

John Barber's Pioneering Work on the Economics of Measurement Standards

Notes for Workshop
in Honour of John Barber

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Introduction

In April 1987 the DTI published a review of their work on measurement standards (Dobbie et al, 1987). Modestly tucked away as Annex 5 of this report was a brief paper entitled, 'Economic Rationale for Government Funding of Work on Measurement Standards'. This Annex does not admit to an author, though each page is marked with the letters, 'JMBAAJ'. I don't know who AAJ is, but I am pretty confident that JMB is the colleague in whose honour we meet today.

That paper is a remarkable one. It anticipates so much of what later writers thought they had *discovered* about the economics of measurement standards. And yet these later discoveries were not new discoveries – just a confirmation of what John Barber already knew. In this brief note, I want to quote some of the remarkable insights in John Barber's 1987 paper, and show how these have found support in subsequent research findings. I can't do justice to all that is to be found in his paper, but I hope this will encourage people to read John Barber's pioneering work on measurement standards.

Measurement Standards and Wealth Creation

Barber (1987)¹ starts by 'examining the role of measurement standards in wealth creation'. To many who studied the economy in 1987 – and not just economists – this might have seemed a bit surprising. Most people, including the politician and the economist, had little

¹ There are no page numbers in that Annex, so I am not able to give specific page references here.

appreciation of the central role played by measurement in a modern economy. It is a hidden part of the infrastructure that we take for granted, and which is largely unnoticed – unless it goes wrong. Barber reminds us that measurement standards in fact have a big role in wealth creation.

Now, this was not of course a new idea. Babbage (1835, chapter 8) had identified the central role of what he called ‘registering operations’, including measurement standards, for efficiency in production and exchange. And while this may not have been well understood by all, a least one measurement instrument (and one measurement standard) was well recognised to have had a huge economic impact. This is the mechanical clock, and what it measures. Karl Marx was one of the first to observe the importance of this:²

‘The clock is the first automatic machine applied to practical purposes; the whole theory of *production and regular motion* was developed through it’ (*his emphasis*).

The spectacular increases in measurement accuracy following the invention of the pendulum by Huygens (Landes, 2000, pp. 128-130) made possible a step change in the division of labour and trade. And Mumford (1934, p. 14) famously concluded that:

‘The clock, not the steam-engine, is the key-machine of the modern industrial age.’

NIST (2003) has recently prepared a summary of some 29 case studies that have looked at the economic impacts of various measurement activities. NIST attempted to summarise the main mechanisms by which measurement delivers economic benefits in each case. The most important mechanisms are as follows:

<i>Mechanism</i>	<i>Number of Citations</i>
Increase productivity	12
Lower transaction costs	12
Increase R&D efficiency	11
Enable new markets	3
Increase product quality (or durability)	3

Source: Authors calculations using data in NIST (2003)

We find that most of these are discussed in John Barber’s (1987) paper.

Measurement Standards and the Functioning of Markets

Barber (1987) makes a key observation about the role of measurement standards in the efficient functioning of markets.

² Letter to Friedrich Engels, 1863, here quoted from Mumford (1967, p. 286)

‘Markets cannot function effectively unless buyers and sellers have adequate information about the trading opportunities open to them. Information about the characteristics of the products which buyers seek and those which sellers are prepared to offer needs to be expressed in quantitative and not just qualitative terms. Describing the characteristics of products in quantitative terms requires measurement standards which are clearly understood and are acceptable to both buyers and sellers.’

And Barber (1987) notes that discrepancies in measurements – where, for example, there are no generally agreed standards – is damaging to the efficient functioning of markets.

‘If the definition of the foot employed by different timber merchants varies then customers will find it much more difficult to compare the prices at which lengths of wood are being offered for sale. If there are economies of scale in offering wood for sale in a limited number of standard lengths then these will almost certainly not be realised without a standard for measuring distance which is commonly understood and applied. Any system of product specification or product specification standards is only possible if a system of universal measurement standards is already in place. Similarly any system of describing quality or setting quality standards requires that a universal measurement standard exists.’

A lack of generally agreed measurement standards means that transaction costs will be high, companies decide to do things in-house rather than outsource them to more efficient specialists, and hence we lose the potential benefits from the division of labour. As Barber puts it:

‘markets will allocate resources much less effectively and the gains from economic specialisation and trade would be significantly reduced.’

Chuah and Hoffman (2004) have explored this further. They note (2004, p. 3):

‘As transaction costs arise in the interactions between economic agents primarily as a result of information incompleteness and asymmetries between them, the major role of institutions is to, “reduce uncertainty by establishing a stable ... structure to human interaction.” (North, 1990, p. 6)’

And Chuah and Hoffman go on (2004, p. 3):

‘As measurement can be readily identified as an important source of transaction cost, measurement standardization has historically been an important step in the evolution of most societies’ institutions.’

