R E P O R T

Benefit of Legal Metrology for the Economy and Society

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CIML Honorary Member

A study for the

International Committee of Legal Metrology

The purpose of studying economics is to avoid being deceived by economists

Joan Robinson
Prof. Economics, Cambridge Univ. (1965-1971)

And still they come, new from those nations to which the study of that which can be weighed and measured is a consuming love

W.H. Auden (1935)

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About the Author

John Birch was Executive Director of the Australian National Standards Commission from 1986 to 2000 and represented Australia on the CIML for that period. He was a member of the CIML Presidential Council from 1990 to 2000 and was appointed a Member of Honour of CIML in 2001.

In 1994 John Birch was instrumental in establishing the Asia Pacific Legal Metrology Forum (APLMF) and was Foundation President of APLMF from 1994 to 2001. He was appointed an Honorary Member of APLMF in 2001

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Preface

When Gerard Faber asked me to undertake this study for CIML, I accepted with enthusiasm as I had been interested in the topic for over thirty years but never had the time to conduct any significant analysis. However my reading had made me aware of the difficulty in quantifying the benefits of metrology and for that reason I suggested a short exploratory study of five weeks that would identify and survey the literature on the topic, provide some initial views about methodologies that have been used to quantify the benefits and suggest proposals for future work.

There was some delay in commencing the study due to a very limited response from CIML members to provide studies conducted in their national systems. However a Progress Report was produced in August 2002 and discussed at the CIML meeting in Saint-Jean-de-Luz in October and a further brief progress report was provided to the Presidential Council in February 2003.I also at this time received comments from a number of CIML members and incorporated these into the draft final report.

I would hope that the Final Report will stimulate an increased engagement by the legal metrology community with governments and economists and lead to further studies to quantify the considerable economic and social benefits provided by legal metrology.

I would like to express my appreciation of the assistance and encouragement I have received from CIML members and a wide range of metrologists and economists. I would particularly like to thank Gerard Faber for proposing the study and Jean-Francois Magana for his continuing encouragement and advice. I was also greatly assisted by information, advice and discussions with Dr Gregory Tassey, Dr Chuck Ehrlich and Henry Oppermann of NIST, Aves Thompson and Ross Andersen of NCWM, Alan Johnston and Giles Vinet of Measurement Canada and Richard Knapp, Dr Seton Bennett of NPL, Jeff Llewellyn of NWML, Shelley Charik of DTI (UK),Ron Gainsford of TSI (UK), Dr Geoffrey Williams of University of Oxford, Dr Frank Kinghorn of NEL and Dr Knut Birkeland.

I also greatly appreciated the comments on the Progress Report received from Dr Manfred Kochsiek, Dr Wilfried Schulz and Dr Schwartz of PTB, Lex Rooijers and Gep Engler of NMI, Wayne Stiefel of NIST, Alan Johnston of Measurement Canada and the late Kialou Angat of NISIT, PNG, and for the interest shown in the study by Gabrielle Rebello de Silva, INNOQ, Mozambique, Cho Young of MPI and Yeon-Jae Lee of KATS of Republic of Korea, Ricardo Munoz Rodriguez of DGN, Mexico, Dr Hidetaka Imai and Dr Mitsuru Tanaka of AIST, Japan, C M Lo of SCL, Hong Kong, Ivan Skubic of MIRS, Slovenia and K. Mordzinski of Central Office of Measures, Poland.

Abbreviations

ASEAN	Association of South East Asian Nations
APEC	Asia Pacific Economic Co-operation
APLMF	Asia Pacific Legal Metrology Forum
BIML	International Bureau of Legal Metrology
BIPM	International Bureau of Weights and Measures
CGPM	General Conference of Weights and Measures
CIML	International Committee of Legal Metrology
CIPM	International Committee of Weights and Measures
DTI	Department of Trade and Industry (UK)
EU	European Union
GDP	Gross Domestic Product
GNP	Gross National Product
INMS	Institute for National Measurement Standards (Canada)
ISO	International Standards Organisation
KPMG	an international management consulting firm
LDC	Least Developed Country
LGC	Laboratory of the Government Chemist (UK)
MAA	Mutual Acceptance Agreement
MRA	Mutual Recognition Agreement
NBS	National Bureau of Standards (USA) now NIST
NCSL	National Conference of Stadardising Laboratories (USA)
NCWM	National Conference on Weights and Measures
NEL	National Engineering Laboratory (UK)
NIST	National Institute of Standards and Technology (USA)
NMI	Netherlands Measurement Institute
NMI's	National Measurement Institutes
NMS	National Measurement System
NPL	National Physical Laboratory (UK)
NWML	National Weights and Measures Laboratory (UK)
OECD	Organisation for Economic Co-operation and Development
OIML	International Organisation of Legal Metrology
PNG	Papua New Guinea
PTB	Federal Physical and Technical Institute (Germany)
QOL	Quality of Life
SI	International System of Units
TBT	Technical Barriers to Trade
UNCTAD	UN Conference on Trade and Development
VAT	Value Added Tax
WTO	World Trade Organisation

Foreword

In November 2001 the International Bureau of Legal Metrology contracted the author to undertake a study on *The Benefit of Legal Metrology for the Economy and Society* with the following terms of reference.

