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Value Creation in a Model Enterprise

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Abstract: A stochastic model of a dissipative physical system is used to simulate the commercial behaviour of an innovative enterprise. Two parameters specify this behaviour. Perceived value within a population of consumers is assumed to comprise a Gaussian distribution specified by a single standard deviation parameter. This standard deviation relates to the value creation of the enterprise by defining the breadth of value perception for the consumer population. A second parameter relates to the replication of this value through the production activities of the enterprise. This uncoupling of value creation and value replication enables the parameters to provide indices for the innovation and production capacity for seven multinational companies whose real commercial data is fitted to the stochastic simulation of each enterprise. Furthermore, these commercial companies are compared with organisations that are sustainable but non-profit to identify a "Sustainability Limit" for each enterprise.

Keywords: value creation; innovation; value replication; production; enterprise simulation; cost of goods sold; operational expenses; labour theory of value; sustainability; viscoelasticity

1 Introduction

The core activities of a commercial enterprise are two-fold: the creation of value through the research, design, development and marketing of their products and services, and the replication of this value in the production and commercialisation of those goods. This paper aims to uncouple the enterprise activity into these two fundamental components and examine how their interaction relates to the profitability of the enterprise.

Clearly the creation of value and its subsequent replication is related to financial investments made and also to the subsequent profits gained by an enterprise. Here we derive a relationship between investment, innovative activity and value creation using a simulation of an enterprise as a dissipative physical system. It is a mechanical analogy that can be fitted to the empirical financial accounts of real commercial organisations.

For centuries the physical sciences and economics have combined to explore the nature of value creation. The classical economics of Adam Smith were inspired around 1760 by the Lumières in Paris, particularly by the Physiocrats led by François Quesnay (Coquelin, 1854). One hundred years later the marginal economics of Léon Walras sought to associate a theory of maximum satisfaction through the exchange of commodities with the maximum energy of a balanced beam, and also the theory of general economic equilibrium of the market and that of a universal equilibrium of celestial bodies (Walras, 1909). Another one hundred years later, the neo-classical economics of Paul Samuelson were directly rooted in the thermodynamics of chemical equilibria developed by Willard Gibbs (Samuelson, 1947).

Previously, through ISPIM we have followed in this tradition with a reformulation of Smith and Ricado's Labour Theory of Value, so that it may apply to a modern enterprise. Essentially, total investment made by an enterprise is uncoupled into separate innovation and replication (production) components. Furthermore, the modern market was simulated as a population of consumers with a defined statistical distribution in their perceptions of value. In this market simulation, the reformulated Labour Theory of Value delivers a maximum return on investment (almost) with a Gaussian distribution of consumer perceived value with a zero mean and non-zero standard deviation (Egan, 2014).

This paper further develops the statistical model based on an analogy in which the transactions of the enterprise have analogous counterparts in the mechanics of the viscoelastic material. In particular, value creation is analogous to energy storage and the dissipation of this energy occurs through product sales that return income to the enterprise. This approach enables a simulation of input (investment) and output (cost, profit) data for real innovative companies and also for sustainable organisations that are typically non-profit, and thereby provides a novel analysis of the comparative performance of real enterprises.

2 The Viscoelastic Enterprise

The analysis of an innovative enterprise is founded on an equivalence of enterprise activity with the mechanics of the viscoelastic material. Whenever mechanical work is used to deform a viscoelastic material, energy is either stored within "elastic" components of the system, or dissipated in the "viscous" components. Such materials are useful for their shock absorbing properties.

Typically, models of viscoelastic behaviour are constructed from elemental elastic springs and viscous dashpots and their configuration and individual properties of stiffness and viscosity are set to simulate a specific balance of energy storage and dissipation (Figure 1). A large number of such models and forms of analysis have been developed to understand the properties of viscoelastic materials (Ferry, 1970). Previously, the author has developed a stochastic model of a viscoelastic material that replicates precisely the mechanical behaviour of a standard linear viscoelastic solid (Egan, 1997).

In the innovative enterprise, investment is considered as the equivalent source of the energy that creates value, which is conserved in the products, services and systems of the organisation.

