of increase,
but a species of ***poor competitive ability*** *at* ***low resource density*****.**
*It is focused on **short-term returns** and operates by spotting opportunities and **acting quickly**.*
*An **'equilibrium'** or **K-strategist** is a species with a **low** maximal intrinsic rate of increase,*
*but it is capable of growing at its maximal rate at very **low levels of resource density**.*
*It makes **substantial investments** to develop the market and open up potential positions*
*of market power. Such firms are necessarily **slower to act**."*[103]

[100] Note that the Cumulative Wealth is measured in units of Dollar-Years.
[101] Acemoglu, Robinson and Verdier (2017), pg. 1284.
[102] Microeconomists (Law & Stewart, 1983; Mai & Hwang, 1989; Horowitz, 1991; Cremer & Crémer, 1992; Futagami & Okamura, 1994; Neary & Ulph, 1996; Lambertini & Rossini, 1998; De Fraja & Delbono, 2002) have similarly modelled competition between firms having different objective functions ('profit maximising' and 'labour managed') as 'mixed duopolies'.
[103] Brittain and Freeman (1980), pg. 311-312.

3.2 Model Sensitivity

Next, the model is tested for sensitivity to changes in parameters and to determine which parameters have the most significant effect on the overall system performance, chosen to be the Cumulative Wealth of LMEs and CMEs after 200 years. One at a time, values of parameters are doubled and the overall change in system performance is measured as shown in Figure 37 below.

Figure 37: Parametric Analysis of Model Sensitivity[104]

Parameter Doubling	Cumulative Wealth at Time = 200					
	LME	%LME	CME	%CME	Total	% Base
CME LW FDR = 0.1	51,275	**0.913**	4,860	0.087	56,135	0.78
CME International LW Transfer Rate (CME I LW TR) = 0.1	50,936	0.885	6,587	0.115	57,523	0.80
LME CW FGR = 0.2	64,734	0.834	12,901	0.166	77,635	1.08
CME LW FTR = 0.1	46,298	0.722	17,860	0.278	64,158	0.89
CME CW FDR = 0.2	45,374	0.683	21,027	0.317	66,401	0.92
CME International CW Transfer Rate (CME I CW TR) = 0.2	47,729	0.681	22,351	0.319	70,080	0.97
LME CW %CC AT = 80	53,567	0.657	27,978	0.343	81,545	1.13
LME Labour Tolerance = 8	44,116	0.607	28,583	0.393	72,699	1.01
LME Initial CW = 160	51,842	0.606	33,763	0.394	85,605	1.19
LME LW FGR = 0.1	43,804	0.605	28,546	0.395	72,350	1.00
CME Labour Tolerance = 0.5	42,390	0.599	28,413	0.401	70,803	0.98
FRR = 0.02	**87,886**	0.592	**60,476**	0.408	**148,362**	**2.06**
LME LW FTR = 0.2	42,799	0.589	29,841	0.411	72,640	1.01
Initial CC = 2000	54,640	0.585	38,720	0.415	93,360	1.30
LME Initial LW = 40	44,352	0.585	31,521	0.415	75,873	1.05
CME LW %CC Anchor = 0.16	41,827	0.581	30,178	0.419	72,005	1.00
LME LW %CC AT = 40	41,763	0.579	30,393	0.421	72,156	1.00
LME %LW Anchor = 0.4	41,588	0.577	30,433	0.423	72,021	1.00
CME Capital Sensivity = 0.5	41,541	0.577	30,479	0.423	72,020	1.00
LME %LW AT = 8	41,525	0.576	30,515	0.424	72,040	1.00
LME CW FTR AT = 4	41,506	0.576	30,554	0.424	72,060	1.00
CME CW %CC Anchor = 0.04	41,509	0.576	30,559	0.424	72,068	1.00
CME %LW Anchor = 1.6	41,505	0.576	30,568	0.424	72,073	1.00
Base Case	41,495	0.576	30,576	0.424	72,071	1.00
CME CW FTR AT = 8	41,495	0.576	30,576	0.424	72,071	1.00
CME %LW AT = 4	41,501	0.576	30,569	0.424	72,070	1.00
CME CW FTR Anchor = 0.14	41,498	0.576	30,573	0.424	72,071	1.00
LME LW %CC Anchor = 0.04	41,488	0.576	30,588	0.424	72,076	1.00
CME Order Delay = 3	41,445	0.575	30,579	0.425	72,024	1.00
RIF = 1	60,677	0.575	44,809	0.425	105,486	1.46
LME CW FTR Anchor = 0.04	41,459	0.575	30,630	0.425	72,089	1.00
FER = 0.02	22,444	0.574	16,688	0.426	39,132	0.54
CME CW %CC AT = 40	41,391	0.573	30,807	0.427	72,198	1.00
LME Order Delay = 1	41,763	0.572	31,191	0.428	72,954	1.01
CME Initial CW = 40	43,277	0.568	32,964	0.432	76,241	1.06
EIF = 2	24,194	0.566	18,530	0.434	42,724	0.59
CME LW %CC AT = 20	40,928	0.565	31,529	0.435	72,457	1.01
LME CW %CC Anchor = 0.16	40,709	0.562	31,730	0.438	72,439	1.01
CME Initial LW = 160	46,726	0.534	40,771	0.466	87,497	1.21
CME CW FTR = 0.2	39,540	0.530	35,014	0.470	74,554	1.03
CME CW FGR = 0.1	38,632	0.517	36,119	0.483	74,751	1.04
LME Capital Sensivity = 8	35,644	0.515	33,623	0.485	69,267	0.96
LME CW FTR = 0.1	33,441	0.493	34,337	0.507	67,778	0.94
LME LW FDR = 0.2	31,953	0.479	34,700	0.521	66,653	0.92
LME International LW Transfer Rate (LME I LW TR) = 0.2	32,961	0.464	38,115	0.536	71,076	0.99
CME LW FGR = 0.2	29,945	0.363	52,533	0.637	82,478	1.14
LME International CW Transfer Rate (LME I CW TR) = 0.1	7,817	0.142	47,125	0.858	54,942	0.76
LME CW FDR = 0.1	4,614	0.098	42,606	**0.902**	47,220	0.66