Terms of Reference

The Consultant will review previous studies of the economics of metrology and particularly legal metrology and provide a summary report and analysis in accordance with the following schedule.

1. *BIML will contact all CIML members and Corresponding members to obtain copies of studies relevant to the topic of this study.*
2. *The Consultant will review these studies and provide a draft report to BIML by 31 March 2002*
3. *The Consultant will visit appropriate authorities to discuss previous studies and the draft review and provide a report to BIML BY 31 May 2002*
4. *The Consultant will prepare an analysis of the material obtained with the aim of developing*

    a) *Economic and social analysis criteria to assist legal metrology authorities to determine priorities for resource allocation*
    b) *A rudimentary cost/benefit analysis of the main components of legal metrology*
    c) *An analysis of the costs and benefits of State operated versus privatised legal metrology systems.*

    and provide the final report and analysis to BIML by 31 July 2002

Mr Magana the Director of BIML contacted all CIML members and corresponding members in December 2001 requesting copies of any studies conducted in their nation on the topic. With a few notable exceptions, very few studies were received and as a result the author then drew upon studies that he had collected over the past twenty-five years which provided the bibliography of this study.

Key publications were then reviewed for their relevance to the topic of the study and Attachment 2 provides a summary of the ideas and concepts that were seen as relevant, particularly to the central issue of quantifying the economic and social benefits of legal metrology.

In June 2002 the author visited a number of the institutions which have been active in the field of economic analysis of metrology, in particular N.I.S.T. (USA), Measurement Canada and the Measurement Policy Unit of the Department of Trade and Industry in UK. These discussions were valuable in focussing the study.

Whilst there has been little analysis of the economics of legal metrology there has in the past few years been a number of studies on the economic and social benefits of scientific metrology. In particular studies by K.P.M.G. for the Institute of Measurement Standards (Canada) and the International Bureau of Weights and Measures and studies undertaken by the European Measurement Project. These studies have been particularly considered as to whether their methodologies could be applied to legal metrology.

The author made a presentation on the Progress Report at the October 2002 CIML meeting in Saint-Jean-de-Luz and there was considerable interest from members. Following discussions with Mr Magana the Progress Report was placed in December 2002 on the OIML members web site and members were asked for their comments and particularly requested to provide any brief case studies, illustrating benefits, that could be included in the Final Report

A further report was provided to the CIML Presidential Council meeting in February 2003. Subsequently comments on the Progress Report were received from Canada, Germany the Netherlands and the Presidential Council and the Final Report has included a number of the suggestions that were made.

BENEFIT of LEGAL METROLOGY for the ECONOMY and SOCIETY

1. Introduction

Legal metrology developed over 5000 years ago with the development of civilizations that required consistency of a wide range of measurements used in everyday life. These included;

Time and the calendar
Distance and area
Weights and measures

The relationship between the State and metrology was symbiotic. The State needed measurements to provide the information necessary to organise, plan, defend and tax with efficiency. Such accounting depended on uniform measurements across wide geographical areas and across a broad spectrum of farming and manufacturing practices and work organisation. Metrology on the other hand required the mandate of the State to ensure conformity to measurement requirements.

As well as being a user of metrology the State was also required to provide the necessary trust and confidence in measurement by mandatory standards and requirements. This ensured the integrity of commerce and was realised by the State decreeing and enforcing measurement standards and requirements and controlling fraud to underpin market transactions.

The fundamental requirement, to ensure consistency, was that all measurement be derived from (royal) standards, what we now define as traceability. In addition moral precepts to ensure the integrity of the measurements were contained within the holy books - e.g. the Torah, Bible and Koran and in The Analects (Lun Yu) of Confucius and in early India the Arthashastra of Kautilya.

Trust and confidence inherent in the measurement system is a significant component of the social capital of all societies and contributes to the maintenance of a civil society.

In metrology confidence is generally used to indicate the extent to which the technical requirements for consistency have been met, trust relates to the normative relationship between parties to a transaction. Kenneth Arrow the Nobel laureate in Economics has written extensively about the importance of trust in economic transactions and the two following quotations from his publications highlight aspects of this concept.

