Copyright: John Bryant, VOCAT International Ltd, 2015, for personal use only.

ENTROPY MAN

John Bryant

Copyright: John Bryant, VOCAT International Ltd, 2015, for personal use only.

© VOCAT International Ltd 2015

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise without the prior permission of the publisher.

Published by

VOCAT International Ltd
Harpenden
Herts
AL5 3ES
UK

ISBN 978-0-9562975-4-9

Front Cover: Getty Images.

Copyright: John Bryant, VOCAT International Ltd, 2015, for personal use only.

Contents

Copyright: John Bryant, VOCAT International Ltd, 2015, for personal use only.

Copyright: John Bryant, VOCAT International Ltd, 2015, for personal use only.

Preface

The seeds for this book were sown in the 1970s, four decades ago, when I was then working as group economist for the engineering corporation Babcock International Plc. At that time the group employed about 30,000 people in subsidiaries spread all around the world, engaged in the design, manufacture and installation of capital plant for a variety of industries, including nuclear & conventional power generation, coal mining, gas, chemicals & petroleum, steel, automotive, cement, construction and environmental engineering. Prior to that, my formal university education had included a degree in engineering at University of Bath and a Masters in management science, allied to student sandwich experience with Amalgamated Power Engineering *[now a subsidiary of Rolls Royce]* and ASEA Brown Boveri, Switzerland, followed by working for SKF, the Swedish bearing manufacturer, often considered to be a bell-weather of world economic output.

From the 1980s onwards I worked as director of a consultancy, and subsequently also as an expert witness to the Courts, which roles I continue to the present day. These experiences have taught me to maintain an enquiring, dispassionate and impartial mind regarding the complex workings of human endeavour, the natural world and changes arising thereof.

My particular research interests in those early years concerned the parallels between the disciplines of economics and thermodynamics *[the science of energy & heat]* and how they relate to each other, as a result of which I published two peer-reviewed papers on the subject in *Energy Economics [1979 & 1982]*. Subsequent to these I gave presentations to international gatherings of government ministers, energy industry executives and academia.

Not being based at a university however, and with no research grant at my disposal, my main thrust had been to make a living from consultancy and therefore, until more recently, opportunities to spend time on research were few. Nevertheless, by the turn of the millennium I was able to find time to return to some research and published another peer-reviewed paper in the *International Journal of Exergy [2007]*, followed up by several working papers on monetary aspects and energy models. Subsequently in 2009 I wrote a technical book on the subject, to bring together all the facets of the work into a coherent whole: *'Thermoeconomics – a thermodynamic approach to economics'*. The book was subsequently revised, corrected and

Copyright: John Bryant, VOCAT International Ltd, 2015, for personal use only.

added to, up to a third edition *[2012]*, covering topics such as production and consumption processes, employment, money, interest rates and bonds, energy resources, climate change and sustainability, and including more up to date statistics. It has now been superseded by this book.

Whilst not being tied to a university, government agency, industrial enterprise or other organisation has disadvantages in terms of recognition and time available for research, it does nevertheless have the advantages of freedom to investigate and pursue a course of enquiry of one's own choosing and of drawing conclusions independent of those that pay the piper or who may have pre-set agendas, however well-intentioned these may be.

The nature of the subject requires significant proof for economists and scientists to accept that similarities between thermodynamic and economic phenomena might imply more than just a passing analogy or isomorphism, and relations between the two disciplines have rarely been comfortable, with scientists sometimes having scant regard for the work of economists; and many economists believing that science has little to offer their discipline which, by its nature, can be thought of as anthropocentric rather than eco-centric. One eminent energy scientist advised me that he did not know of an economist who could follow a thermodynamic argument. Certainly a concept such as entropy means very little to most economists, still less to the man in the street – money is their language of communication. The latter is not, however, the language that Nature and the environment converse in.

This book is intended for a mixed readership of scientists, economists and those of an enquiring mind. It is a challenge therefore to convey the nub of the argument in terms that all can appreciate, with particular reference to the effects of potential problems such as 'peak resources', humankind's effect on the ecosystem and the maelstrom that would ensue should resource failure or climate change ever come about to a significant degree.