[104] The parameters have been ordered vertically based on the %LME Cumulative Wealth (and in reverse order for %CME Cumulative Wealth). The largest values are shown in bold. The base case is shown in grey shading and the highest leverage parameters are shown in blue shading for LMEs and in red shading for CMEs.

The parameters which have the greatest impact on the total wealth of the global political-economic ecosystem are unsurprisingly those characterizing the Carrying Capacity. For example, doubling the Fractional Regeneration Rate from 0.01 to 0.02 results in a doubling of the total wealth.

The parameters which most affect the cumulative wealth of each variety of capitalism are: 1) the fractional decay rate of its competitor's primary factor of production (i.e. for LMEs, it is the CMEs' LW FDR); 2) the fractional international transfer rate of its competitor's primary factor of production (i.e. for LMEs, it is CMEs' LW international transfer rate); and 3) the fractional growth rate of the variety of capitalism's primary factor of production (i.e. for LMEs, it is their own CW FGR). The system's nonlinearity is shown by the fact that a doubling of one of the critical parameters in some cases can lead to nearly an order of magnitude change in performance.

3.3 Model Validity

*"There is no reason that a **generic** model should reproduce any **historical time series**. Instead, it should generate **the kind of dynamic behavior** that is observed in the systems that are being represented."*[105]

The notion of model validity is closely linked with model purpose (Barlas, 1996), which varies epistemologically from mainstream orthodox economics, where econometric models are used to establish parameter values in order to achieve tight model fit with time series data (Barlas and Carpenter, 1990; Barlas, 1996; Radzicki, 2011). System Dynamics, however, focuses on understanding and pattern-matching over point-prediction, on accuracy over precision. This is particularly important in the model, which has the potential to generate limit cycles and deterministic chaos, making point-predictions near-impossible. Confidence-building in SD therefore arises not necessarily from *external* validity associated with reproducing historical time series, but also from *internal* validity or the logic of the causal relationships (Barlas, 1996).

*"I would prefer a structure in which I had confidence using **intuitively estimated coefficients** rather than an **unlikely structure** and functional relationships for which coefficients could be **derived accurately from statistical data**."*[106]

Unlike econometric modelling which strives for precision over accuracy in its short-term predictions, nonlinear dynamic simulation modelling seeks understanding long-term system behaviour that arises from its causal structure, in order to test policy designs to improve the system (Forrester, 1961; Sterman, 2000; Radzicki, 1990; Keen 1995) as part of a pragmatic instrumentalist epistemology (Peirce, 1898, 1903; Dewey 1910, 1916).