Chuah and Hoffman (2004) distinguish two sorts of measurement system that arose as a result: the *evolutionary* system and the *planned* system.

Measurement Standards and Productivity

We have already cited Babbages’s (1835) observations on the use of measurement to enhance

efficiency in production. A further step forward in efficiency and productivity was obtained when manufacturers started to use measurement standards to produce interchangeable parts. One of the first to observe this was Thomas Jefferson in 1785, after a visit to France (here quoted from Gilbert, 1958, pp. 437-438):

‘An improvement is made here in the construction of muskets, which it may be interesting to Congress to know It consists in the making every part of them so exactly alike, that what belongs to any one, may be used for every other musket in the magazine ... I put several together myself, taking pieces at hazard as they came to hand, and they fitted in the most perfect manner. The advantage of this when arms need repair are evident. He effects it by tools of his own contrivance, which, at the same time, abridge the work, so that he thinks he shall be able to furnish the musket two livres cheaper than the common price.’

Interchangeable manufacture started in the United States with Eli Whitney’s production of muskets. The system was especially efficient because it facilitated the division of labour: the manufacture of the musket could be broken into many operations, each of which would be produced by a specialised workman on a specialised machine (Gilbert, 1958, p. 438). This method was later applied to a whole range of manufactured machines: typewriters, sewing machines, bicycles, cars and so on.

In the UK, Joseph Whitworth was a pioneer in insisting on the application of rigorous methods of measurement. And it was the application of these rigorous measurement standards that revolutionised interchangeable manufacture in the UK, and the attainable levels of productivity – especially from 1853 onwards (Galloway, 1958, pp. 638-639).

Measurement Standards and Trade

Barber (1987) recognised the central role of common measurement standards in the growth of international trade:

‘The definition of the standard needs to be universally recognised and accepted throughout the geographical area in which trade commonly takes place’

This idea has entered into the *vernacular* of the measurement community. In his history of the Australian Measurement System, Todd (2005, p. 243) quotes a slogan which was adopted by measurement agencies in Australia to express its central economic role: ‘Tested in one place, accepted in all.’ Internationally comparable measurements and standards are essential to the growth of international trade.

Measurement Standards and Innovation

Barber (1987) is also clear about the role of measurement standards in innovation. We have discussed above their use in process innovation (interchangeability) but the role in product and service innovations is important as well:

‘Rapid technological innovation increases the economic importance of measurement standards. Without such standards it would be much more difficult

for the producer of a new innovative product to indicate to potential buyers what the new product could do for them. This will increase the risk to buyers of purchasing new generations or types of products and slow down the rate at which such products are diffused.’

Once again, this idea is now part of the measurement vernacular. Todd (2005, p. 243) again: ‘If you can’t measure it, you can’t improve it.’ Innovation requires measurement standards.

King et al (2005) have explored this using data on the transactions between the National Measurement System and users of measurement, and data from the Community Innovation Survey (CIS 3). They find that there is a relationship between their measure of measurement spillovers and innovation – especially product innovation.

Measurement Standards as a Public Good

A large part of Barber’s (1987) paper is concerned with explaining when and why measurement standards are a public good:

‘They exhibit the two principal characteristics of public goods. The first is non rivalry of benefits ... one person’s use of the standard metre does not preclude its use by another ... The second characteristic ... is that in principle their benefits are non excludable. Thus once the standard metre has been established and promulgated ... it is virtually impossible to prevent any one using it without payment.’

As Barber explains, non-rivalry in consumption means that it is not desirable to charge people to use measurement standards. For if, as seems quite likely, such a charge had a significant effect on the use of the standard then lead to a misallocation of resources, and a variety of economic inefficiencies. And in any case, non-excludability of benefits may mean that it is not possible to charge for the use of measurement standards. But as Barber stresses,

‘The provision and upkeep of measurement standards is not cost free and, if this cost is not met by charging for use, it must be met by some other way’

A large part of his paper is therefore concerned with how such open measurement standards might be funded fairly and efficiently. However, I want here to focus on another implication of this public good character of open measurement standards. Barber (1987) argues that non-excludability will tend to lead to insufficient private investment in measurement standards:

‘Firms will typically not be able to appropriate a substantial proportion of the economic benefits of any investment they made in developing measurement standards or associated measurement and calibration equipment and technology. These unappropriable benefits, or externalities, cause the social rate of return to development of measurement standards etc. to typically be significantly higher than the private rate of return to the investing firm. Consequently if left to itself, the private sector working through the free market will devote fewer resources to the development of measurement standards than is desirable from the point of view of the economy as a whole.’