> "Virtually every commercial transaction has within itself an element of trust, certainly any transaction conducted over a period of time. It can be plausibly argued that much of the economic backwardness in the world can be explained by the lack of mutual confidence;" (137)

> "Now trust has a very important pragmatic value, if nothing else. Trust is an important lubricant of a social system. It is extremely efficient; it saves a lot of trouble to have a fair degree of reliance on other people's word. Unfortunately

> this is not a commodity that can be bought very easily. If you have to buy it, you already have some doubts about what you have bought. Trust and similar values, loyalty or truth-telling, are examples of what the economists would call "externalities." They are goods, they are commodities; they have real, practical, economic value; they increase the efficiency of the system, enable you to produce more goods or more of whatever values you hold in high esteem. But they are not commodities for which trade on the open market is technically possible or even meaningful." (136)

China (155) well illustrates this traditional relationship between the State and metrology. During the Shang Dynasty some 3500 years ago a system of standard measuring instruments for length, mass and capacity was established. A State organisation with special officials was assigned responsibility for checking the accuracy of these instruments twice a year. As well as trade in commodities these standards were also mandatory for the production of weapons, vehicles, a wide range of handicrafts and the construction of buildings.

With the development of the modern State royal decrees and moral precepts were replaced by Weights and Measures legislation which gave legislative force to the rules of the measurement system and established enforcement mechanisms to ensure compliance. This provided the trust in the system, ensured consistency of measurement and established the foundation for what we now describe as legal metrology.

What is clear from the history of metrology is that its development was driven by a need of the State for information. Where the State was strong the need, particularly by the bureaucracy, was greatest and there was a strong commitment to the metrology system. As the State declined metrology declined with it and over the centuries the national metrology systems have ebbed and flowed with the power of the State.

France at the time of the Revolution, where non-uniformity of measures was upheld as a feudal right, illustrates this problem of metrological fragmentation. Over 800 differently named measures and untold units of the same name ensured inconsistency of measures, fraud and constant disputation. Hence the overwhelming demand at the meeting of the Estates General in Paris in 1789 for the establishment of a uniform system of weights and measures, out of which grew the metric system.

2. Metrology in the 20th Century

2.1 Scientific Metrology

The late 19th century saw a marked increase in international trade and metrology responded to this with initiatives to enhance the global consistency of measurements. The 1875 Treaty of the Metre with its aim of "international uniformity and precision in standards of weights and measures" was the most significant of these metrological initiatives and it resulted in the establishment of the International Committee of Weights and Measures (CIPM) and the establishment of National Measurement Institutes (NMI's) in the developed nations to maintain national standards of measurement and provide traceability to these standards. This was to provide one of the necessary infrastructures for the development of science and technology throughout the century.

In this regard the National Academy of Sciences (US) commented; (140)

> "precise measurement is the hallmark of the remarkable advancement in understanding the physical universe in modern times"

Whilst the Treaty of the Metre was originally focussed on measurement of length and mass, the physical quantities of the weights and measures system, it's scope was extended in the 20th century to measurement of electricity (1927), photometry and radiometry (1937), ionising radiation (1960) and to time scales (1988) and a degree of coherence in the measurement system was established by the adoption in 1960 by the 11TH CGPM of the International System of Units (SI).

2.2 Legal Metrology

One institutional aspect of the development of metrology in the 20th century was the separation of metrology in many countries into scientific metrology, led by the NMI's, and practical or legal metrology, administered by weights and measures authorities, which continued to provided a legislative basis for measurements and measuring instruments when used for legal purposes, and supported the development of domestic and international trade and a wide range of government regulations. This division was eventually formalised in the two International metrology treaties.

Technological change also facilitated the development of a wide range of new measuring instruments and processes and a massive expansion in the scope of metrology. Metrology responded to these changes with the development of a range of new control mechanism that complemented traceability and were designed to maintain confidence in the integrity of the measurement system. These included

1. Introduction from the late nineteenth century of national pattern approval requirements and certification of trade measurement instruments to ensure fitness for purpose.
2. Introduction from 1947 of accreditation of calibration and testing facilities to ensure confidence in measurement capability.
3. Development of national and international documentary standards for measuring instruments and processes which ensured greater consistency of measurement

4. Development of the SI system of units of measurement, which replaced a multiplicity of national, craft and industry units.

The need to ensure international consistency of trade and regulatory measurements, and to "resolve internationally the technical and administrative problems raised by the use of measuring instruments", led to the establishment in 1955 of a second metrology Treaty organization, the International Organisation of Legal Metrology (OIML). Originally focussed on trade metrology, the rapid expansion in the use by governments of regulatory measurements has seen OIML become increasingly involved in establishing international requirements for a wide range of environmental, occupational health and safety and medical measurements.

Legal metrology comprises both regulated measurements conducted by private individuals and controlled by a State authority e.g. trade metrology and regulated measurements conducted by State authorities e.g. environmental & traffic control etc. As each of these types of legal metrology have distinctive costs and benefits they will be generally be dealt with separately in this report.