While some chapters, notably chapters 4 through to 8, do contain some mathematical expressions, explanatory points are included to guide non-mathematicians onwards. Formal proofs and derivations have been relegated to the notes on each chapter.
Although economic man may currently have the ascendency, he does not actually *'own'* the Earth. He is there on sufferance, and the Earth would

Copyright: John Bryant, VOCAT International Ltd, 2015, for personal use only.

quickly forget him along the ecological timescale, should human civilisation fail or spoil the proceedings.

I am indebted to my wife Alison for all her support and for providing me with an atmosphere conducive to my research.

John Bryant

.

CHAPTER 3 CONNECTING TO ECONOMIC VALUE

The particular discipline that this book is concerned with is that of thermodynamics, with entropy being the connector to the way the Earth and its systems work, as described in chapter 1. It is also clear from chapter 2 that the problem of 'economic' man has arisen only the last three hundred years of the Earth's evolution, being driven by a voracious appetite for energy, lit by the touch-paper of science and invention, and moderating previous constraints to development. A trawl through the literature of economic research indicates that there have in fact been quite a number of attempts to link economics with science. A selection is highlighted in the following paragraphs.

Economist Paul Samuelson, in his book *Foundations of Economic Analysis [1947]*, used the analogy of the Le Châtelier Principle and classical thermodynamics to explain the constrained maximisation problem, and acknowledged in his Nobel lecture *[1970]* that the relationships between pressure and volume in a thermodynamic system bear a striking similarity in terms of differentials to price and volume in an economic system. Other early contributors included Lisman *[1949]*, who saw a similarity between money utility and entropy, Pikler *[1954]*, who highlighted the connections between temperature and the velocity of circulation of money, and Soddy *[1934]*, who suggested that if Marx had substituted the word energy for labour he might have conceived an energy theory rather than a labour theory of value. Perhaps the earliest suggestion of a relationship between the two disciplines was by Irving Fisher *[1892]*, who related marginal utility to force, utility to energy and disutility to work. Fisher himself was mentored by Willard Gibbs, the founder of the theory of chemical thermodynamics.

The 1970s saw a rise in interest in the connections between economics and energy/thermodynamics, famously pioneered by Georgescu-Roegan in his book '*The Entropy Law and the Economic Process' [1971]*. In a later contribution *[1979]* he noted that economic systems exchange both energy and matter with their environment and are best represented as open thermodynamic systems. He argued that the entropy law was important. Another strand of work, begun by Odum *[1971, 1973]*, was to try to define the content of a product in energy terms, and he developed the term *"Embodied Energy"* as totalling the energy input into a product.

The 1970s were also notable for the work of Meadows et al *[1972]* in *'Limits to Growth' [a book sponsored by the Club of Rome]* which, while not concerned with relationships between thermodynamics and economics, certainly highlighted the potential links between economic output, resource consumption and pollution.

By the 1980s growth of energy consumption was in full swing, as has been highlighted in chapter 2, and the writer had begun some research on a thermodynamic approach to economics, publishing two papers in 1979 and 1982. Ayres *[1984]* also began some work to establish the relationship between energy consumption and economic output. Other researchers, in particular Costanza *[1980]* and Hannon *[1989]*, looked at the problem of mixing dissimilar factors together, such as manpower, capital plant, resources and energy consumption to produce output – how do they combine together, given that they are all different in nature? This problem is not just confined to 'economic' man – even birds grapple with it. They commandeer twigs and mud to make a nest, consume food and water to survive and produce offspring, and at the end of the nesting season the nest is discarded – in economic terms it is fully depreciated. Mud, water, twigs, seeds, insects and snails are all different, but the end result is the rearing of avian offspring. Money, however, never entered the birds' thoughts. The decade finished with the work of Mirowski *[1989]* in his book *'More Heat than Light'*. His was a sustained attack on the foundations of modern neoclassical economics, that economics had copied the reigning physical theorems of the 1870s, with the economic notion of utility corresponding to energy.

In the 1990s, concern about the continuing rise in the use of resources fired the work of Daly *[1991, 1992]*, who posited the ideas of steady state economics and the relevance of entropy to the economics of resources.

