This paper was presented at The XXV ISPIM Conference – Innovation for Sustainable Economy & Society, Dublin, Ireland on 8-11 June 2014. The publication is available to ISPIM members at www.ispim.org.

A Labour Theory of Value Creation

John Egan

Medical Technologies Innovation and Knowledge Centre
University of Leeds
Leeds - LS2 9JT - UK
E-mail: jegan@jegan.org

Abstract: The evolutionary knowledge theory of Karl Popper has been extended to the innovation domain by considering a value appreciation stage that follows on from knowledge and value creation. This paper now adapts the classical Labour Theory of Value (LTV) to interpret value appreciation as an essential thermodynamic driver of the evolutionary cycle, and hence of innovation itself. A model of a contemporary market situation indicates that if the innovative and replicative components of labour can be uncoupled, the LTV can apply throughout a conventional product life-cycle with a shift from innovation to replication with time. This life-cycle shift from the earliest stages of innovation through to purely repetitive activity provides a means to understand value creation in terms of the endeavour of the innovator and how this can appear in the performance of real organisations.

Keywords: value appreciation; scientific knowledge theory; early-stage innovation; technology translation; labour theory of value; Popper;

1 Introduction

In earlier contributions to ISPIM we have deployed Karl Popper's rationale for scientific discovery to follow the early stage translation of scientific research into a form that is suitable for commercialisation. Using case studies drawn from our experiences in medical technology innovation, we have followed research translation (Williams *et al*., 2013) thereby extending the evolutionary epistemology of Popper that is represented by the sequence:-

Problem 1 >> Tentative Solution >> Error Elimination>> Problem 2

into the cyclical problem-solution sequence shown in figure (1), in which appears an additional stage of Value Appreciation. This value appreciation is actually implicit in Popper's approach, as for scientific research this represents the expert opinion through which the validity of scientific findings are determined. By associating different "consumers" of research projects and translation projects with their different appreciation of value, we have been able to link these two domains.

This paper deals with an analysis of value appreciation. A starting point is to consider the information that is flowing around the cycle of figure (1). This is the information that defines the problem and its possible solutions; it includes optimum

project parameters that eliminate errors and the information within reports, papers and brochures that communicate research findings and proof of concept that signals the value of related innovative concepts.

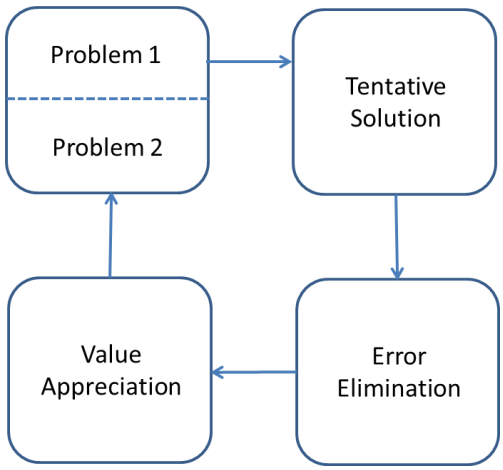

Figure (1): The evolutionary development of scientific knowledge proposed by Popper that is extended to include an explicit stage of value appreciation

It is uncontroversial to associate innovation with value creation and hence a subjective appreciation of value is a normal appraisal for an innovation. For scientific knowledge, Popper describes a value appreciation that is achieved through inter-subjective testing, expert peer review and publication and through which the knowledge becomes objective (Popper 1972, Egan *et al*. 2013). In each case, this passage of information from the objective world, through a subjective link before being recycled back as objective knowledge needs to be understood to include the social and economic processes through which an appreciation of value might arise. A combined physical and economic analysis is required.

Furthermore, we need to consider what is driving the flow of information around the cycle of figure (1). One could observe that this problem-solution cycle enables an evolutionary process that is necessary for survival, and without survival there would be no loop to observe. However, such an optimisation process must have thermodynamic consequences. Otherwise, in an equivalent paradox to that presented by Maxwell's Demon, the cyclical flow of information could lead to a decrease in overall entropy which would contradict the universal 2nd law thermodynamics. Fundamentally, the economic endeavours of the innovator could be a source of the required entropy.