3. The National Measurement System

The wide application of measurement after World War 11, promoted by the development of electronic technologies, saw the introduction of physical measurements into a wide range of new applications with a proliferation of industry based units for physical quantities. A major advance in bringing coherence to this highly diverse and fragmented system was the adoption in 1960 by the CGPM of the International System of Units (SI) that established a single unit for each physical quantity.

There was also a massive expansion in expenditure on measurement related activities. Studies conducted by NBS (9,11,12,14,17) between 1967 and 1984 indicated that the expenditure on measurement by industry, government and the community was between 3 and 6% of GNP and sectoral measurement intensity i.e. the expenditure on measurement related activities as a percentage of total expenditure varied between 20% and less than 1% of sector expenditure. Major users included Government, trade, electric gas and water utilities.

This expansion created concerns that the lack of centralisation of control of these measurements could be effecting their quality. Hunter (14) expressed these problems most clearly when noting the very large expenditure by government and industry on measurement activities that had been identified by NBS (US) said

> "If the direct cost of making measurements is large, the indirect cost of making poor measurements must be huge."

And concluded

> "The responsibility for and control of the nation's measurement systems is poorly centralized. It is possible that this diffusion is healthy for the development of viable measurements. Further, it is probably impossible to coalesce the nation's diverse measurement requirements into any single pattern. But clearly the quantity of the scientific measurements now required by our measurement-intensive laws and regulations are piling up, while many of the desirable physical and statistical characteristics of good measurement methods and associated measurement systems are being given short shrift. The result is that the quality of many scientific measurements is suspect. The time appears ripe for a review of the adequacy of our present approach to scientific measurement."

In 1967 a paper by Huntoon (9) put forward the Concept of a National Measurement System and the concept was further developed at NBS in the early 1970's (9, 11, 12) and was defined as comprising (11)

> "All of the activities and mechanisms-intellectual, operational, technical and institutional –used by the country to produce the physical measurement data needed to create the objective, quantitative knowledge required by our society. This knowledge is used to describe, predict, communicate, control and react in many aspects of our personal and social lives, science and technology. The structure was seen as having five levels
>
> 1. The conceptual system that defines measurement quantities and units

2. Basic technical infrastructure that provides the tools and techniques to implement the conceptual system
3. Realized measurement capabilities, that allows the measurement of specific quantities to known accuracies
4. The institutional dissemination and enforcement network
5. End-use measurements, which all other levels of the system exist to support

The same definition was proposed for Canada in 1987.

The Australian National Standards Commission which has a legislative responsibility to co-ordinate the Australian national measurement system developed a similar definition viz.

> "The national measurement system provides a coherent formal system which ensures that measurements can be made on a consistent basis throughout the country. It comprises all the activities and mechanisms in the Australian community that provide physical measurement data. These data provide a quantitative basis for decisions in many aspects of our life, for example commerce, industry, science, engineering, international trade, health and safety."

More recently Birkeland has proposed an equivalent definition for the global measurement system (88)

> . "The global measurement system provides a coherent structure which ensures that measurements can be made on a consistent, appropriately accurate, transparent and internationally recognised basis throughout the world. It comprises all activities that provide measurement data as a basis for decisions in many aspects of life - politics, commerce, industry, science, engineering, international trade, human health and safety, environmental and resource protection"

These definitions provided both a comprehensive and coherent way of studying the role of measurement and introduced a systems approach to the analysis (143). It should be noted that measurement legislation while not explicitly mentioned in these definitions is a key component of the national measurement system.

3.1 Measurement Infrastructure

Economic Infrastructure has generally been defined as those industry sectors that support the market economy e.g. energy, transport, water supply and sanitation and telecommunications. They are further underpinned by the Social Infrastructure e.g. schools, universities, hospitals, legal system, law enforcement. Due to their public good qualities these infrastructure have generally been regulated or provided by government.

In addition to the economic infrastructure there is also recognition of a technical infrastructure that also supports the social economy, many elements of which have public goods characteristics. Tassey (23) has coined the expression infra-technologies to cover

> "a varied set of technical tools that include measurement and test methods, artefacts such as standard reference materials that allow these methods to be used efficiently, scientific and engineering data bases, process models and the technical basis for both physical and functional interfaces between components of systems technologies such as factory automation and communications."

In this regard the national measurement system includes a substantial infrastructure to support the consistency of those measurements that are used as the basis for decision making both in industry, science and technology, the market economy, in government regulation and in the community.

This measurement infrastructure includes the International System of units of physical quantities (SI), the NMI's that maintain and develop the national standards of measurement, the calibration laboratories that maintain the traceability path and the laboratory accreditation organizations, the pattern approval testing laboratories, the measurement legislation and the enforcement of these measurement regulations, the scientific and technical committees that develop international measurement standards and recommendations and the training of metrologists and measurement engineers and technicians. This is equivalent to the first four levels in the NBS definition of the national measurement system, which exist to support the end-use measurements.