The turn of the millennium saw a renewed interest in the connections between thermodynamics, energy and economics, spurred on no doubt by the advent of potential climate change and peak oil/gas. Candeal et al *[2001]* highlight similarities between economic utility and entropy, as do Smith and Foley *[2002, 2004]* and Sousa and Domingos *[2005, 2006]*, who also cite the Le Chatelier Principle in their work. They concluded that while neo-classical economics is based on the formulation of classical mechanics, it is actually analogous to equilibrium thermodynamics. Chen *[2002, 2007]* has developed a thermodynamic theory of ecological economics from a biophysical point of view, encompassing non-equilibrium thermodynamics and Martinás *[2002, 2005 & 2007]* too has explored the idea of non-equilibrium economics, stressing that microeconomics and thermodynamics are both based on the idea of exchange *[of value or energy]*.

A number of researchers have concentrated their efforts in the area of what is called *'econophysics'*, in particular, thermodynamic formulations of income and wealth distributions. Among these are Dragulescu & Yakovenko *[2001]*, Ferrero *[2004]*, Purica *[2004]*, Yuqing *[2006]* and Chakraborti & Patriarca *[2008]*. Park & Bera *[2009]* have concluded that many statistical distributions, including log-normal and gamma, can be derived from a maximum entropy approach.

Ayres & Warr *[2002, 2007]* have produced several papers confirming the importance of exergy *[equals available energy or maximum useful work]* as a determinant of economic output, backed up by empirical research going back 100 years for the USA and UK economies. The writer also published another paper *[2007]* on a thermodynamic theory of economics, along with further working papers, including empirical research, and culminating in a book 'Thermoeconomics' *[2009]*, up to a third edition *[2012]*. It has now been superseded by this book.

From all of the above it can be seen that there exists a body of opinion that acknowledges that analogies or isomorphic links between the disciplines of thermodynamics and economics can be observed. It is just that mainstream economics has so far chosen not to pursue this avenue, but to favour classical economic themes, now shown to be wanting in some respects.

Productive Content

One of the more important concepts in this book is that of productive content or embodied value. It differs fundamentally from economic monetary value. The latter is the price that economic agents, buyer and seller, agree in money terms for the exchange between them of a given product or resource that has an *exact* specification, a money currency being the agreed value comparator for the exchange.

Imagine a potential customer walking into a car showroom looking to buy a car. The chances are that he/she will look at a brochure describing in detail the car specification, and all the add-ons that might be available to include in that specification. Productive content represents that exact specification. It could be a barrel of oil or a grain of wheat; each of these is different, even in the method they were produced and the distance they were transported. A book has productive content, but if some more pages are added to it its productive content changes *in definition*, but its price may not. Each twig or lump of moss that a bird collects to make into a nest has a productive content. Each individual blade of grass that a cow eats has a specific productive content. Everything in this world has more or less productive content however one defines it; until it is consumed or decays to something else, resulting in an increase in entropy.

A scientist might venture to describe the productive content of an item by reference to some outside measure, such as the amount of energy consumed to make it, the volume and weight of its constituents, its biological content, the energy needed to transport it across the world, what it does and even the amount of human brainpower needed to design it, but each of these measures is different and has its own individual scale of productive content. Fuels and minerals will have an inherent useable energy content, and food sources such as animate stocks, crops and agricultural land, will have vitamin, nutrient and energy content. In this complex world of ours, defining productive content, from a power station to a pin, may be nigh on impossible; it just exists. We designate the symbol **k** for productive content, and it is no coincidence to state that it has some equivalence, in a manner, to the Boltzmann constant **k**, which we encountered in chapter 1.

Clearly a concept such as productive content or embodied value might appeal to a scientist who is accustomed to measuring variables against specific set reference points. An economist might argue however, and with some justification, that economics is not an absolute discipline, but a comparative, anthropocentric one, where value is not ascertained by deterministic processes used by scientists, but depends on the views of individual humans at different times as to the utility that each wishes to attach to a particular set of productive content.

It should be strongly emphasised that by positing the idea of productive content it is not implied that an absolute economic scale can be constructed by reference to some independent, fixed reference body of value, partly because such a body has yet to be found, but also because the agreed exchange value of one product with a specific productive content, set against that of another product with a different productive content, can and does change, arising out of changes in economic circumstances and over time.

In ages past barter was the prime means of equating one type of productive content with another, but subsequently of course this was replaced by the more practical concept of an intermediary – money – coupled with attempts at various times to anchor its exchange value against some physical standard such as barley *[the shekel]* or gold *[the dollar]*. But in the modern economy reliance is now placed on responsible central financial management to uphold confidence in the exchange value of money, usually by reference to control over interest rates and the supply of money. Given stability of value, then economics simply defines *both* the productive content **k** of a currency and its exchange value as one, £1 of value, or 1 of any currency denomination, and leaves it to the market as to what it may buy.