These considerations lead us to seek a physical origin to the value that is created through the Popperian cycle. As both the creation of value and its perception are elements of human behaviour, the Labour Theory of Value in the classical economics of Smith, Ricado and Marx therefore has some appeal, if this can be adapted to overcome the limitations of its classical formulation. To more a contemporary audience it seems

anachronistic to suggest that the value of a commodity is determined largely by the labour employed in its production. This represents a highly idealised case of a single factor (labour) economy that is also probably quite primitive. The other factors of land and capital, as well as time needed for production, complicate the classical Labour Theory of Value and reveal its limitations (Samuelson, 1959a, 1959b). Furthermore, this theory takes no account of the demand side of the economy introduced later by the marginal economists including Walras (1909). However, the classical Labour Theory of Value does provide some insights into the economics of an industrial society, for example empirical studies in a number of different economies indicate that labour values actually can be closely correlated with market prices (Tsoulfidis et al., 2002, Fröhlich, 2013).

The aim of this paper therefore is to reformulate the classical Labour Theory of Value so that this may apply to a modern enterprise with the creation of value through innovation and with the subsequent replication of that value through production. In this case, the innovation cycle as shown in figure (1) is driven by the human endeavour in the creation of value associated with and communicated by the cycled information. Additional productive effort is consumed by the replication of this valuable information, which we consider to include combinations of labour-based operations involving production, marketing, distribution and sales that organisations might use in different ways, but with a combined effect in the transmission of the information that communicates an appreciation of value to a population of potential consumers. This uncoupling of the innovative and the replicative aspects of labour is a primary feature of the proposed analysis.

2 A Labour Theory of Value with a Consumer Population

We start with the classical formulation of the Labour Theory of Value, which is supplier based, and add into this a statistical population of consumers through which we are able to include a demand-side variable appreciation of value.

In classical economics an enquiry into the nature of value begins by comparing the value after capture of a beaver and a deer in some primitive society. Both have a use-value or utility which for the two animals are qualitative and different. They also have a quantitative exchange value one for the other, whereby the beaver hunter might acquire the utility of the deer and vice versa through some mutual exchange. This transaction must be determined by the relative value in exchange of the beaver and deer.

In an original formulation of this commodity law of exchange, David Ricado (Ricardo, 1817) made a primary assumption:-

> In the early stages of society, the exchangeable value of these commodities, or the rule which determines how much of one shall be given in exchange for another, depends almost exclusively on the comparative quantity of labour expended on each.

If it takes twice the labour to capture a beaver than a deer, then one beaver will exchange for two deer.

This classical transaction between the beaver and deer hunters we interpret as a single incidence of a generic *Consumer-Product Interaction* (CPI) which we can extend over a statistical population of consumers. Earlier we have considered that an innovative

product (or service) embodies the information that communicates its utility and hence its value (Egan *et al.*, 2013). Now we examine how, on receipt of this information through a CPI, a consumer is able to make a cost/benefit or price/value judgement upon which depends the classical transaction.

We assume that a typical distribution of perception of value across a population of consumers would take the form of a Gaussian distribution with mean ξ_{mn} and a standard deviation ξ_{sd}. In this case, the exchange based on the Labour Theory of Value has a uniform perceived value for the whole population based on embodied supplier labour. This situation is obtained if ξ_{mn} takes the uniform exchange (natural) value and ξ_{sd} would approach zero. In this special case, the statistical cumulative distribution function would be a step function between 0 and 1 occurring at the natural value. For a commercial transaction, if we can imagine a supplier has the freedom to set the price of the goods, then in this trivial case it is clear that maximum income is achieved when the price is set to the natural value, as above this level no goods will sell as price exceeds perceived value for all consumers. So an adapted Labour Theory of Value with a consumer population will deliver the same classical outcome if supplier price is adjusted to obtain maximum income.