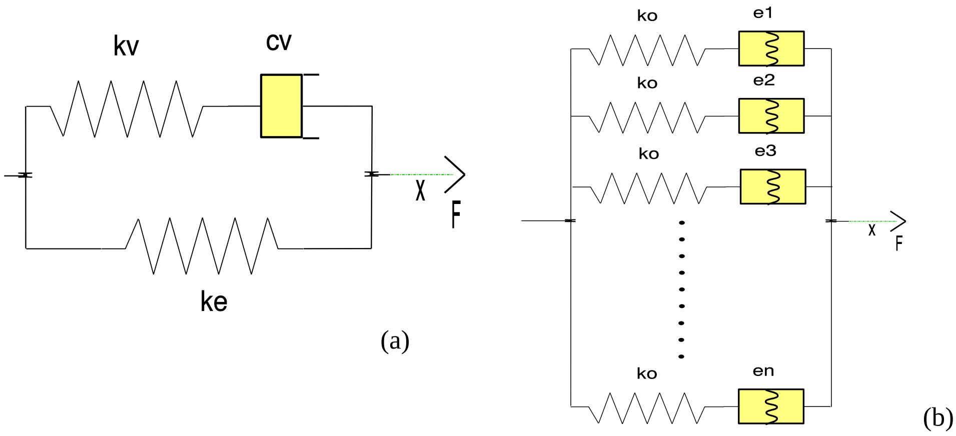

Figure 1 (a) a standard linear viscoelastic combination of springs and a dashpot. (b) a stochastic alternative that can provide an identical mechanical behaviour in which the yellow bound elements fail when the energy in the connected spring reaches a critical threshold.

If the innovative endeavours of the enterprise are deployed and "stored" as a potential in value created, then the equivalent of energy dissipation is assumed to occur through the sale of the company products. Such product sales are discrete events that occur under the particular condition where perceived value exceeds the cost of acquiring the goods. In the standard viscoelastic solid in Figure 1a, energy dissipation is a continuous process. The stochastic alternative in Figure 1b is therefore suited for use in the commercial domain to simulate the sale-events that comprise the discrete transactions of an enterprise[i].

Previously we have identified a Consumer-Product Interaction (CPI) as the key event through which a perception of value occurs as a precursor to product sale. Quintessentially, all enterprise activities and investments are dedicated to the creation of favourable CPIs through which perceived value exceeds a set price, whereupon a sale-event will occur and income will be remunerated to the enterprise in exchange for the newly purchased products (Egan, 2014).

For an enterprise simulation that is analogous to the stochastic viscoelastic analysis, investment is dedicated to creating the perception of value through a number of CPIs, so that these individual consumers may incrementally approach a threshold for a sale-event to occur. Let us then start with a nominal representation of 100 CPIs, as shown in Figure (2), which represent the effect of the invested capital on each CPI[ii]. Each of these 100 lines will appear at a different height, marking differing individual perceptions of value, and each of the lines in this model is tethered through a linkage that represents the properties of the CPI. This CPI linkage remains dormant until the height gained by the corresponding line reaches a threshold determined by the price of the goods. The linkage then separates, representing the occasion of a sale-event as is apparent in CPI unit 2 of Figure (2b).

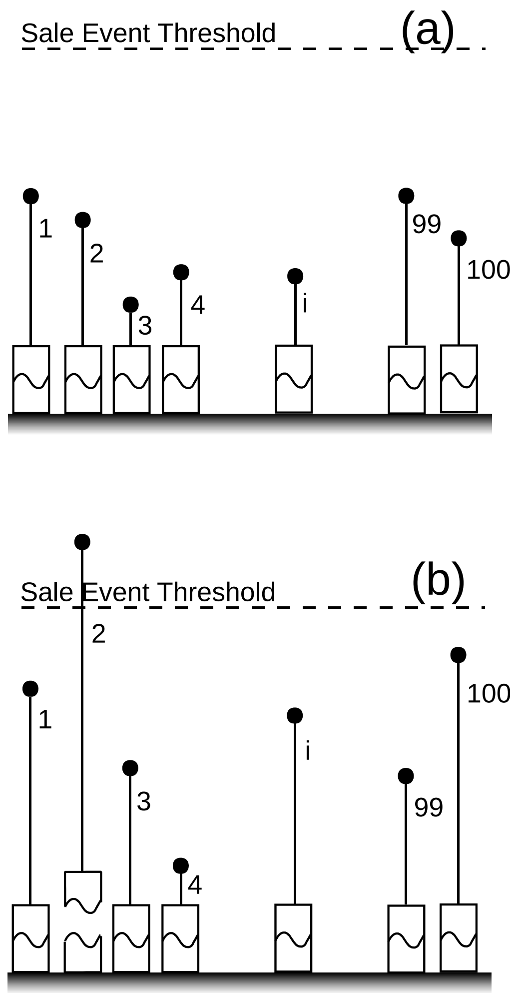

Figure 2 CPI units representing the value creation (a) after initial investment and (b) with further incremental investment of capital leading to a sale-event for unit 2