Another contentious area is the concept of the productive content of human labour output, deriving from the stock of competencies known as *human capital*. First, it is not constant over a lifetime, generally growing in the early years through the absorption of inputs of education and experience from others, levelling to maturity before declining with old age. Second, particularly in developed countries, humankind has progressed further from being primarily a workhorse, inputting energy to produce output, to being a factor supplying intelligence, information and management/ownership to the process. Even construction and farm workers often now use machines powered by energy sources *[rather than human power]* in their work to produce output, and their role now involves inputting information via hand and foot controls. This assumes of course that a source of energy will always be there in the future to fuel this work. Third, some humans tend to work harder than others. Fourth, each human has an individual set of attributes and abilities from physical to cerebral. Fifth, some humans generate more value than others do. Sixth, some humans do no work at all but receive an income from a fund of money or value, by virtue of accepted ownership or deferred wage *[pension]* from previous work undertaken. Irrespective of all these points however, economics gets around the problem just by defining the productive content **k** of labour as *1 person*, with the price for labour representing the variation in value, usually as a wage rate per unit of time per person for the job, individually or in groups. The price thus becomes a subjective assessment by humans as to the variation in the productive content that particular individuals make to the production process at particular times and what they can reasonably acquire to their benefit. While this approach to valuation is both simple and practical in conception, one should nevertheless be mindful that the primary source of productive content in many production processes is *not* a human, but energy and resources in one form or another.

Thus, in summary, given the difficulty in defining a scale of productive content, the value **k** in an economic system is simply given the value 1 by economists; 1 person, 1 power station of a specific technical definition, 1 ear of barley or 1 unit of currency. It is left to the market to determine variation in exchange value. In passing it may be noted that the value 1 appears also to be the same as the value of **k** used in information-based entropy to the natural logarithm base **e**, being numerically equal to 1, which was alluded to in the opening chapter.

The Source of Economic Value

Proceeding further, while we may all agree that the real source and sink of value in a production or consumption process is the productive content made or consumed, such as inanimate resources *[energy and materials]* and living resources *[animals, fish and crops]*, augmented by contributions from the productive content of humans and capital stock; economic accounting values are set out in three ways, all in monetary terms: first, the net value added produced of goods and services, second, the types of expenditure by humans that this represents, and last, the income to humans, such as wages and profits, and with a net export/import adjustment to take account of inter-country trading.

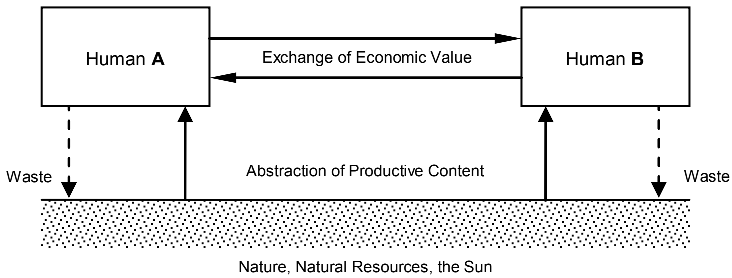

Figure 3.1 The Source of Economic Value.

From an *economic perspective* therefore ultimately resource consumption is defined in terms of a common money exchange value *attributed only to humans.*

To follow an example: imports of oil can be regarded as resource consumption expenditure, having productive content measured in tonnes and heat value per tonne, ultimately abstracted from the ground. The imported oil has a price *[per tonne or barrel]* attached to it representing the *[variable]* money exchange value of the productive content. The economic money value of expenditure on the oil is represented on the other side by the bought in costs, transport costs, wage costs and capital stock costs *[depreciation]* and any particular market conditions involved to produce and transport the oil. Bought in and transport costs also involve labour and capital stock depreciation costs and energy costs; and energy supply used up in transport in turn involves labour and capital stock costs; and capital stock production also involves labour costs - and so *ad infinitum.* These costs travel in the opposite direction to the productive content. A consumer does not comprehend the myriads of productive contents that went into the litres of petrol that he/she bought; only the cost per litre made up of wage costs and profit attributed or imputed to humans along the line of geographic connecting production processes from resources to final output.