It is this rationale we will use with a more realistic consumer population for which price can be adjusted and only those individuals with a higher value appreciation will proceed to complete the transaction. Also we assume that in a modern economy under a capitalist law of exchange, an objective to maximise profitable return on invested capital operates and that we can use invested capital as a proxy measure of the labour deployed in the creation of the CPIs, recognising the additional requirement for a surplus value to provide a return on invested capital (Foley 2011).

3 Value-Surface and Innovation

On the 13th November 2013 a diamond known as the Pink Star was sold at auction in Geneva for $83m. It was a record price for a gemstone. Here we will present a situation analysis based on this event to exemplify a case of labour adding value to a unique item through innovation.

A conveyor belt carries debris from a South African mine and a prospector scans the rubble. The prospector is an economic entity who can bestow an individual appreciation of value. But value remains negligible until the vibration of the belt disturbs a rock to reveal protruding from the newly exposed surface a translucent incongruity. Within an instant the previously anonymous rock soars in value - for that single, individual prospector. This is not as swift a transition as it sounds, for the prospector is but one small contributor to a vast consensus by which the value of an item is to be determined.

The act of discovery here is equivalent to invention. It is the initial creative act from which follows all subsequent innovation. At this stage there is a significant risk that the discovered item may be worthless and no amount of subsequent endeavour will prove worthwhile. The recovered diamond, still in its primitive state is transported to another continent, where for over two years in the hands of expert craftsmen it is fashioned into the Pink Star jewel. Faceted and iridescent it is placed into ring housing to be presented to the world. The contributions of the craftsmen add value. Many who view the now sparkling gemstone conclude it is indeed a rare and valuable item. Occasionally,

someone may be unable to differentiate the subject of our story from other pieces of cut glass found in the vicinity. Others may be unimpressed by its distinct lack of utility. Some perceptions of value will be less than others. And still there are vast numbers of potential acquirers that remain ignorant of the presence of the gemstone.

The craftsmen that have added such value to the diamond have done so by changing its information content that encourages individuals to appreciate its value. As these craftsmen are working on a single unique concept, their activity is quintessentially innovation. Through their creative labour they are adding value to the original invention that was the raw diamond at discovery. These craftsmen may feel their work is to some degree repetitive, using the same techniques to fabricate a collection of similar jewels. Here we seek to uncouple the singular act of innovation from its replication and so an ideal situation here concerns the deployment of labour to create an entirely unique item.

Further innovation occurs as the jeweller's sales and marketing team take matters to hand with a mission to inform as many relevant people as possible of the availability of the now sought-after diamond. Through this advertising many more perceptions of high value are created for individuals who have yet to come face-to-face with the item itself. The gemstone is unique, so the price should appear as a ceiling to all individual assessments of value. An auction is needed to identify the single individual for whom the perceived value reaches this ceiling.

Two things are driving the evolution of value of the diamond over time. First is the purposeful deployment of investment due to the economic efforts of the prospector, through the auctioneer to those of the craftsmen and the sales and marketing group. Also in the background are other numerous agents involved in the physical editing and transmission of the information content in the evolving product which serves to create an appreciation of value for a population of potential consumers. This is the combined effect of the deployment of investment in innovation, adding value through labour.

Secondly, external events will continuously disturb any economic equilibrium. The availability of alternative competing products, taxation changes or a lack of economic confidence, and individual perceptions of wealth and the need to demonstrate this, all of which can contribute to fluctuations of individual perceived value for the diamond product.

Importantly for an innovation, the goal is to sell the unique item at the highest valuation possible. The capitalist law of exchange implies that this single sale should reimburse the cost of the labour-power described above and provide additional surplus value as a return on investment. The latter profit depends on meeting expected consumer valuations and this is related to the inherent risk of innovation. In any case, the value created through innovation remains a function of the embodied labour of the innovators.

The above situation can be replayed replacing the diamond with a new medical technology. An initial invention needs to be shown to be effective through a series of measures designed to reduce technical, clinical and commercial risk and thereby increase the value of the concept (Egan *et al*., 2013). In this case, the role of the craftsmen is replaced by that of the "labourers" of the innovation project. In the end, if all is successful, such an innovative medical technology can become a clinical therapy and be commercially profitable. But whilst an innovative concept it remains unique, with a value that is based on the intellectual labour-power of those engaged in its development.