The difference between (a) and (b) of Figure (2) is due to the increasing amount of investment into the enterprise. As perceptions of value will be subject to perturbation by any number of external influences, individual CPI units in Figure (2) may rise or fall as time proceeds. The aggregate result of effective investment however, is to increase height overall, so that the occurrence of a sale-event within the population of consumers becomes more likely.

Assuming that investment is distributed evenly between all the CPI units that comprise the model shown in Figure (2), the different propensity of the represented consumers to value the goods can be captured by a linear relationship: -

$$Val_i = \xi_i \, . \, E_i \qquad i = 1, \ldots\ldots, 100 \qquad \text{(Eqn 1)}$$

Where $\mathbf{E_i} = \mathbf{E}/100$ gives the portion of the total investment **E** that is distributed to each of the population of 100 CPIs. $\mathbf{Val_i}$ is the value perceived by the consumer **i**.

We now re-employ the statistical description of the creation of value in a typical population of consumers, recognising that a majority of CPIs register low value and only a small minority of consumers will seriously desire the goods. In this case, the ξ_i values for the consumer population are assumed to follow a Gaussian (normal) statistical distribution with a zero mean and a set standard deviation ξ_{sd} (Egan, 2014).

This sequence of sale-events is analogous to the failure of the energy dissipating elements in Figure (1b) when energy is applied to this viscoelastic assembly. Moreover, when one such element fails then $\mathbf{q_s}$ new elements are recruited to receive a share of the applied energy at subsequent time increments as shown in Figure (3).

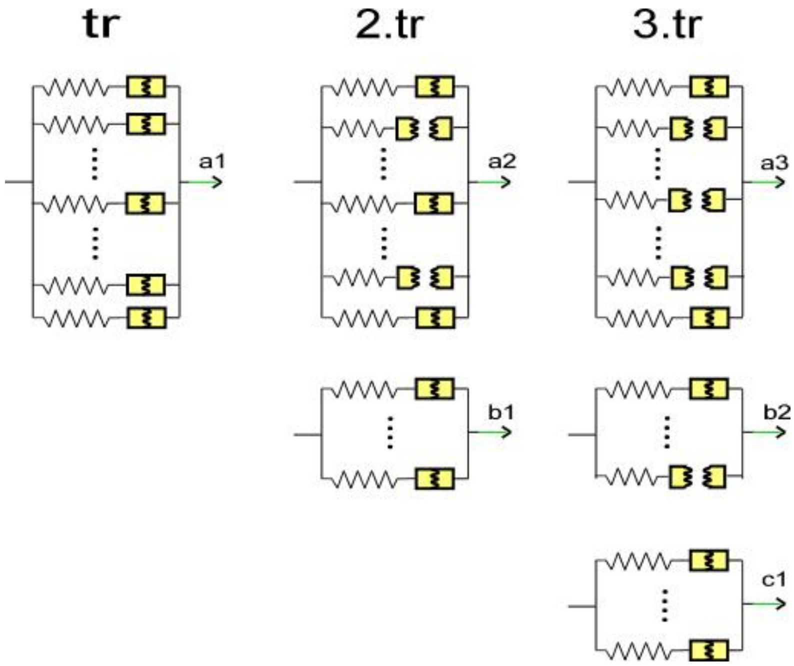

Figure 3 Deformation of the stochastic viscoelastic model through three time increments $\mathbf{t_r}$ with the recruitment of $\mathbf{q_s}$ new elements with each failed unit

To complete the analogy for the enterprise simulation, it is necessary to assume that each successful sale-event initiates the creation of further $\mathbf{q_s}$ new CPIs that are made available to receive a portion of further investment. These newly recruited CPIs may then reach up to the price limit and lead to subsequent sale-events just as their predecessors did.