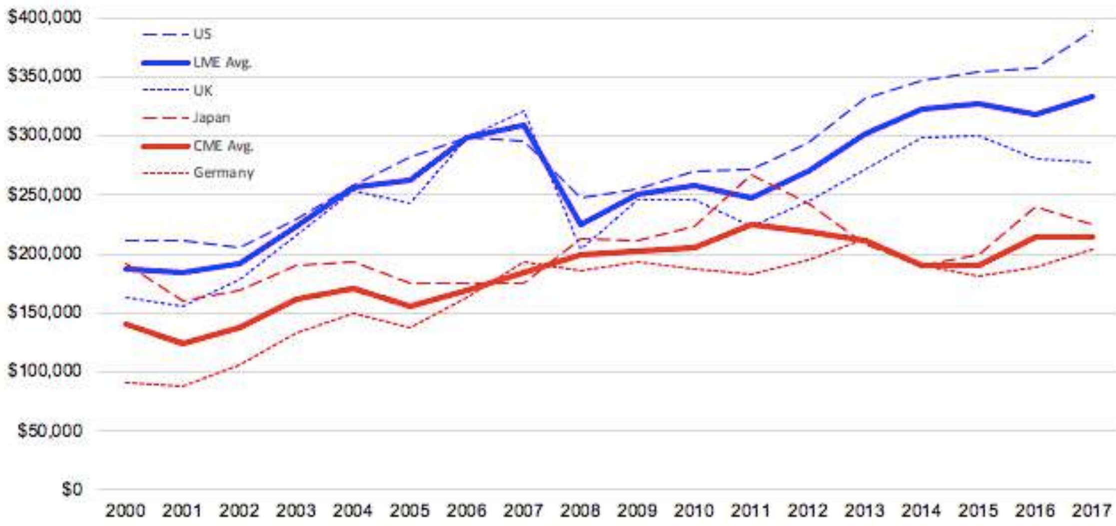
*"One of the lessons **of nonlinear dynamics** is that such **accurate** quantification is in fact **impossible**. The emphasis of modeling therefore shifts from **prediction** to **simulation**."*[107]

The purpose of this model is not to forecast the absolute value of wealth of any single nation at any point in time. It is rather to get an understanding of the relative wealth of aggregate varieties of capitalism over relatively long periods of time and to compare the relative proportions of capital wealth and labour wealth within these varieties of capitalism over time.

[105] Forrester, J.W. 2013, pg. 30.
[106] Forrester, J.W. 2003, pg. 345.
[107] Keen (1995), pg. 618.

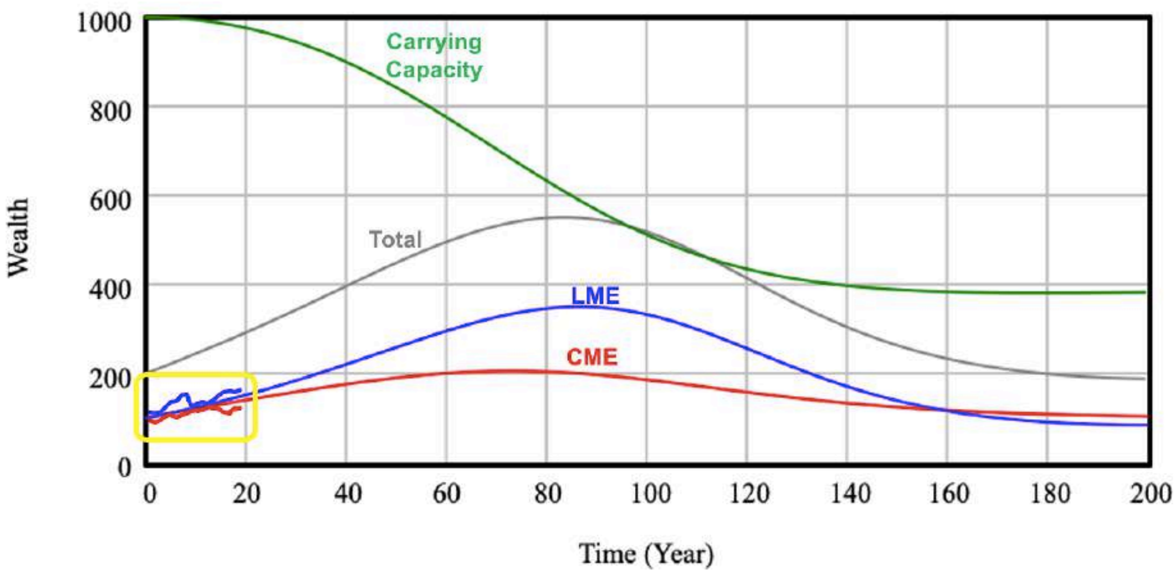
Unfortunately, reliable empirical data of such variables over long time periods is difficult to obtain.[108] Figure 38 below shows World Bank data on Wealth per Capita for archetypal LMEs (US and UK) and CMEs (Japan and Germany) over the past two decades.

Figure 38: Historical data of Wealth per Capita in Varieties of Capitalism



A number of observations can be made. First, LME nations tend to cluster together, as do CME nations. Second, LME Wealth is both higher and more variable than CME Wealth.[109] Although very limited temporally, these trends are qualitatively broadly in line with the simulated behaviour of the model over a wide range of parameters, as shown in the yellow rectangle below in Figure 39.

Figure 39: Historical Data and Simulation Comparison of Wealth per Capita



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[108] Although high-quality historical empirical data on national wealth *stocks* (i.e. assets minus liabilities) is difficult to find, GDP could be used as a reasonable proxy for the *flows* out of the wealth stocks.