This is certainly a strong possibility. Another possibility is that those who invest in creating measurement standards will only do so if they can make some artificial form of exclusion. This is achieved by creating closed rather than open measurement standards, for it is only those closed measurement standards which give the creator an advantage that cannot be enjoyed by its rivals. Closed measurement standards are unattractive for a variety of reasons - most important of all because they do not alleviate the information asymmetries that created transaction costs in the first place.

But Barber (1987) is careful to stress that this public good issue does not apply to all measurement activity:

‘Although the benefits of measurement standards as such are non—excludable the benefits of the equipment used to apply them are not. While it will not always be appropriate to charge for the use of a standard, and hence for its development and maintenance it will always be appropriate to charge for measuring equipment and generally speaking for calibration also since neither of these are public goods.’

And moreover:

‘Although for reasons set above it may well be appropriate for the NSB to undertake work on the development of measuring equipment there is no economic reason why it should be involved in the commercial production and sale of measuring equipment.’

Impartiality and Integrity of Measurement Standards

These observations lead onto an important requirement of measurement standards. Barber (1987) is clear that:

‘Transactors must have confidence in the impartiality (i.e. they do not favour any particular party to a transaction) and integrity (a metre is a metre is a metre) of measurement standards. This means that primary standards must be set in an impartial manner and that an appropriate system for calibrating secondary tertiary, or even quaternary standards which guarantees their traceability must be available.’

The economics of measurement lays great emphasis on the observation that trade works best when both parties to the trade have symmetric information about the items being traded. If one side has full knowledge while the other has incomplete knowledge, then these information asymmetries will generally lead to inequitable outcomes and market failures.

A striking example of these sorts of problem is found in the *warm petrol* case.³ In petrol wholesaling and petrol retailing because the energy producing (and hence, economic) value of petrol depends on mass while petrol is sold by volume, but the ratio of mass to volume is not constant. This ratio depends on the temperature of the petrol. The buyer may have a

³ This case has generated a great deal of strong feeling – especially in Australia, but also in the UK (see Johnson, 2001). It is hard to discuss this case without committing a bad pun, but I shall try to avoid that !

pretty accurate measure of the volume delivered - at the time of delivery. But he does not know the exact temperature of the petrol on purchase. For that reason, he does not know mass so accurately, and moreover does not know what volume he will have if the petrol cools appreciably after delivery.

The issue has become a sensitive one because small retailers, especially, feel that they are losing out from this information asymmetry. Many of them believe, rightly or wrongly, that the petrol deliveries they receive are on average at a higher temperature than the ambient temperature in their tanks, so that delivery volumes are artificially inflated. Their concern about this matter is heightened by the fact that they are operating on very small margins, and moreover their tax liability is proportional to volume when it is delivered to them - and *not* the volume when delivered to the final customer.

NEL (1999) describes what happens to a given mass and volume of petrol after it leaves the refinery. NEL show that there are various points along the distribution chain where the volume can change. However the main dispute about warm petrol centres on one particular point: *apparent* changes where measured volume changes but the actual mass is unchanged, following changes in density, or errors in the metering chain.

The petrol distribution process can be split into two stages. In the first stage, from the refinery or depot to the petrol station, we find that volume, temperature and mass can be accurately determined on departure from the depot. However, when petrol is delivered from the tanker to the filling station, volume can still be accurately determined, but mass cannot. In principle, it is possible to measure (or at least approximate) the temperature of the petrol on delivery, but in practice this is not done yet in the UK.⁴ Those concerned about the issue of warm petrol believe that temperatures of delivered petrol can vary over a substantial range - see below. In the second stage, when petrol is delivered from pump to car, volume is measured accurately enough, but neither mass nor temperature is measured. But here, it is believed that the temperature range of delivered petrol is narrower, so the degree of uncertainty is lower.⁵

How significant are volume changes in practice? An 8°C change in temperature (say from 12°C to 20°C) implies (roughly speaking) a 1% change in volume. This may seem a small difference, but bear in mind again that margins are very low, and that retailers pay tax in proportion to the volume they receive rather than the volume they sell.

We can show that:

$$m \approx \mu + \gamma.(t_2 - t_1)$$

where m (%) is the actual profit margin, μ (%) is the theoretical profit margin, t_1 is the temperature on receipt and t_2 is the temperature on sale, and γ is the percentage change in volume following a 1°C change in temperature. If the temperature on receipt is greater than the temperature on sale, then the last term in the above equation is negative. If, to take some typical values, $t_2 - t_1 = - 8^\circ\text{C}$ and $\gamma = 0.12\%$, then the actual profit margin is 1 percentage

⁴ NEL (1999, p. 24) summarises practice in other countries.