4 Value-Surface and Replication

Now let us consider an alternative and opposite scenario through which labour is devoted entirely to the replication of a commodity. Obviously, without some initial innovation this commodity would have no value, but in this case we can consider this value creating activity to be *a-priori* to the pure replication of that initial valuable information we are about to consider.

We have considered a statistical population of consumers with a fluctuating perception of value as a result of variations in preference, capital investment and competition. So in this case, we can consider investment to be distributed among **n** individual CPIs that together comprise the consumer population. We shall assume that this investment is dispensed uniformly, albeit with variable effects according to the propensity of different consumers to value the goods. This variation of individual consumer preference is described by equation (1) relating the investment that brought about the CPI to value perceived: -

$$V_i = \xi_i \, . \, I_i \qquad i = 1, \ldots\ldots\ldots, n \qquad (1)$$

Where $\mathbf{I_i = I/n}$ gives the portion of the total investment **I** that is distributed to each of **n** CPIs. $\mathbf{V_i}$ is the individual appreciation of value. The variables $\boldsymbol{\xi_i}$ indicate how investment converts into value in the eye of the beholder, and therefore defines how the information content of a product communicates its value. A typical replicated product can be used to understand how these $\boldsymbol{\xi_i}$ values might represent a real commodity. A block of coal sculpted into the form of a 1950's steam locomotive will be adopted for this purpose.

In a simple market for the coal sculpture let us nominally examine a series of 100 CPIs which together cost £100 in total investment to create. Most of these passing consumers will barely recognise any value in the carved coal artefact. They simply do not need or want an old model steam engine carved in coal. Say 20 of the 100 interactions register this negligible value. For another 19 interactions $\boldsymbol{\xi_i}$ may take a low value of around 1, so that the coal artefact is considered to be worth only the £1 it cost to bring about each CPI. In passing, other consumers recognise in the coal sculpture a sign of bygone communal efforts of local miners. These potential consumers attribute a greater value to the artefact. 17, 14, 11 and 8 consumers present $\boldsymbol{\xi_i}$ values of 2, 3, 4, and 5 respectively. Depending on the price, the locomotive may sell to these opportunistic passers-by.

A further 5 people recognise the coal sculpture as an accurate representation of an A3-class steam engine. $\boldsymbol{\xi_i}$ takes a value of 6 for these enthusiasts, taking their perceived value of the coal sculpture to six times the total cost of their interaction with the product. Finally, a single collector of coal sculpture knows the displayed locomotive is the one that would complete his extensive collection. This isolated individual would pay £9 to acquire the item.

The distribution of perceived value for the 100 potential customers following their interaction with the coal sculpture is shown as a probability density function in figure (2).