Now, referring to figure 3.2, at each stage of the chain of production, as primary productive content is inputted to production processes to produce output, waste of non-relevant productive content is generated. For example, surface mining of coal creates spoil-heaps, power stations and land and sea transport equipment expel waste heat up chimneys and out of exhaust pipes, and industry deposits non-recyclable waste to land fill and elsewhere. Thus, as we process through each connecting stage towards final output, productive content is gradually refined, with waste being discarded along the way. But on an economic basis however, monetary value gradually accumulates at full value towards final output, with humans being recompensed at each stage.

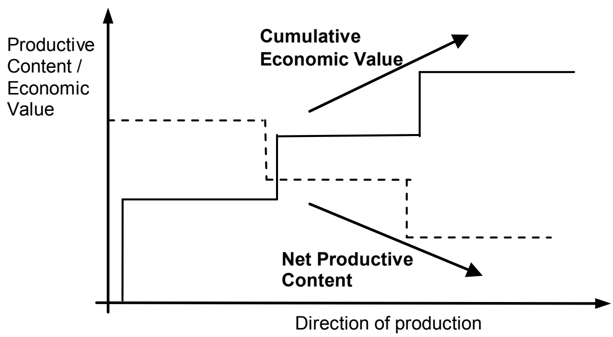

Figure 3.2 Economic Accumulation of Value & Refinement of Productive Content.

Figure 3.3 reconciles the relative differences between economic value and productive content. The contribution of human work is shown to be small compared to the total of productive content consumed, yet human wage accounts for much of economic output. This arises because on an economic basis humankind assumes *'ownership'* of resources, without having to *'recompense'* resources for any losses of value. Ultimately, resources are economically free to humankind – Nature does not sell them to us.

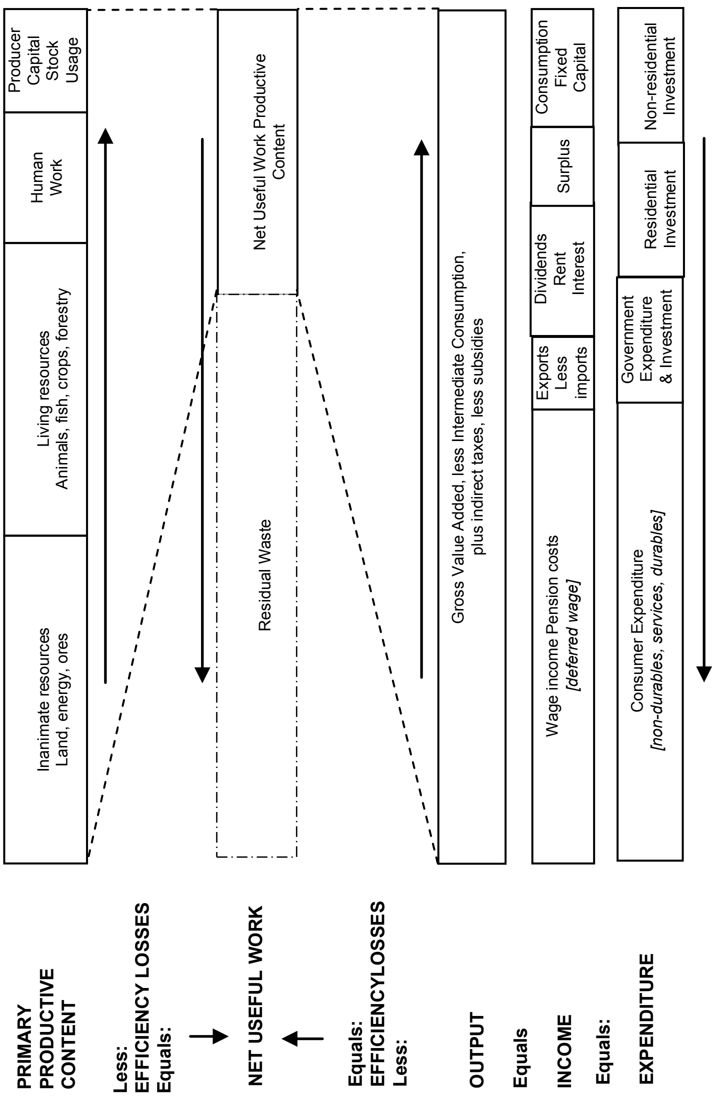

Figure 3.3 Reconciliation of Productive Content with Economic Output.