It is now possible to construct an enterprise simulation as shown in Figure (4), specifying values of ξ_{sd}, $\mathbf{q_s}$ and **price**. The price fixes the sale-event threshold level as shown in Figure (2). In the first time increment (for example, the first day of trading), an initial increment of investment is added to the enterprise model and the varying heights of the initial CPIs can be calculated knowing ξ_{sd} and by using Equation 1. It is likely that no CPIs will instantly achieve the height that indicates a sale-event in this first trading increment, as the investment added is low. There will be no income. On the next and subsequent increments, with further investment, the CPIs that attain the sale threshold are calculated through the numerical integration of the Gaussian distribution that describes how a population of consumers values the commodities in question. This calculation indicates the number of units sold with time and the set price of each unit is returned as income to the enterprise.

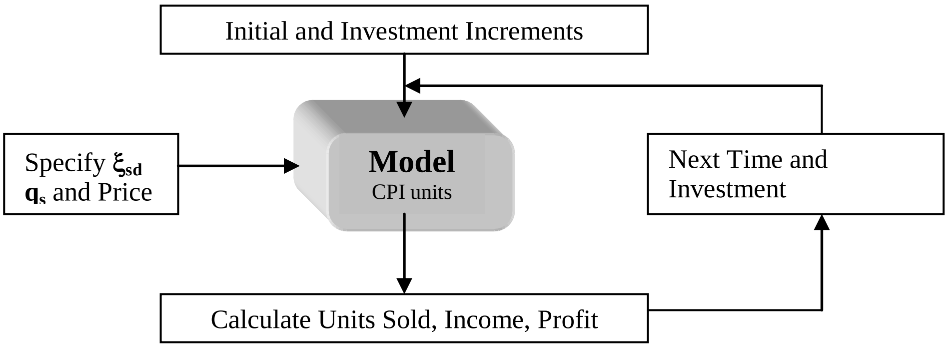

Figure 4 Enterprise simulation

The parameters $\mathbf{q_s}$ and ξ_{sd} and **price** determine the enterprise simulation in Figure (4). However, it has become apparent that specific values of the time increment $\mathbf{t_r}$, at which the market simulation is iterated, and the **price** of the goods are related. As $\mathbf{t_r}$ is shortened, the greater number of iterations over a simulation period will generally increase the quantity of goods sold through the simulated market place, and the price can correspondingly decrease to restore the simulated income[iii]. Meanwhile, the values of $\mathbf{q_s}$ and ξ_{sd} are generally only marginally affected by the size of the $\mathbf{t_r}$ increment. Hence, there is no need to specify actual values for $\mathbf{t_r}$ and **price**, and the commercial simulation can be determined through the two remaining parameters $\mathbf{q_s}$ and ξ_{sd} which are independent of the size of the enterprise they describe.

3 Simulating the Real-World Enterprise

The simulated enterprise described above now needs to be matched with actual companies and the insight it can provide into the commercial performance of these real organisations will be crucial to its value. This insight is essentially held in the values of the two parameters ξ_{sd} and $\mathbf{q_s}$ that represent the real company behaviour. To estimate these representative parameters values, the Least Squares Method has been used to fit the enterprise simulation to real-world commercial data.

In the viscoelastic analogy, at any moment in time a portion of the overall applied energy is stored and the remainder is dissipated. We now need to identify the analogous features of the real enterprise commercial data that are equivalent to this energy storage and dissipation.

The income statement that appears in company accounts conventionally splits overall investment into Cost of Goods Sold (COGS) and Operating Expenses (OPEX). The COGS measurement includes those costs that are directly associated with the production of the commodities. This can include the cost of materials and direct labour costs used to produce the goods. Therefore, it is assumed that with each sale-event it is the investment in COGS that is “dissipated” with the product sale and which no longer contributes to the company activity. OPEX on the other hand comprise the remaining portion of the investment that is retained within enterprise.

What is not included in the analysis are the Capital Expenses (CAPEX) that appear on company balance sheets as property, plant and equipment. The effects of such capital investment will appear in the value added by the operational activities. OPEX on the other hand contribute directly to the creation of value within the organisation to encourage sale-events by enhanced consumer perception of value. They are independent of the actual goods themselves: brand image, customer service, sales-force, technical capability, administrative competence, etc.[iv]

This association of the conventional items of company accounts with equivalent features of the commercial enterprise simulation are summarised in Table (1). These provide the associated correlations we will employ in matching the enterprise simulation to the real commercial data to estimate the $\boldsymbol{\xi_{sd}}$ and $\mathbf{q_s}$ parameter values for specific companies.