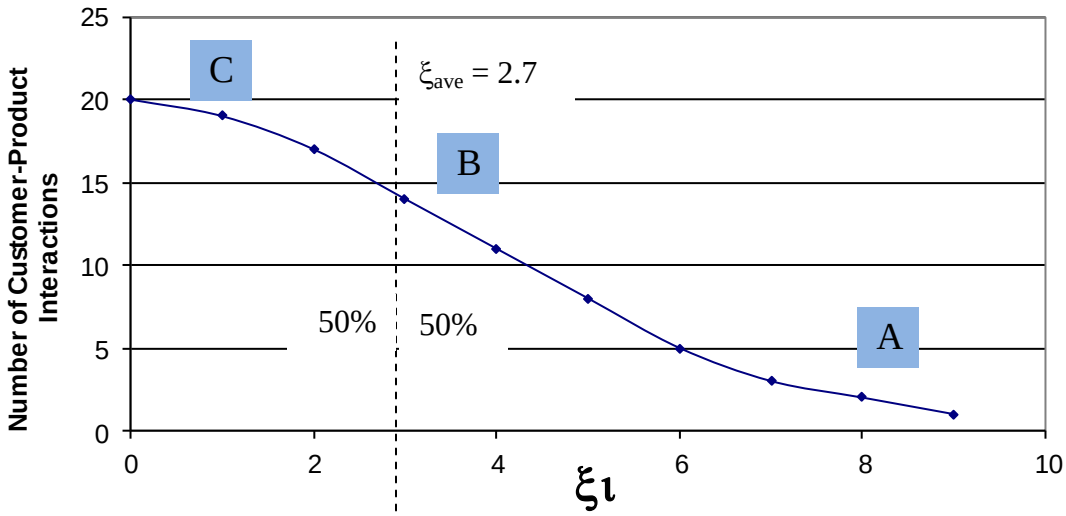

Figure (2): Example statistical distribution of ξ_i for 100 CPIs. These ξ_i values follow a half-Gaussian distribution with a standard deviation of 4. The dotted line sets a price which, in this case, 50% of CPIs will lead to a sale.

Again we can consider that the supplier has a freedom to set the price of the goods, in which case only those consumers to the right of the dotted price line in figure (2) would purchase the goods, as they value these higher than the set price. Conversely, there will be no exchange for those consumers to the left of the price line. Figure (3) shows how the total income obtained through the sales to the population of consumers varies with the fixed price.

A Gaussian distribution of $\boldsymbol{\xi_i}$ values has been selected to define the pattern of appreciated value associated with the CPIs in figure (2). It is assumed that in such a commodity market the peak value of this Gaussian distribution is set at zero[i], indicating a zero mean value and a standard deviation $\boldsymbol{\xi_{sd}}$ which here is set to an arbitrary value of 4 for the coal sculpture example.

The standard deviation of the Gaussian distribution, $\boldsymbol{\xi_{sd}}$ is related to how much a few dedicated enthusiasts are prepared to pay for the goods. Higher values of the standard deviation $\boldsymbol{\xi_{sd}}$ is a property of a consumer market that enables higher prices for greater profit.

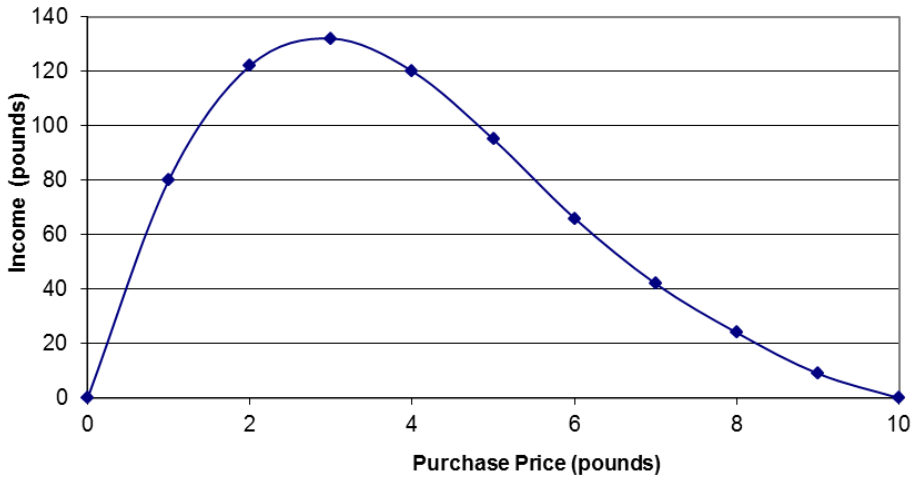

Figure (3): Variation of total income with price for the sculpted steam train. Note that £100 income is the break-even point for the business

This example of the trade of a coal sculpture is highly simplified so that the economic activity can be described by the single number ξ_{sd}. The variation of income with price shown in figure (3) is a direct consequence of this standard deviation value. If we now return to the assumption that the investment is distributed equally between the **n** different CPIs, then the total added-value is: -

$$\sum_{i=1}^{n} V_i = \sum_{i=1}^{n} \xi_i . I_i = I_i . n . \left(\sum_{i=1}^{n} \xi_i / n \right) = I . \xi_{ave} \qquad (3)$$

Here ξ_{ave} is the average of all the **n** different ξ_i values, which for the half-Gaussian distribution[ii] is the dotted line shown in Figure (2) that splits the area under the distribution curve (probability density function) into two equal halves and where in this case:-

$$\xi_{ave} = 0.675 \xi_{sd} = 0.675 \text{ x } 4 = 2.7 \qquad (4)$$

Hence, the total added value for the sculpture of a steam locomotive carved in South Yorkshire coal is I. ξ_{ave} = £100 x 2.7 = £270.