[109] Note that the 2007-2008 'global' financial crisis was more damaging to LME Wealth that to CME Wealth. An argument can be made that CMEs outperform LMEs in harsh environments (Piepenbrock, 2009), not unlike the long-term secular stagnation of the 21st century that *Limits to Growth* models (Meadows et al., 1972, 1992, 2004) predict. COVID-19 presents another 'natural experiment' to which VoCs are all subjected to a common 'exogenous shock'. Early indications demonstrate that in such low growth environments, it is the LMEs who fare worse than CMEs (Piepenbrock, G., 2020a and 2020b).

3.4 Further Research and Conclusions

Further conceptual developments of the model which would add to internal validity would be to disaggregate the capital stock into a separate third 'intermediary' factor of production: money and debt via a banking class (Minsky, 1982, 1986; Keen, 1995; Rammelt, 2019).

> *"Constant income shares then ensue for the three 'classes' in the model –*
> ***workers**, **capitalists**, and **bankers**."*[110]

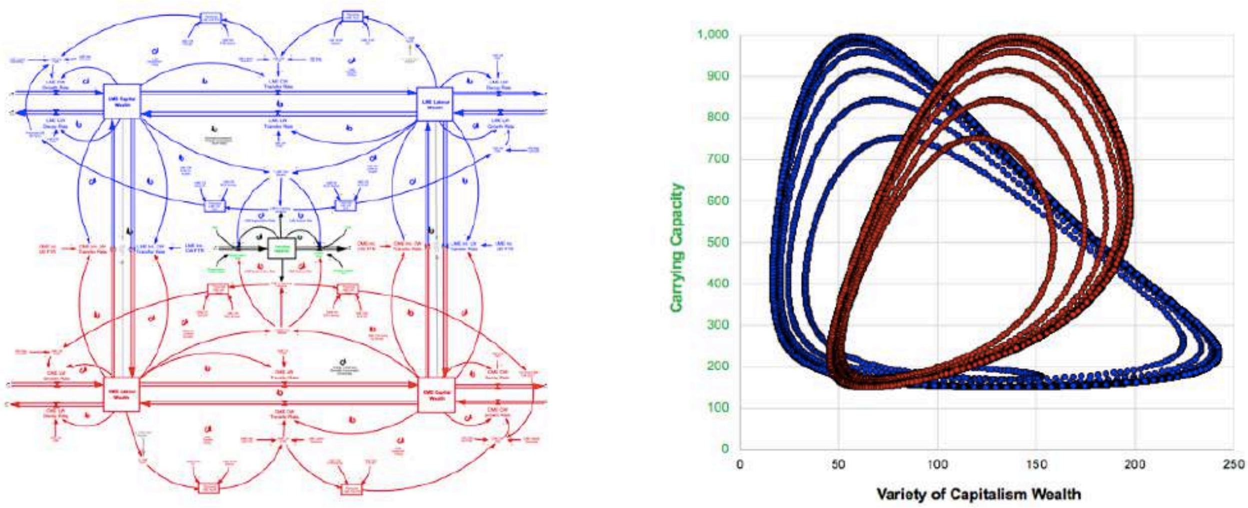
In addition, adding a government sector which attempts to initiate policies to control instabilities (Keen, 1995) would also be an important next step in strengthening internal model validity.

> *"The importance of **government** is emphasized by… a **stylized government** into the model... These simulations provide strong support for Minsky's proposition that the **institutional arrangements** instituted in the aftermath of the Great Depression '**worked**,' since though cycles occurred, **breakdown did not**."*[111]

Further refinements would also include additional empirically-based parameter estimation using econometric methods, which would help with model validity (Sterman, 2018).

The creation of formal models capturing the role of political and economic institutions in long-run economic growth has been called the 'Holy Grail' of political economy research (Acemoglu, Johnson and Robinson, 2005). While such a quest is certainly formidable and I have only humbly attempted to scratch the surface, I hope that the use of numerical simulation modelling of systems of nonlinear differential equations can begin to shed some light on the nonlinear dynamic interactions between: 1) capital and labour within a political economy, 2) LMEs and CMEs in competitive international trade more broadly, and finally, 3) the global political economy and the supporting ecological ecosystem. The symbiotic interaction between capital and labour have been demonstrated to enable and constrain growth of wealth *endogenously*, while the environment enables and constrains growth of wealth *exogenously*. The simulations demonstrate that while LMEs outperform CMEs in the shorter term, the converse is true in the longer term, with LMEs maximising capital wealth and *efficiency* and CMEs maximising labour wealth and *equity* as summarised in Figure 40 below. The quest continues.

Figure 40: Structure and Behaviour of the Evolution of the Political Economy



[110] Keen, S. (1995), pg. 620.
[111] Keen, S. (1995), pg. 634.