Table 1 Relationship between the financial items of a company's accounts and their equivalent features in the enterprise simulation

Company Account Item	***Enterprise Model***
Total Investment	Total energy added to the model
Cost of Goods Sold (COGS)	Energy dissipated as a consequence of the sale-events.
Operating Expenses (OPEX)	Residual energy stored within the products, services and systems of the organisation.
Total Income (Revenue)	Price x Number of sale-events.

For each company account item in Table (1) real commercial data has been obtained from quarterly reports (10Q and 10K) from 2008 to 2014 obtained from the US Securities and Exchange Commission EDGAR database[v] for seven companies selected to cover a range of sectors: 3M, Amazon, Apple, Intel, Kodak, Microsoft and PepsiCo. The least squares method is now able to estimate values for the two parameters $\mathbf{q_s}$ and $\boldsymbol{\xi_{sd}}$, using the equivalence of the enterprise simulation with this data from company accounts.

Here, rather than considering an individual commodity commercial performance, as this data is generally not available in the public domain, the overall performance of a company is considered. This is equivalent to the commercial trading of a single constitutive commodity that is representative of the entire enterprise.

Table 2 Parameter estimates obtained by fitting the enterprise simulation to the financial data of seven companies.

	3M	*Amazon*	*Apple*	*Intel*	*Kodak*	*Microsoft*	*PepsiCo*
q_s	1.303	1.074	1.030	1.830	1.162	3.700	1.710
ξ_{sd}	3.753	4.099	8.027	3.708	3.152	4.604	3.159

The best-fit estimates of $\mathbf{q_s}$ and ξ_{sd} for the seven commercial organisations modelled are presented in Table (2). The enterprise simulation provides an extremely close fit to real commercial data, the minimum error being less than 1% in all cases. This is exemplified in Figures (5) and (6) for two of the companies, Apple and Microsoft, which sit at two extremes of the range of $\mathbf{q_s}$ and ξ_{sd} parameter estimates. Also, the stability of these $\mathbf{q_s}$ and ξ_{sd} parameter estimates when the least squares best fit is repeated with different start points and with different time increments is high and indicative of unique points of minimum error.

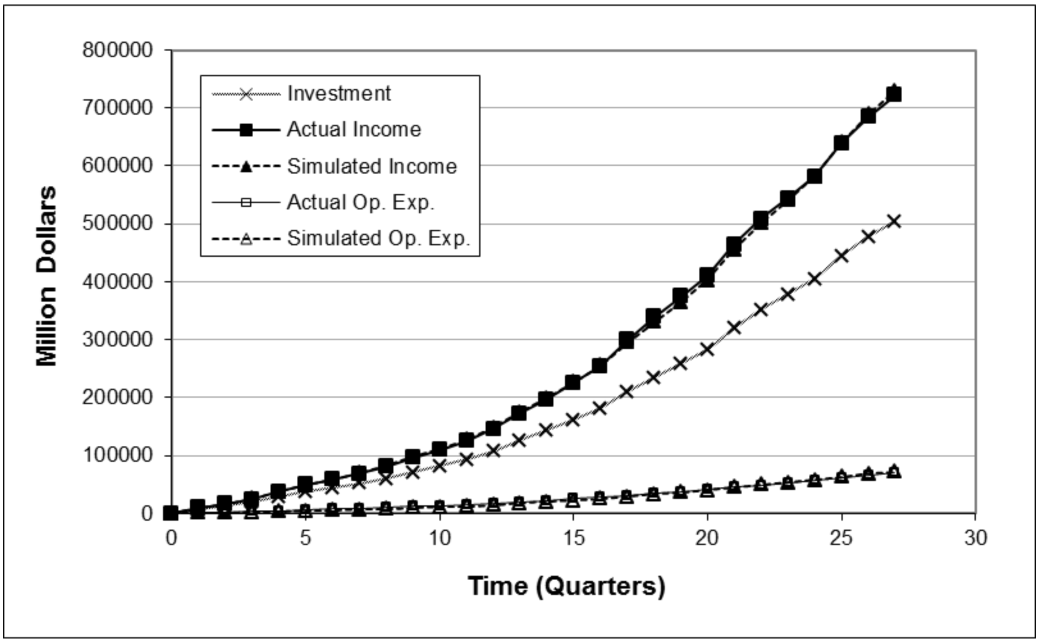

Figure 5 Best fit of the simulated income and Operating Expense to the equivalent real commercial for Apple between 2008-14. Also shown is the company investment that was the input into the model enterprise over this period.