We should note that when the price is set to ξ_{ave} = £2.70 then figure (3) reveals a maximum profit is close to being achieved. This price reimburses the initial investment of £100 together with a profit of around £35[iii] as a return the invested capital.

A combination of labour-based operations involving production, marketing, distribution and sales coalesce to bring about the CPIs as described above. Different businesses might use these ingredients in different ways, but their fundamental effect is the replication and transmission of information that communicates an appreciation of

value to consumers. This information may be carried by the actual product or be communicated through marketing collateral or other proxies to generate an appreciation of value through the CPIs. For the replication of the coal sculpture, we have observed that maximum profit occurs when the price is close to ξ_{ave}. Let us now generalise this observation.

If f(t) represents a general probability distribution function of perceived value of the type shown in figure (2) and p is a set price, then goods will be sold to all consumers who value the goods equal of higher than p, so that:-

$$income = np\int_{p}^{\infty} f(x)\ dx \tag{5}$$

$$income = np\left[1 - \int_{-\infty}^{p} f(x)\ dx\right] = np[1 - F(p)] \tag{6}$$

Where F(p) is the cumulative distribution function describing the variation of consumer appreciation of value, so that income will be maximum when:-

$$\frac{dincome}{dp} = 1 - p\frac{dF(p)}{dp} - F(p) = 0 \tag{7}$$

Maximum income can be found to occur at the average price with a linear cumulative distribution function given in figure (8), which corresponds to a rectangular probability density function.

$$\left.\begin{aligned} &F(p) = 0\ when\ p \leq 0 \\ &F(p) = {}^{p}/_{m}\ when\ 0 < p \leq m \\ &F(p) = 1\ when\ p > m \end{aligned}\right\} \tag{8}$$

Here maximum income will occur when optimum price p_{opt} satisfies equation (9)

$$1 - p\frac{dF(p)}{dp} - F(p) = 1 - {}^{p_{opt}}/_{m} - {}^{p_{opt}}/_{m} = 0 \tag{9}$$

Hence, p_{opt} = m/2, which corresponds to the point when half the goods are sold equivalent to the dotted line in figure (2).

Now in the case of a Gaussian distribution with a zero mean and a standard deviation ξ_{sd}, the cumulative distribution function is:-

$$F(p) = \frac{1}{2} erfc\left(\frac{-p}{\xi_{sd}\sqrt{2}}\right) \quad (10)$$

where erfc is the complementary error function and its derivative is:-

$$\frac{dF(p)}{dp} = \frac{1}{\xi_{sd}\sqrt{2\pi}} e^{-\frac{-p^2}{2\xi_{sd}^2}} \quad (11)$$

Again maximum income will occur at a price p_{opt} that is a solution to equation (7) in which case:-

$$\frac{p_{opt}}{\xi_{sd}\sqrt{2\pi}} e^{-\frac{-P_{opt}^2}{2\xi_{sd}^2}} + \frac{1}{2} erfc\left(\frac{-P_{opt}}{\xi_{sd}\sqrt{2}}\right) = 1 \quad (12)$$

This leads to a solution where p_{opt}= 0.75 for which

$$\frac{0.75}{\sqrt{2\pi}} e^{-0.2278} + \frac{1}{2} erfc\left(\frac{-0.75}{\sqrt{2}}\right) = 1 \quad (13)$$

with a total income from equation (6) of £136 when ξ_{sd} = 4.