Acknowledgements

*"… **System dynamics models** can become the vehicle for*
*a **relevant** and **exciting pre-college economics education**."*[112]

I attended my first System Dynamics (SD) Society Conference in New York in 2003 when I was just one month old. The conference had a theme of 'Economic Dynamics' and Jay Forrester gave a lecture on 'Economic Theory for the New Millennium'. I am told that I slept quietly through it, but somehow his words must have sunk in, as I found myself 17 years later attending my second SD Society Conference in Norway in 2020. Professor Forrester made my dad (who was working on his PhD at MIT in SD at the time) promise him that my dad would teach me SD throughout my K-12 education, which he did. I remember my dad telling me when I was a child that SD was 'the science of sciences'. I think he was trying to get me interested – and it worked!

I specialize in Economics, Political Science and Advanced Mathematics at A-Level (the 11th and 12th grades of secondary school in the UK), and I had spent my spare time in my 16th year (during COVID-19 lockdown) building SD models exploring the evolution of wealth creation and distribution in the political economy, which formed the basis of this paper. I hope that this research serves in some small way to show the power of K-12 System Dynamics education, in honour of Jay Forrester.

*"As we look to the future, I see a **most important role for system dynamics***
*in developing material on **economic behavior** for kindergarten through **12th grade education**."*[113]

I would like to thank MIT Professor John Sterman, first for his textbook, *Business Dynamics* (2000), which has been a 'touchstone' for much of my SD knowledge; and second for allowing me to audit a graduate MIT SD class in the Spring of 2021, for which I would also like to thank MIT Professor David Keith. Additionally, I would like to thank Professor David Wheat for kindly allowing me to audit his graduate SD class on modelling the macroeconomy in Autumn of 2020 and for giving a lecture at Eton College on this topic. I would also like to thank Professor Steve Keen for his generous support of my work in SD and for giving a lecture on SD and post-Keynesian economics at Eton College on this topic. I would like to thank Professor of Political Economy, Peter Hall of Harvard University for his kind feedback on my work on Varieties of Capitalism, a field that he launched with his book of the same name (Hall and Soskice, 2001). I would also like to thank Professor Ha-Joon Chang of the University of Cambridge for his kind feedback on my work on the role of economic development in the evolution of the political economy and for giving a lecture at Eton College on this topic. I would also like to thank the Lawson family, the Carole and Geoffrey Lawson Charitable Foundation, Michael Wargel, the Balliol Society Educational Trust, Professor Elena Lombardi and Eton College for their generous support of my studies at Eton.

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[112] Forrester, J.W. (2013), pg. 26.
[113] Forrester, J.W. (2013), pg. 39.
[114] Although I have been guided and supported by many people on this work, I take full responsibility for all errors.

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Appendix 1: Abbreviations

CME	Coordinated Market Economy
LME	Liberal Market Economy
CW	Capital Wealth
LW	Labour Wealth
FGR	Fractional Growth Rate
FTR	Fractional Transfer Rate
FDR	Fractional Decay Rate
α	Capital Sensitivity
β	Labour Tolerance
AT	Adjustment Time
ICWTR	International Capital Wealth Transfer Rate
ILWTR	International Labour Wealth Transfer Rate
CC	Carrying Capacity
FRR	Fractional Regeneration Rate
FER	Fractional Erosion Rate
RIF	Regeneration Impact Factor
EIF	Erosion Impact Factor

Appendix 2: Model Parameters

Figure A1: Parameters used in Submodel Build-up

General Parameters	Liberal Market Economies	Coordinated Market Economies
Initial Capital Wealth (CW_0)	50	50
Initial Labour Wealth (LW_0)	50	50
Capital Wealth Fractional Growth Rate (CW FGR)	0.1	0.05
Capital Wealth Fractional Transfer Rate (CW FTR)	0.05	0.1
Labour Wealth Fractional Decay Rate (LW FDR)	0.1	0.05
Labour Wealth Fractional Growth Rate (LW FGR)	0.05	0.1
Labour Wealth Fractional Transfer Rate (LW FTR)	0.1	0.05
Capital Wealth Fractional Decay Rate (CW FDR)	0.05	0.1
Capital Sensitivity (α)	4	0.25
Labour Tolerance (β)	4	0.25
Capital Wealth Fractional Transfer Rate (CW FTR) Anchor	0.003	0.04
Capital Wealth Fractional Transfer Rate (CW FTR) Adjust. Time	2	4
% Labour Wealth (% LW) Anchor	0.5	0.5
% Labour Wealth (% LW) Adjustment Time	4	2
Capital Wealth % Carrying Capacity (CW %CC) Anchor	0.05	0.05
Capital Wealth % Carrying Capacity (CW %CC) Adjustment Time	40	20
Labour Wealth % Carrying Capacity (LW %CC) Anchor	0.05	0.05
Labour Wealth % Carrying Capacity (LW %CC) Adjustment Time	20	10