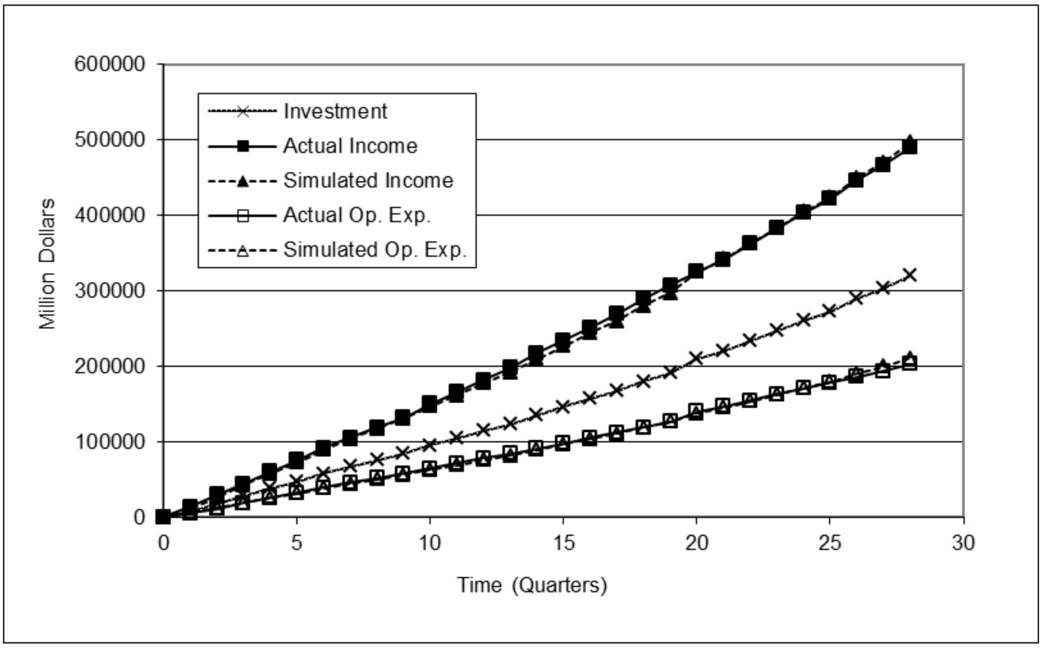

Figure 6 As with Figure (5) showing the enterprise simulation of the commercial data from Microsoft.

4 Simulating a Sustainable Organisation

The parameter values in Table (2) are intended to provide an insight into their associated commercial enterprise. To understand what these parameters are revealing about the enterprise, it is helpful to consider and compare the behaviour of these organisations with others which are ideally sustainable and also non-profitable. For this it is necessary to adjust the conventional accounting terms COGS and OPEX to express the conditions for sustainability.

All organisations require investment and income to survive. Sustainability is consequential to equality between the supply of input investment and income arising from their activity, so that the income can be recycled for a sustainable input. This sustainability principle is translated into the data presented in Table (3), in which seven scenarios are derived with equality of investment and income, but with differing levels of operating expenses. As these operating expenses are increased from negligible in OPEX1 to high in OPEX7, we can again estimate the parameters $\mathbf{q_s}$ and $\boldsymbol{\xi_{sd}}$ by fitting the enterprise simulation to the Table (3) data using the least squares method. The estimates of $\mathbf{q_s}$ and $\boldsymbol{\xi_{sd}}$ thus derived are also shown in Table (3) and together they establish a Sustainability Limit curve as shown in Figure (7).

Table 3 Idealised commercial data along with associated parameter estimates for seven survival scenarios where investment equals income and which differ only in their OPEX requirements.