3.2 Alternative definitions

The 1989 UK White Paper *Measuring up to the Competition,* defined the UK National Measurement System as "the technical and organisational infrastructure which ensures a consistent and internationally recognised basis for measurement in the UK". This definition has been used in the subsequent studies by DTI (UK).

The European Measurement Project has defined (87) the National Measurement System as the "NMI's, Legal Metrology Laboratories and the national accreditation system."

These definition by not including the end use measurements in the NMS, are equivalent to the national measurement infrastructure definition in 3.1.

In considering the costs and benefits of metrology there are advantages in distinguishing between the measurement system and it's infrastructure.

4. Benefits of Legal Metrology to the Economy

4.1 Trade Metrology

In trade based on measurements Trade Metrology is generally perceived as providing the following benefits

1. Reduced disputation and transaction costs
From its beginning measurement was recognised as a provider of objective information. However when used in trade transactions where the measurement process lacked transparency, and there was asymmetry of information between the trader providing the measurements and the trader accepting these measurements (usually the purchaser in retail transactions, the producer in farm produce transactions and the smaller business in commercial transactions) there was considerable scope for uncertainty, disputation, transaction costs and market inefficiency. (133, 134, 139).

These transaction costs can result from concerns about the accuracy of the measurement e.g. short measure, and the consistency of the measurement e.g. paying more than other customers.

Typical examples of trade measurement transactions that may lack transparency and are difficult to check are

1. Petroleum sales to service stations and motorists.
2. Billing of telephone calls.
3. Sale of firewood
4. Sale of grain and rice by farmers based on moisture measurements.
5. Sale of alcohol where stamped glasses are not used
6. Utility measurements i.e. electricity, water and gas.

The State metrological compliance system was developed to provide, through legislative requirements, trust and confidence in the measurements and minimise disputation and transaction costs. Elements of the system included pattern approval of measuring instruments to ensure they were fit for purpose and third party auditing and inspection of instruments to ensure accuracy and detect fraud.

This central role of the State in setting rules was emphasised by The World Bank in its 1997 World Development Report on “The State in a Changing World” (97) that made the point;

“an effective State is vital for the provision of the rules and institutions that allow markets to flourish. Without it sustainable development both economic and social is impossible”.

However in recent years a number of governments in developed countries have reduced their commitment to their metrology system and placed greater reliance on the market to resolve measurement disputes.

2. Consumer protection
Measurement, and goods packed by measure, has generally replaced number and simple measures (bucket, plate etc.) as the basis of transaction for a wide range of consumer commodities and products. The increased consistency of these

measurements, when adequately controlled, has significantly reduced disputation, and fraud and increased the efficiency of the marketplace.

3. Level playing field for commerce
Metrological control ensures fair trading by eliminating the use of short measure to obtain commercial advantage over competitors in the market place and, through pattern approval and certification, eliminates the manufacture and sale of many trade measuring instruments that are not fit-for-purpose and would not meet internationally recognised standards.

4. Effective stock control
The aggregation of trade measurements by individual businesses provides accurate and effective stock control to facilitate the ordering of new stock. This is a spill-over benefit of the trade measurement system.

5.Control of fraud
As well as the control of fraud in the marketplace by State inspection, stock control by measurements can also provide effective fraud control for individual businesses. Pattern approval and certification also ensures that the design of measuring instruments do not facilitate fraud.

6.Full collection of government excise and taxes based on measurement
Governments of both developed and developing nations collect significant amounts of revenue through excise and resource rent taxes based on measurement. Papua New Guinea revenue well illustrates this point (76), viz.

- Mineral products contribute 70%of PNG export income and 17% of government revenue
- PNG has recently changed its taxes on alcohol and tobacco from an ad valorem tax to taxes based on weight and volume
- There is a proposal to develop the PNG natural gas deposits and export the gas to Australia by a high pressure gas pipeline.

All of these sources of government revenue and national income rely on accurate and consistent measurement.

7. Full national benefit for commodity exports
Export income from the sale by measure of bulk and pre packed commodities is a significant component of both export and national income for many nations. Often for reasons of jurisdiction or lack of technical capability these measurements are not metrologically controlled by the State with a consequent risk of loss of national income (107).

Recent concerns by the European Commission on the accuracy of the quantity of grain exported from Europe led to the development of the UNISTOCK Charter for grain measurements, based on OIML international Recommendations

Developing countries have even greater concerns. In trade contracts to meet the short measure requirement of trade contracts, commodity export countries give away value to the extent of the uncertainty of the measurement (107). The Asia Pacific Legal Metrology Forum (APLMF) has also expressed concern about the use of draft surveys

(112) for commodity exports rather than the more accurate weighing and measurement systems. UNCTAD has noted (95) the importance for commodity dependent countries to develop an adequate measurement system for accurate valuation of goods.