Figure A2: Parameters used in Carrying Capacity

Carrying Capacity Parameters	Base Case	Limit Cycle	Chaos
Carrying Capacity (CC)	1,000	1,000	1,000
Fractional Regeneration Rate (FRR)	0.01	0.03	0.10
Fractional Erosion Rate (FER)	0.01	0.03	0.10
Regeneration Impact Factor (RIF)	0.5	0.0	0.0
Erosion Impact Factor (EIF)	1.0	1.0	1.0

Figure A3: Parameters used in International Trade Model

General Parameters	**Liberal Market Economies**	**Coordinated Market Economies**
Initial Capital Wealth (CW_0)	80	20
Initial Labour Wealth (LW_0)	20	80
Max Capital Wealth Fractional Growth Rate (CW FGR)	0.1	0.05
Max Capital Wealth Fractional Transfer Rate (CW FTR)	0.05	0.1
Labour Wealth Fractional Decay Rate (LW FDR)	0.1	0.05
Labour Wealth Fractional Growth Rate (LW FGR)	0.05	0.1
Labour Wealth Fractional Transfer Rate (LW FTR)	0.1	0.05
Capital Wealth Fractional Decay Rate (CW FDR)	0.05	0.1
Capital Sensitivity (α)	4	0.25
Labour Tolerance (β)	4	0.25
Capital Wealth Fractional Transfer Rate (CW FTR) Anchor	0.02	0.08
Capital Wealth Fractional Transfer Rate (CW FTR) Adjust. Time	2	4
% Labour Wealth (% LW) Anchor	0.2	0.8
% Labour Wealth (% LW) Adjustment Time	4	2
Capital Wealth % Carrying Capacity (CW %CC) Anchor	0.08	0.02
Capital Wealth % Carrying Capacity (CW %CC) Adjustment Time	40	20
Labour Wealth % Carrying Capacity (LW %CC) Anchor	0.02	0.08
Labour Wealth % Carrying Capacity (LW %CC) Adjustment Time	20	10
International Capital Wealth Fractional Transfer Rate (ICW FTR)	0.05	0.1
International Labour Wealth Fractional Transfer Rate (ILW FTR)	0.1	0.05

Appendix 3: Full Model Documentation

(001) "1. LME %LW"= "1. LME Labour Wealth"/"1. LME Total Wealth"
Units: Dmnl

(002) "1. LME Total Wealth"= "1. LME Capital Wealth"+"1. LME Labour Wealth"
Units: Wealth

(003) "2. CME Accumulated Wealth"= INTEG (CME Wealth Accumulation Rate, 1)
Units: Wealth Year

(004) "2. CME Total Wealth"= "2. CME Capital Wealth"+"2. CME Labour Wealth"
Units: Wealth

(005) "1. LME Accumulated Wealth"= INTEG (LME Wealth Accumulation Rate, 1)
Units: Wealth Year

(006) "1. LME Capital Wealth"= INTEG (LME CW Growth Rate+LME LW Transfer Rate-LME CW Decay Rate-LME CW Transfer Rate -"LME Int. CW Transfer Rate"+"CME Int. LW Transfer Rate", Initial LME CW)
Units: Wealth

(007) "1. LME Labour Wealth"= INTEG ("CME Int. CW Transfer Rate"+LME CW Transfer Rate+LME LW Growth Rate-"LME Int. LW Transfer Rate"-LME LW Decay Rate-LME LW Transfer Rate, Initial LME LW)
Units: Wealth

(008) "2. CME %LW"= "2. CME Labour Wealth"/"2. CME Total Wealth"
Units: Dmnl

(009) "2. CME Capital Wealth"= INTEG (CME CW Growth Rate+CME LW Transfer Rate+"LME Int. LW Transfer Rate"-CME CE Decay Rate-CME CW Transfer Rate-"CME Int. CW Transfer Rate", Initial CME CW)
Units: Wealth

(010) "2. CME Labour Wealth"= INTEG (CME CW Transfer Rate+CME LW Growth Rate+"LME Int. CW Transfer Rate"-CME LW Decay Rate-CME LW Transfer Rate-"CME Int. LW Transfer Rate", Initial CME LW)
Units: Wealth

(011) Carrying Capacity= INTEG (Regeneration Rate-Erosion Rate Initial CC)
Units: Wealth

(012) "CME % Carrying Capacity"= "2. CME Total Wealth"/Carrying Capacity
Units: Dmnl

(013) "CME %LW Anchor"= 0.8
Units: Dmnl

(014) "CME %LW AT"= 2
Units: Year [0.01,1000,0.1]

(015) CME Capital Sensitivity= 0.25
Units: Dmnl [0,10,0.1]

(016) CME CE Decay Rate= "2. CME Capital Wealth"*CME CW FDR
Units: Wealth/Year

(017) "CME CW %CC Anchor"= 0.02
Units: Dmnl [0,1]