Economics assumes that humankind has effectively commandeered resources, and is distributing them over time to create a more ‘ordered’ state for itself, at the expense of creating more disorder and entropy elsewhere over time. While such a process may not in principle be different to our bird commandeering materials to build a nest, the scale involved is of course much greater.

Now the author would be among the first to admit that the economic approach of evaluating everything in terms of a common value denominator called money is a wonderful thing, which conveniently simplifies the problems of comparison and barter, and makes for a very efficient means of running an economic system. We should not, however, lose sight of the productive content of units of economic stock, and its impact and origins with respect to the eco-system, as opposed to the varying monetary values that may be attached to it, and its assumed 'ownership' attributed to humans.

Figure 3.4 illustrates a simplified thermodynamic representation of an economic cycle from resources through to waste. Resources are abstracted from the ecosystem over time, having high potential productive content and low entropy value, and are combined with labour and capital stock consumption to produce output. The output per unit of time so produced is directed to replace/augment the productive content of labour and capital stocks used up, and the rest to appear as productive content in consumer goods and stocks. Waste productive content of low value from the production process and from the consumption of consumer goods stocks is returned to the ecosystem, resulting in the generation of entropy over time.

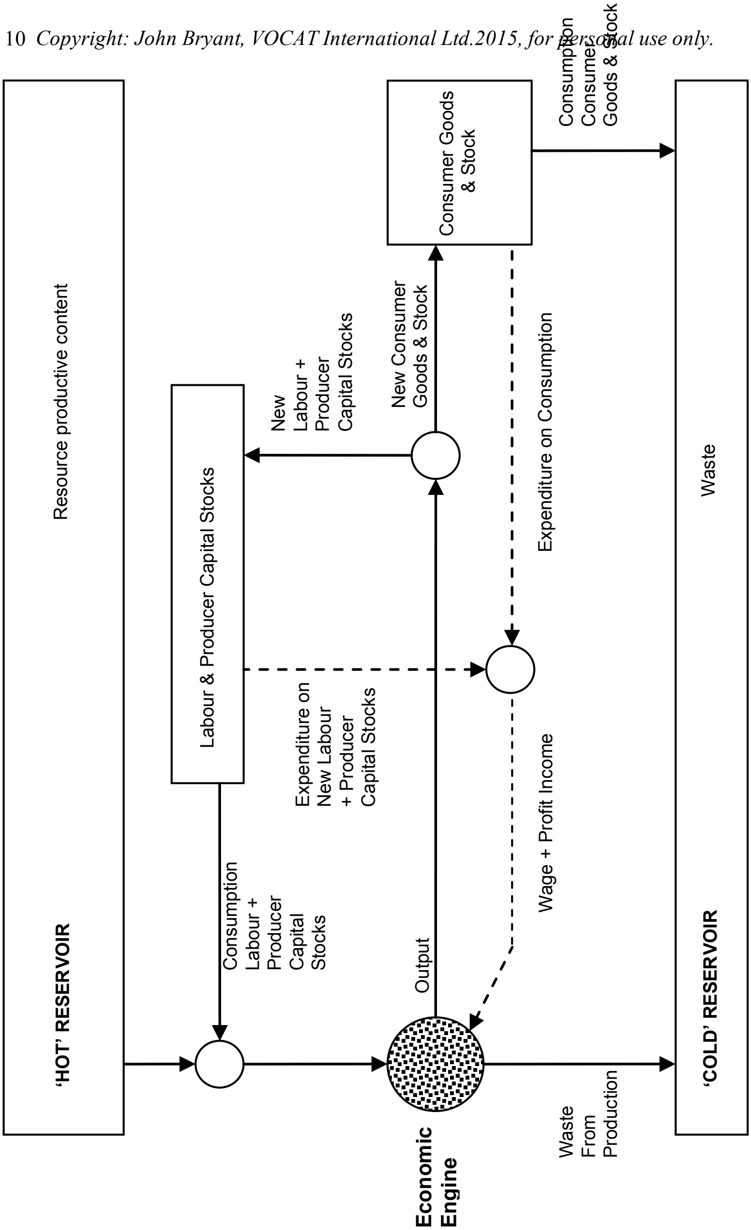

Figure 3.4 A Simple Economic Cycle.