So in fact, p= ξ_{ave} = 0.675 from equation (4) does not provide precisely the maximum income in the case of the Gaussian distribution. It is 90% of the optimum price. However, the use of this average price in equation (6) gives a total income of £135, which thus differs only marginally from the absolute maximum income. The cumulative distributions functions of equations (8) and (10) are similar in shape and because of this, the finding that maximum income occurs when the price is $\boldsymbol{\xi_{ave}}$ is a close approximation in both cases[iv].

Let us now compare the Gaussian variation value appreciation in figure (2) with that described by the classical Labour Theory of Value from section (2). In the latter the cumulative distribution function is a step function (equation 14) and in this case maximum income occurs when price p_{opt} equals the natural price p_{nat}., which is also the average $\boldsymbol{\xi_{ave}}$ value, since all $\boldsymbol{\xi_i}$ values are equal to this value.

$$\left.\begin{aligned} F(p) &= 0 \; when \; p \leq p_{nat} \\ F(p) &= 1 \; when \; p > p_{nat} \end{aligned}\right\} \quad (14)$$

In summary, the Gaussian cumulative distribution of equation (10) is quite different from the step function of equation (14). However, both behaviours share the characteristic that maximum income occurs at a price that approximates to $\boldsymbol{\xi_{ave}}$ for their particular distribution of consumer perceived value. Therefore, in a contemporary market with a

realistic distribution of value appreciation, maximum income occurs when the price of goods is comparable to that which would appear under the classical Labour Theory of Value. However, there is an important difference. All consumers will purchase the goods at a price p_{nat} under the Labour Theory of Value, whilst only half will do so when price is set to ξ_{ave} for the realistic Gaussian scenario in figure (2). Furthermore, in section (3) we have noted that only one single consumer will receive the unique product of pure innovation. Value creation through labour dedicated to pure innovation differs fundamentally for that deployed in pure replication, and they should therefore form separate independent components of an adapted Labour Theory of Value Creation.

5 Innovation, Product Life-Cycle and Consumer Behaviour

In the analyses of the classical economists, the initial effect of innovation is temporarily to provide an additional (relative) surplus value to enhance return on investment, until the competition catches up. This can be recognised as a point that corresponds to the premium phase of a product lifecycle. In this premium phase a high price is set by the producers and there are relatively few sales. Innovation predominates as the situation is similar to that of the diamond in section (3). Indeed, for the very special case of the diamond, there is only one item available for sale and accordingly the price is set so high as to correspond to the highest valuation. The labour-power used to bring the diamond to market is fully consumed on innovation in making the information content of the diamond valuable. The creation of perception of value goes unrewarded for all but one consumer.

For the sculpted steam engine there are many identical products available for sale. Accordingly, the time dependent effects of any initial innovation will have diminished. Setting the price of a commodity to the average CPI valuation, as in the Labour Theory of Value, can very nearly bring about a maximum return on capital invested in the production and distribution of that replicated commodity. Whilst some value due to earlier innovation is retained, replication is starting to dominate in value creation.

With further reductions in price due to the maturation of the commodity, more consumers will still purchase the goods. Information replication through production dominates, but this cannot last long, as production requires an adequate return on invested capital. In figure (2) are three areas of the curve representing three types of consumer: (A) those that value the commodities highly for a particular reason, (B) those opportunists that might have a marginal use-value if the price is right and (C) those individuals who see little value in the goods.

To benefit from residual surplus value resulting from innovation whilst this is available requires strategic management a product through the premium, commodity and mature phases of its lifecycle, which relate to the consumers A, B and C respectively in figure (2). Clearly, through this product lifecycle there is a shifting influence from the innovation component to the replication component of value creation.

Having uncoupled labour into its independent components of innovation and replication we will later proceed to recombine these using mechanical models that are analogous to economic systems, as originally proposed by Walrus (1909), and thereby link patterns of consumer behaviour shown in figure (2) to changing balance between innovation and replication through the commodity lifecycle.

6 Conclusions

A Labour Theory of Value Creation has been adapted from the classical Labour Theory of Value by differentiating value creation through innovation from that created by replication. Additionally we have incorporated a subjective appreciation of value through the use of a statistical distribution of consumer-product interactions (CPIs).