Investment	*Income*	*OPEX1*	*OPEX2*	*OPEX3*	*OPEX4*	*OPEX5*	*OPEX6*	*OPEX7*	*Time*
0	0	0	0	0	0	0	0	0	0
1000	1000	10	50	100	300	500	700	900	1
2000	2000	20	100	200	600	1000	1400	1800	2
3000	3000	30	150	300	900	1500	2100	2700	3
4000	4000	40	200	400	1200	2000	2800	3600	4
5000	5000	50	250	500	1500	2500	3500	4500	5
6000	6000	60	300	600	1800	3000	4200	5400	6
7000	7000	70	350	700	2100	3500	4900	6300	7
8000	8000	80	400	800	2400	4000	5600	7200	8
9000	9000	90	450	900	2700	4500	6300	8100	9
10000	10000	100	500	1000	3000	5000	7000	9000	10
11000	11000	110	550	1100	3300	5500	7700	9900	11
12000	12000	120	600	1200	3600	6000	8400	10800	12
13000	13000	130	650	1300	3900	6500	9100	11700	13
14000	14000	140	700	1400	4200	7000	9800	12600	14
15000	15000	150	750	1500	4500	7500	10500	13500	15
16000	16000	160	800	1600	4800	8000	11200	14400	16
17000	17000	170	850	1700	5100	8500	11900	15300	17
18000	18000	180	900	1800	5400	9000	12600	16200	18
19000	19000	190	950	1900	5700	9500	13300	17100	19
20000	20000	200	1000	2000	6000	10000	14000	18000	20
$\mathbf{q_s}$		1.0003	1.001	1.005	1.21	2.03	4.58	22.4	
$\boldsymbol{\xi_{sd}}$		79.8	16.0	8.05	3.11	2.65	3.16	6.77	

Also shown in Figure (7) are the positions of the seven real commercial enterprises on account of the estimated values of their $\mathbf{q_s}$ and $\boldsymbol{\xi_{sd}}$ parameters. Generally, for these organisations to be profitable they need to occupy the space above the Sustainability Limit curve. This is not the case for two of the seven companies under consideration.

5 Discussion

As any simulation is by necessity a simplification of the real world, caution must be exercised in the interpretation of the model behaviour. The complexity of a multi-national organisation cannot be fully represented by two numbers. The aim is to help understand empirical commercial data within the inevitable limits that are set by the simplicity of the simulation.

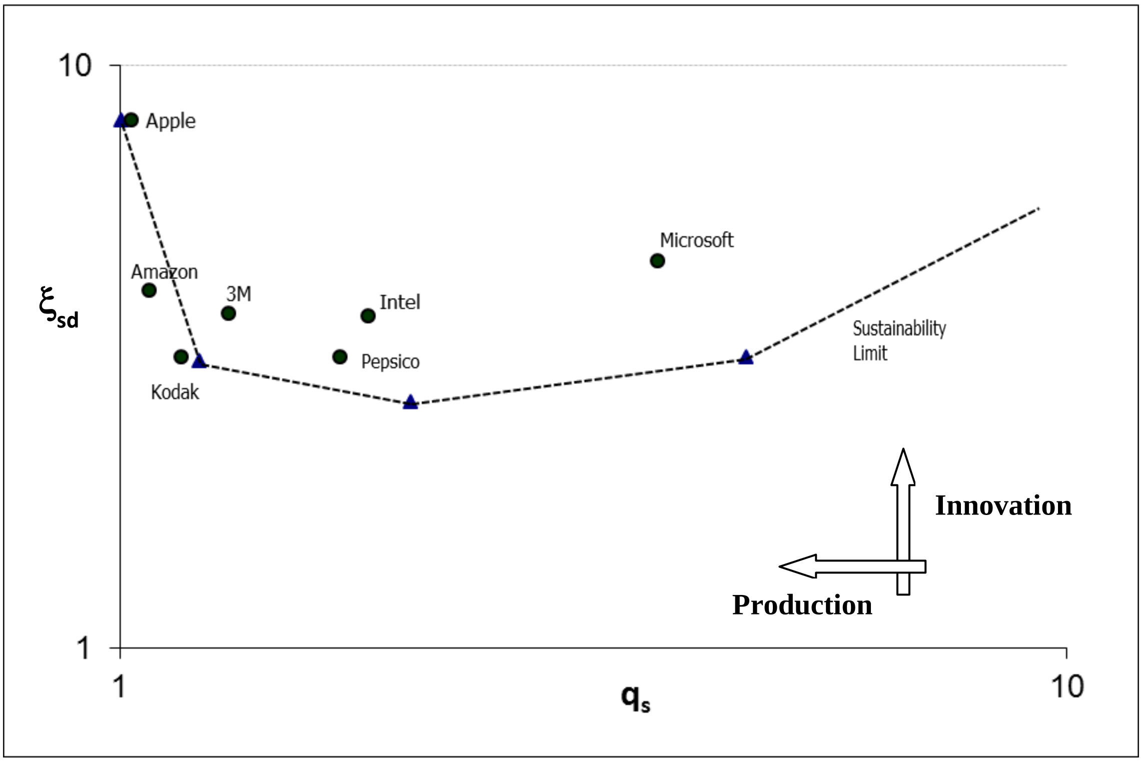

Figure 7 Parameter estimates for commercial organisations in comparison with the Sustainability Limit curve (log-log scale)