(018) "CME CW %CC AT"= 20
Units: Year [0.01,100,0.1]

(019) CME CW FDR= 0.1
Units: percent/Year [0,1,0.05]

(020) CME CW FGR= CME Max CW FGR*((1-Perceived CME CW FTR)^CME Capital Sensitivity)*(1-"Perceived CME CW %CC*")
Units: percent/Year [0,1,0.05]

(021) CME CW FTR= CME Max CW FTR*(1-"Perceived CME %LW")^CME Labour Tolerance
Units: percent/Year [0,1,0.05]

(022) CME CW FTR Anchor= 0.07
Units: Dmnl

(023) CME CW FTR AT= 4
Units: Year [0.01,1000,0.1]

(024) CME CW Growth Rate= "2. CME Capital Wealth"*CME CW FGR
Units: Wealth/Year

(025) CME CW Transfer Rate= "2. CME Capital Wealth"*CME CW FTR
Units: Wealth/Year

(026) "CME Int. CW FTR"= 0.1
Units: percent/Year [0,1,0.01]

(027) "CME Int. CW Transfer Rate"= "CME Int. CW FTR"*"1. LME Labour Wealth"*"2. CME Capital Wealth"/"LME LW + CME CW"
Units: Wealth/Year

(028) "CME Int. LW FTR"= 0.05
Units: percent/Year [0,1,0.01]

(029) "CME Int. LW Transfer Rate"= "CME Int. LW FTR"*"1. LME Capital Wealth"*"2. CME Labour Wealth"/"LME CW + CME LW"
Units: Wealth/Year

(030) CME Labour Tolerance= 0.25
Units: Dmnl [0,10,0.1]

(031) "CME LW %CC Anchor"= 0.08
Units: Dmnl [0,1]

(032) "CME LW %CC AT"= 10
Units: Year [0.01,100,0.1]

(033) CME LW Decay Rate= "2. CME Labour Wealth"*CME LW FDR
Units: Wealth/Year

(034) CME LW FDR= 0.05
Units: percent/Year [0,1,0.05]

(035) CME LW FGR= CME Max LW FGR*(1-"Perceived CME LW %CC")
Units: percent/Year [0,1,0.05]

(036) CME LW FTR= 0.05
Units: percent/Year [0,1,0.01]

(037) CME LW Growth Rate= "2. CME Labour Wealth"*CME LW FGR
Units: Wealth/Year

(038) CME LW Transfer Rate= "2. CME Labour Wealth"*CME LW FTR
Units: Wealth/Year

(039) CME Max CW FGR= 0.05
Units: percent/Year

(040) CME Max CW FTR= 0.1
Units: percent/Year

(041) CME Max LW FGR= 0.1
Units: percent/Year

(042) CME Wealth Accumulation Rate= "2. CME Total Wealth"
Units: Wealth

(043) Erosion Impact Factor= 1
Units: percent/Year [0,1,0.1]

(044) Erosion Rate= FER*Carrying Capacity*(("1. LME Total Wealth"+"2. CME Total Wealth")/(Initial CME CW +Initial CME LW+Initial LME CW+Initial LME LW))^Erosion Impact Factor
Units: Wealth/Year

(045) FER= 0.01
Units: Dmnl [0,1,0.01]

(046) FINAL TIME = 200
Units: Year
The final time for the simulation.

(047) FRR= 0.01
Units: Dmnl [0,1,0.01]

(048) Initial CC= 1000
Units: Wealth [0,10000,100]

(049) Initial CME CW= 20
Units: Wealth [0,100,10]

(050) Initial CME LW= 80
Units: Wealth [0,100,10]

(051) Initial LME CW= 80
Units: Wealth [0,100,10]

(052) Initial LME LW= 20
Units: Wealth [0,100,10]

(053) INITIAL TIME = 0
Units: Year
The initial time for the simulation.

(054) "LME % Carrying Capacity"= "1. LME Total Wealth"/Carrying Capacity
Units: Dmnl

(055) "LME %LW Anchor"= 0.2
Units: Dmnl

(056) "LME %LW AT"= 4
Units: Year [0.01,100,0.1]

(057) LME Capital Sensitivity= 4
Units: Dmnl [0,10,0.1]

(058) "LME CW %CC Anchor"= 0.08
Units: Dmnl

(059) "LME CW %CC AT"= 40
Units: Year [0.01,100,1]

(060) "LME CW + CME LW"= "1. LME Capital Wealth"+"2. CME Labour Wealth"
Units: Wealth

(061) LME CW Decay Rate= "1. LME Capital Wealth"*LME CW FDR
Units: Wealth/Year

(062) LME CW FDR= 0.05
Units: percent/Year [0,1,0.05]

(063) LME CW FGR= LME Max CW FGR*((1-Perceived LME CW FTR)^LME Capital Sensitivity)*(1-"Perceived LME CW %CC*")
Units: percent/Year [0,1,0.05]