Using this approach it has been shown that a Labour Theory of Value Creation applies as a close approximation in the following three scenarios:-

1. Under the classical Labour Theory of Value in which a commodity value is equivalent to embodied labour content. In this case the price must equal the natural value to provide maximum income.
2. For an innovation with a realistic and subjective interpretation of value appreciation. In this case price must equal the highest valuation to provide maximum income from a unique sale to reimburse the cost of labour input and a risk-based additional profit derived from the innovation related additional value.
3. For a replicated commodity with a realistic and subjective interpretation of value appreciation. In this case price must depend almost exclusively on the average consumer perceived value to provide maximum income from multiple sales.

Therefore, for replicated commodities, a natural price set by the adapted Labour Theory of Value Creation provides a close approximation to the average price around which the continual perturbation of the subjective appreciation of value occurs in realistic markets.

These observations provide a rationale to proceed with a mechanical analysis of an economic market that is able to use the adapted Labour Theory of Value Creation to provide physical input that drives the creation of value, by recognising the physical phenomena that are the innovative and replicative components of labour. Defining these input metrics for an innovation process will enable the process itself to be modelled and outputs correlated with the performance of real innovative organisations.

References and Notes

Egan J, C Williams, J Dixon-Hardy, and P Ellwood. “When Science Meets Innovation: a new model of research translation.” presented at the 6th ISPIM Innovation Symposium. Melbourne, Australia 8-11 December 2013

Foley Duncan K. “The Long-Period Method and Marx’s Theory of Value.” In *The Evolution of Economic Theory: Essays in Honour of Bertram Schefold* edited by Volker Caspari, Oxford, Routledge, 2011

Fröhlich Nils. “Labour values, prices of production and the missing equalisation tendency of profit rates: evidence from the German economy”. Cambridge J Econ. 37: 1107-1126, 2013

Popper Karl R., *Objective Knowledge: An Evolutionary Approach*, Oxford, Oxford University Press, 1972.

Ricardo David. *On the Principles of Political Economy and Taxation (1 ed.)*, London: John Murray, 1817.

Samuelson Paul A. "A Modern Treatment of the Ricardian Economy: I. The Pricing of Goods and of Labor and Land Services." The Quarterly Journal of Economics, 73: 1-35, 1959a

Samuelson Paul A., "A Modern Treatment of the Ricardian Economy: II. Capital and Interest Aspects of the Pricing Process." The Quarterly Journal of Economics, Vol. 73: 217-231, 1959b

Tsoulfidis Lefteris and Thanasis Maniatis. "Values, prices of production and market prices: some more evidence from the Greek economy." "Cambridge J Econ 26: 359-369, 2002

Walras Léon. « Économique et mécanique », Bulletin de la Société Vaudoise de Sciences Naturelles, 45: 313-325, 1909

Williams C., E Ingham, J Dixon-Hardy, and J Egan. "A Popperian Analysis of Translation in Biological Science.", presented at the 6th ISPIM Innovation Symposium. Melbourne, Australia 8-11 December 2013

---

[i] This is not the average as only half of the Gaussian curve is considered. It is assumed that there are no people with negative ξ_i values who would have to be paid to acquire the product. In reality the assumption of zero mean value can be an approximation when the standard deviation $\boldsymbol{\xi_{sd}}$ is significantly greater than the mean.

[ii] Note that we have set the mean value for the full Gaussian distribution to be zero, but since the negative values are not considered, the average of all positive values $\boldsymbol{\xi_{ave}}$ is a factor (0.675) of the standard deviation that marks the 75^{th} percentile of the Gaussian distribution.

[iii] This £35 is higher than the £32 originally stated as the latter figure is calculated by adjusting the Gaussian curve to match with an integer number of product sales. If a smoother and more accurate solution is allowed with a non-integer number of sales then £35.20 is a more accurate maximum profit.

[iv] This does not apply to all forms of value-surface. One might envisage two mixed populations one which associates a very low value and one a high value to some commodity. Here $\boldsymbol{\xi_{ave}}$ would take an average value between these extremes, but a higher profit will occur at a higher price, where the higher valuation population only will purchase.