The enterprise simulation effectively considers the trading of a single abstract commodity that is representative of the totality of the commercial operations of each company over the duration of the simulation that was between 2008 and 2014. It appears that over this seven year interval the operations in each case are stable with a close fit between the real and simulated behaviour and with stable estimated values of the model parameters for each of the seven companies under scrutiny. This indicates that at this analytical level, change occurs slowly in these organisations. One might expect more dynamic fluctuations at the level of individual commodity or business unit commercial performance. However, the approach taken is relevant as it enables a comparison of innovative enterprises where the representative product provides a common index of performance, rather than a comparison of their real but dissimilar products.

The value of the current analysis lies in the additional insight the enterprise simulation provides in the interpretation of the raw financial data. This insight comes largely through the fitted parameter values that represent the overall trading behaviour of each of the seven innovative enterprises. The value of the parameter $\mathbf{q_s}$ seems to reflect the OPEX/COGS balance in the company accounts, with a higher ratio demanding a higher value of $\mathbf{q_s}$, as is apparent in Table (3). That is, the lower values of $\mathbf{q_s}$ indicate organisations with an emphasis on the replication of value through production and the commercialisation of their representative product. Apple and Amazon lie at the left hand margin indicative of this behaviour. This does not mean these organisations need not be innovative. Indeed, Apple needs to be highly innovative for it to be a profitable enterprise.

The innovative capacity of companies is apparent through parameter ξ_{sd}, which represents the spread of perceived value through a consumer population, and where high values indicate a greater proportion of consumers attribute a high value to the companies' products, services or systems. Essentially, ξ_{sd} represents the efficacy by which a company converts investment in innovation into the creation of value. This investment may take many forms, but its aggregate effect is captured in the value of ξ_{sd}. Hence, ξ_{sd} in a single number also must recognise the effects of competing products, as perceptions of value will generally be relative to equivalent products that are available elsewhere. Therefore, parameter ξ_{sd} epitomises the impact of innovation. By expanding the Gaussian distribution of value perception horizontally, so that statistically more consumers attribute a higher value to a commodity, this is effectively making the information transferred through the Consumer-Product Interactions more valuable.

The "U" shaped Sustainability Limit curve may offer some insights to understand and manage the strategy of organisations regarding their innovative capacity. It appears easier to survive without high levels of innovative capacity away from the margins of the Sustainability Limit curve and, indeed, this is where the more mature organisations are collected. It will be interesting to consider how companies move over this $\mathbf{q}_s$ - ξ_{sd} plot with time and where the company might move in the future.

The previous theoretical concept of a labour theory of value creation, uncoupling the "labour" into its innovative and replicative components is advanced by the current analysis with a means of recognising these independent components of real organisations through the stochastic simulation of the enterprise. By linking the innovative and replicative endeavour to OPEX and COGS investments, although this association is inevitably approximate, we have a practical means to assess company operations in the creation and replication of value.

6 Conclusions

- A viscoelastic dissipative physical system can be used to simulate the commercial activities of an innovation enterprise where:-
    - The creation of value by the enterprise is equivalent to energy storage
    - The production and sale of goods is analogous to energy dissipation

- The two parameters of the viscoelastic system ξ_{sd} and $\mathbf{q}_s$, respectively provide indices for the innovation and production capacity for real companies whose commercial data is fitted to the viscoelastic simulation.

- The "U" shaped Sustainability Limit curve suggests that it may be easier to survive without high levels of innovative capacity away from the margins of this curve, and this is where the more mature organisations are collected.

- Further validation of the viscoelastic simulation is required to ascertain the relevance of the analysis for real companies.

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[i] The correspondence between the physical dissipative system and its commercial analogue is further developed and described in www.viscoelastic.com

[ii] Note that the number of 100 is arbitrary and can represent the behaviour of a much broader distribution of consumers, as the simulation can work with a fractional consumer.

[iii] For simplicity, and later for comparability of different commercial organisations, the constitutive product is assumed to have zero unit cost in production.

[iv] The precise definition of the activities that contribute to COGS or OPEX may differ from one business to another depending on whether costs are determined to be direct and variable with the sales of the products.

[v] http://www.sec.gov/edgar/searchedgar/companysearch.html