8. Support of global trade in measuring instruments
The development of International Recommendations for the Pattern approval of measuring instruments supports the global market for measuring instruments to internationally recognised standards.

4.2 Regulatory Metrology

Governments now use measurements in a wide range of government regulations, particularly for the environment, occupational health and safety, traffic control and medicine. The benefits of legal metrology in these applications include

1. Increased compliance
Measuring instruments used for regulatory purposes are able to provide continuous monitoring and greatly increase the probability of apprehension. The objectivity of the measurements also provides enhanced acceptance by industry and the community

2. Sound evidential basis for the measurements
The legal metrology authority can provide a sound evidential basis for regulatory measurements by providing for certification of standards, measuring instruments, measurements and reference materials under National Measurement Legislation. Without such certification the measurements may be incorrectly interpreted by the courts using such rules as the English common law rule of the "presumption of accuracy of scientific instruments" (153). In addition the certification enhances community confidence in the measurements.

3. Benefit/cost of metrology regulation can be greater than other policy options
Regulation by legal metrology can provide cost effective solutions to a wide range of community issues by "social engineering" e.g. the application of radar speed devices and breathalysers have had a marked impact in changing the behaviour of car drivers and markedly reduced the road toll (67). An alternative policy option of road construction to avoid accidents would be much more costly

4. International Recommendations provide level playing field for sale of appropriate measuring instruments
OIML International Recommendations provide confidence in the instrument being fit for purpose and establish a level playing field for the manufacture and sale of these instruments.

5. International Recommendations support global regulatory agreements

OIML International Recommendations provide confidence in the global consistency of a wide range of environmental and health and safety measurements that are referenced in International Treaties, e.g. Greenhouse Gas Emissions.

Arrow (152) has proposed eight principles for Benefit – Cost Analysis in Environment, Health and Safety Regulation that could be applied to legal metrology.

5. Benefits of Legal Metrology to Society

Legal Metrology provides considerable benefits to society including:

1. Support of a Civil Society

As mentioned in the Introduction, measurement has been an important component of the culture of all civilisations. However when measurements are used in trade transactions or government regulation there is a lack of transparency and imperfect information about the measurements. This is overcome by government legislation that establishes the rules of the measurement system and by Government enforcement of these rules This system reduces disputation over trade transaction and government regulation and is an important component of the social capital of a society. As such an effective measurement system provides essential social capital and supports a civil society.

2. Technological Education

The systematic structure of the measurement system provides an important but largely unrecognised educational tool for industry and the community. The regular use of measurements in everyday life transfers simple but important technological concepts to the community (c.f. 141, 142, 144).The effectiveness of this education is particularly demonstrated by shoppers detecting fraud in the marketplace (157).

3. Reduction of deaths and injuries from accidents

Application of legal metrology in health and safety applications can significantly reduce accidents by changing peoples behaviour, providing early warning signals and providing effective enforcement of safety requirements. Birch (67) provides an example of the impact of the use of radar speed devices and breathalysers on the Australian road toll.

The economic impact of such reduction in fatalities can be very high. Stiglitz (8) provides a discussion on the economic value of a life with numbers of between $US2million and $US8million (in 1997 dollars).A study in Victoria, Australia estimated the saving to the community from a reduction in road fatalities of 380 was approximately $A1.6 billion

4. Improvement in the natural environment

Legal metrology has a wide range of applications in the monitoring and control of the natural environment (35). Kleppan et al (113) provide an example of resource control in the fishing industry and OIML have developed a number of International Recommendations for instruments measuring organic and metal pollutants, pesticides and toxic substances and automobile emissions

5. Improved health from standardisation of measurement and testing

Legal metrology through timely and accurate diagnosis provides significant economic and social benefits in medicine and health. The NIST studies (34, 35) on cholesterol and radiopharmaceutical standards highlights these benefits and a number of case studies on medical applications of legal metrology are provided in *Measuring Man* (80).

OIML has developed a range of International Recommendations in the fields of medicine, occupational health and safety.

6. Reviewing the Literature

A major component of this report was to review previous studies of the economics of metrology, and particularly legal metrology and provide a summary report and analysis.

The literature of the economics of metrology when published appears in a wide range of scientific, economic and industry publications rather than in metrology journals. However many studies were Government Department reports which are unpublished. Of the studies identified in the bibliography only three were published in the OIML Bulletin and seven in Measurement and Control. Searching the internet for "measurement" and "economics" identified few, and no new, publications.

Every effort was made to obtain a international balance of publications, however very few publications were received from CIML members and as a result the bibliography is heavily biased towards the authors contacts and reading over the past twenty-five years, and to publications in English.

Every effort was also made to include not only technical economic studies but also more introductory studies from journals such as Scientific American.

Attachment 1 provides a bibliography of 158 publications, published over the past twenty-five years, that were seen as relevant to the study. The survey of publications by Anglophone metrology authorities is reasonably comprehensive but the sectoral studies section is only a small sampling of what is a large and diverse literature.