⁵ Moreover, the driver has a low price elasticity of (aggregate) demand - even if the cross-brand-price elasticity is quite high for some drivers. Although this problem of warm petrol may directly disadvantage the end consumer, it is the effect on small retailers that seems to create the greatest concern.

point below the theoretical profit margin.

Is this a big deal? Yes it is. Recent data from the Petrol Retailers Association suggest that on a litre of petrol, retailing at 90 pence (say), the retailer's theoretical profit is about 2 pence. That implies a profit margin on costs of just over 2%. The above calculations imply that an 8°C discrepancy between temperature on receipt and temperature on sale will reduce that to an actual profit margin of just over 1%. And this calculation refers to a typical independent retailer. Small retailers will probably have lower margins still, so the warm petrol problem could be even more significant to them. At these very low margins, the warm petrol problem could matter a lot. However, we have no direct evidence on the actual average discrepancy between t_1 and t_2 .

Much of the discussion by NEL (1999) and others is about the *inequity* of the warm petrol problem. That is important. But economists also recognise that asymmetric information of that sort can lead to market failure. We tend to focus on the Gresham's Law (or 'Lemons') problem: 'bad drives out good'. In this context, Gresham's Law would imply that suppliers who exploit the warm petrol issue to overcharge the customer would tend to drive out suppliers who play it *straight*. According to NEL (1999) some oil companies' response to the discussion of warm petrol tends to be that if customers (e.g. small retailers) are unhappy, then they can switch to another supplier. Gresham's Law would tend to imply that such a switch is forlorn, because customers cannot determine ex ante which are the *straight* suppliers, and moreover if market failure is a reality, the only survivors will be those who do not play it straight. Moreover, NEL (1999) indicates that there are switching costs in changing contracts with suppliers, though it is hard to assess how important these are.

It seems that a more serious source of market failure here could be the implications of the warm petrol problem for market structure. The warm petrol problem appears to be a more serious problem for small retailers. They are the ones with lower turnover of petrol stocks and hence greater stock losses. They are the ones operating on the smallest margins, and who are therefore most affected by stock losses. And they are the ones going out of business: PA Consulting (1999, p. B-23) indicate that petrol loss is a significant causal factor in at least 650 of the 1300 retail petrol outlets that close down every year. In their report, NEL (1999, p. 25) indicated that the Office of Fair Trading did not consider that the warm petrol problem was leading to diminished competition. But at this rate of closure, there surely must be competition implications in the near future. Moreover, the reduction of the number of retailers must add an additional cost to the motorist - over and above any effects of reduced competition on retail prices. There is a particular sort of network effect at work here. The motorist benefits from the convenience of having a large and geographically dispersed network of petrol stations. Those who live in rural areas where the density of petrol outlets is steadily declining face an additional cost from the reduction in density. This translates into the inconvenience of long journeys to the filling station.

Measurement accuracy: neither overstate nor understate

We can draw a final linkage from Barber's (1987) paper to a very important lesson from the theory of measurement errors. Barber argues that standard must be consistently applied so that all parties know the (same) measurement and the relevant margins of error.

As Rabinovich (1993) argues, it is generally important that those who measure do not

overstate the accuracy of their measurements. That seems obvious enough: it does nobody any good to hide our heads in the sand and pretend our measurements are perfect. More surprising, perhaps, is Rabinovich's (1993) argument that it is also important that those who measure do not *understate* the accuracy of their measurements. Why is that?

The easiest way to see this is with a zoological example. Imagine an animal with good, but not perfect, hearing and which is constantly alert to sounds that signal danger. This animal is a bit like the statistician testing a hypothesis. There are two hypotheses: null (*no danger*) and alternative (*danger*). The animal, like the statistician, can make two mistakes. One is the type I error: to reject a true null. The other is the type II error: to fail to reject a false null. In this example it is the type II error that is critical – or perhaps I should say *fatal*. If the null hypothesis is false, but the animal fails to reject it, then the animal becomes prey to the predator. By contrast, in this case, the type I error is a more minor problem. If the null is true, but the animal rejects it, then it takes flight unnecessarily, but lives to see another day.

In this context, those who understate the accuracy of their measurements are liable to make too many type II errors. The signal may suggest danger, but this is erroneously discounted as noise because the measurement technique is considered to be too inaccurate. Consumers concerned about product safety (food safety in particular) should be careful to avoid such type II errors.

Conclusion

When John Barber wrote his short paper in 1987, I would guess that most of those who study the economy did not appreciate the central role of measurement standards in wealth creation. Today, a few more would do so, but still only a minority. Barber's (1987) paper is one of the clearest statements of why measurement and measurement standards are so important to the economy. I urge you to read it, and I hope to persuade John that it deserves publication to a wider audience.

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