(064) LME CW FTR= LME Max CW FTR*(1-"Perceived LME %LW")^LME Labour Tolerance
Units: percent/Year [0,1,0.05]

(065) LME CW FTR Anchor= 0.02
Units: Dmnl

(066) LME CW FTR AT= 2
Units: Year [0.01,100,0.1]

(067) LME CW Growth Rate= "1. LME Capital Wealth"*LME CW FGR
Units: Wealth/Year

(068) LME CW Transfer Rate= LME CW FTR*"1. LME Capital Wealth"
Units: Wealth/Year

(069) "LME Int. CW FTR"= 0.05
Units: percent/Year [0,1,0.01]

(070) "LME Int. CW Transfer Rate"= "LME Int. CW FTR"*"1. LME Capital Wealth"*"2. CME Labour Wealth"/"LME CW + CME LW"
Units: Wealth/Year

(071) "LME Int. LW FTR"= 0.1
Units: percent/Year [0,1,0.01]

(072) "LME Int. LW Transfer Rate"= "LME Int. LW FTR"*"1. LME Labour Wealth"*"2. CME Capital Wealth"/"LME LW + CME CW"
Units: Wealth/Year

(073) LME Labour Tolerance= 4
Units: Dmnl [0,10,0.1]

(074) "LME LW %CC Anchor"= 0.02
Units: Dmnl

(075) "LME LW %CC AT"= 20
Units: Year [0.01,100,1]

(076) "LME LW + CME CW"= "1. LME Labour Wealth"+"2. CME Capital Wealth"
Units: Wealth

(077) LME LW Decay Rate= LME LW FDR*"1. LME Labour Wealth"
Units: Wealth/Year

(078) LME LW FDR= 0.1
Units: percent/Year [0,1,0.05]

(079) LME LW FGR= LME Max LW FGR*(1-"Perceived LME LW %CC")
Units: percent/Year [0,1,0.05]

(080) LME LW FTR= 0.1
Units: percent/Year [0,1,0.05]

(081) LME LW Growth Rate= "1. LME Labour Wealth"*LME LW FGR
Units: Wealth/Year

(082) LME LW Transfer Rate= "1. LME Labour Wealth"*LME LW FTR
Units: Wealth/Year

(083) LME Max CW FGR= 0.1
Units: percent/Year [0,1,0.1]

(084) LME Max CW FTR= 0.05
Units: percent/Year

(085) LME Max LW FGR= 0.05
Units: percent/Year

(086) LME Wealth Accumulation Rate= "1. LME Total Wealth"
Units: Wealth

(087) "Perceived CME %LW"= DELAY1I("2. CME %LW","CME %LW AT","CME %LW Anchor")
Units: Dmnl [0,1,0.05]

(088) "Perceived CME CW %CC"= DELAY1I("CME % Carrying Capacity","CME CW %CC AT","CME CW %CC Anchor")
Units: Dmnl [0,1,0.05]

(089) "Perceived CME CW %CC*"= "Perceived CME CW %CC"
Units: Dmnl

(090) Perceived CME CW FTR= DELAY1I(CME CW FTR,CME CW FTR AT,CME CW FTR Anchor)
Units: Dmnl [0,1,0.05]

(091) "Perceived CME LW %CC"= DELAY1I("CME % Carrying Capacity","CME LW %CC AT","CME LW %CC Anchor")
Units: Dmnl [0,1,0.05]

(092) "Perceived LME %LW"= DELAY3I("1. LME %LW","LME %LW AT","LME %LW Anchor")
Units: Dmnl [0,1,0.05]

(093) "Perceived LME CW %CC"= DELAY3I("LME % Carrying Capacity","LME CW %CC AT","LME CW %CC Anchor")
Units: Dmnl [0,1,0.05]

(094) "Perceived LME CW %CC*"= "Perceived LME CW %CC"
Units: Dmnl

(095) Perceived LME CW FTR= DELAY3I(LME CW FTR,LME CW FTR AT,LME CW FTR Anchor)
Units: Dmnl [0,1,0.05]

(096) "Perceived LME LW %CC"= DELAY3I("LME % Carrying Capacity","LME LW %CC AT","LME LW %CC Anchor")
Units: Dmnl [0,1,0.05]

(097) Regeneration Impact Factor= 0.5
Units: percent/Year [0,1,0.1]

(098) Regeneration Rate= FRR*Carrying Capacity*(("1. LME Total Wealth"+"2. CME Total Wealth")/(Initial CME CW+Initial CME LW+Initial LME CW+Initial LME LW))^Regeneration Impact Factor
Units: Wealth/Year

(099) SAVEPER = TIME STEP
Units: Year [0,?]
The frequency with which output is stored.

(100) TIME STEP = 0.5
Units: Year [0,?]
The time step for the simulation.