Attachment 2. Provides a summary of forty-eight publications that were particularly relevant to the focus of the study. A number of these were by institutions which had developed particular methodologies for determining the economic impact of metrology. These different institutional approaches have been summarised below, with NBS and NIST being treated separately to reflect the change by that institution from analysis of the total measurement system to a sectoral case study approach.

6.1 National Bureau of Standards (NBS, USA)

NBS studies of the national measurement system from 1965 to 1977 included a number of micro and macro economic studies of the system (11,12,13) that identified the labour and equipment costs employed in making measurements in all industry sectors in the US. From these studies it was estimated that the cost of making measurements was 6% of GNP (12). However it was recognised that weaknesses of these studies were (12,14)

1. That they were conducted from the perspective of the physical scientist and the specific measurement function he was concerned with.
2. Improved measurements may not yield benefits in an economic sense, in particular it will depend on the extent to which it satisfies wants and maximises profits.
3. Costs and benefits of measurement to society may be significantly different from the sum of the costs and benefits to individuals due to complex secondary effects arising from political and humanitarian goals of society
4. An alternative approach would be to focus on the user and in particular consumers which would make it easier to explore secondary impacts of costs and benefits of measurement for the society as a whole. In addition measurement problems for consumers probably encompass most types of physical measurement

In 1984 Don Vito (17) further extended these studies of the national measurement system to estimate the cost of measurement and the value added (defined as the value of goods and services sold less non-labour costs plus certain other items such as profits and indirect business taxes). The cost of labour is typically the largest component of value added.

Using Department of Commerce, Bureau of Economic Analysis figures for value added by each of the 81 industry sectors of the US economy, estimates of value added by measurement were calculated using survey estimates of measurement labour intensity and using the labour component of value added as a surrogate for total value added. From this analysis it was estimated that the average value added from measurement related activities was 3.5% of GNP

The total cost of measurement to industry (capital plus labour expenditures) was estimated to be $US 163 billion in 1984, representing approximately two per cent of sales. Approximately three quarters of the cost of measurement was attributable to labour expenditure.

This analysis by Don Vito was strongly criticised by Klein (55 and 56) on the grounds of "the fallacy of estimating output values from input costs" and qualified by Birch (67).

6.2 Measurement Canada

In the 1980's Measurement Canada conducted a series of studies (39, 40) to determine the economic impact of the Canadian trade metrology control system. The value of goods measured across trade measurement instruments was determined and when combined with the performance of these instruments provided an estimate of the benefit/cost ratio of the inspection system- found to be 11.4 for periodic inspection and 28.7 for targeted inspection- and the annual inequity corrected by inspectors.

The total economic impact of the Canadian trade metrology system derived from these studies were consistent with estimates made by NSC, Australia (67) and the Office of Weights & Measures, NIST (USA) (26). viz. that the annual aggregate value of trade measurement transactions was 50-60% of the GNP.

More recently Measurement Canada has developed a Market Place intervention Model for prioritising their degree of intervention in trade sectors based upon their economic significance, dependent vulnerability, metrological practices and negotiations with stakeholders.

6.3 Dept. of Trade & Industry (UK)

For over twenty years the UK government has funded the government measurement infrastructure on the basis of a customer contractor principle. This has been administered by the Measurement Policy Unit of the Department of Trade and Industry (DTI) who have established a variety of advisory bodies as proxy customers to determine priorities for the allocation of funds.

A number of studies have been conducted for the DTI to provide an economic rationale for this process and key elements of these studies relevant to this study have been highlighted in the Review attachment (52,53,55,56and58). The current methodology (58) uses ideas from endogenous growth theory to quantify the economic impact of measurement using the ratio of measurement related patents

(10%) to total patents to determine the percentage of economic growth generated by measurement.

They also use Mapping Measurement Impact (59,63) however it underemphasizes the pervasive impact of the measurement system and as such has limited application to legal metrology. One alternative being considered by DTI is sectoral measurement intensities as a proxy indicator for the influence of measurement

6.4 N.I.S.T. (USA)

Over the last fifteen years the Strategic Planning and Economic Analysis Group in NIST have conducted a large number of sectoral economic impact studies to effectively manage NIST research programs and characterize and estimate the size of various under-investment phenomena that require government co-operation with industry to address. A number of these studies have been included in the bibliography.

The quantitative metrics used are Net Present Value, Benefit-Cost Ratio, Social Rate of Return and Adjusted Internal Rate of Return. These are applied particularly to measurement standards projects where the benefits may be spread over a long period of time.

Two recent studies which directly relate to legal metrology are those on the electric utility industry (33) and Cholesterol standards (34).

The first of these related to the additional measurements required to capture the full benefits of wholesale and retail deregulation in the industry. The study identified a number of impact areas resulting from deregulation that could be addressed at least in part by measurement and standards. The estimates of economic impact were based upon interviews with forty industry experts.

The Cholesterol study limited its economic analysis to the impact of NIST standards on manufacturers and clinical laboratories, and surveys were undertaken with these groups to provide conservative estimates of economic impact

6.5 K.P.M.G. study of I.N.M.S. (Canada)

This study (50) conducted case studies on a number of current and future INMS projects most of which, with the exception of future deregulation of the electric utility industry had small economic impact. In addition the study developed an ISO Proxy Model to measure the public good component of maintaining primary metrological standards. The model uses the costs of registration by Canadian firms for ISO 9000 & 14000 as a measure of their willingness to pay for a known uncertainty in measurement and by extension traceability to national standards. For the 10,823 registered firms the total annual cost is $C 18,929,427 and this is seen as a lower bound for market maintenance impact of primary standards.

6.6 K.P.M.G. study for CIPM

This study (94) examines the potential economic impact of the CIPM mutual Recognition Arrangement (MRA) in terms of the efficiency of a multilateral arrangement over multiple bilateral arrangements and the reduction in technical barriers to trade.

The study is of particular interest to CIML that is currently finalising a MAA for pattern approval and possibly on pre packed goods.

The study conducted surveys of twenty-six NMI's who are signatories to the MRA and their cost of maintaining bilateral mutual recognition and estimated a saving of 75K Euros per annum in maintaining and establishing mutual recognition with each NMI compared with the cost pre MRA.

For the 48 members of the Treaty of the Metre the aggregate benefit is (n/2)(n-1) multiplied by 75k Euros i.e. 85M Euros per annum or about 2M Euros per member.

The study notes that a measure of the extent to which TBT might be limiting or raising the costs of trade has yet to estimated by the WTO, OECD the World Bank or other parties but noting that trade between 28 signatory nations is $4 trillion, a one tenth per cent increase in trade values would translate into an increase in value of $4 billion and this is viewed as a conservative estimate of the impact of the MRA on TBT.

6.7 European Measurement Project

This project "The Assessment of the economic role of measurement in modern society" is funded by DG-Research, of the European Commission as part of the GROWTH Programme. Twelve studies have been published and five that were relevant to this study have been reviewed.

Ref 84 on the scope and dimensions of measurement activity in Europe provided a compilation of information on measurement activity in the EU but it's economic analysis omits legal metrology. Making an assumption that 1% of industrial costs are spent on measurement - which is significantly less than found in the NBS studies - it found that expenditure on measurement in the EU, excluding legal metrology and social expenditure is 0.96% of GDP. It's estimated application benefits and knowledge spill-overs, but excluding externalities and benefits to society, provided benefits of 2.67% of GDP with a resulting Benefit to Cost ratio of 2.73.

Refs 81 and 87 the Summary and the Final Report considered the role of measurement in underpinning technologies that drive growth. It puts forward a model for quantifying the economic impact of measurement, using the percentage of EU patents citing measurement activity as a percentage of total patents, to provide a benchmark estimate of measurement innovation of 0.77% of GNP.

6.8 Summary

Generally the studies by NIST and DTI using detailed surveys of industry to estimate economic impact are valuable methodologies, but suffer from the limitations of the industry perspective of the people surveyed and are not likely to identify benefits for society as a whole. From a policy perspective the results obtained by interviews could be seen as subjective and internalised. The ISO Proxy Model developed by KPMG Canada, and the endogenous growth model, developed by PA Consulting for DTI and also used by the European Measurement Project, that measures the economic impact of measurement using quantity of measurement related patents as a percentage (10%) of all patents, are imaginative attempts to solve the problem of quantifying the economic benefit of metrology but there are major qualifications about the applicability of the models.

7. Economics of Metrology

Paulson in his 1977 Report "The Economic Analysis of the National Measurement System" (12) stated;

> "an analysis of the total measurement system, especially in a quantitative benefit-cost mode, is bound to failure: Since a modern society could not function without a systematic way of acquiring measurement data, the value of having a measurement system is incalculable."

While his sentiments are understandable, in the ensuring twenty five years many governments have moved to a market economy approach to providing government services with a change in emphasis from output to outcomes. As a result there is a need to provide a measure of the benefits of government programs both to support and justify budgetary allocations and to prioritise expenditure between components of a program.

In section 6 we considered the approaches adopted by different metrology institution for quantifying the economic benefits of metrology. Consideration will now be given to the different approaches that have been adopted to assessing the economic impact of:

1) The National Measurement System
2) The Trade Measurement System
3) Specific functions of metrology authorities
4) Trade Measurement Industry Sectors.
5) Regulatory Measurements
6) International Recommendations

7.1 The National Measurement System

References: Paulson (12) Don Vito (17), Swan (57) DTI (UK) (58),
European Measurement Project (81)
These studies developed methodologies for quantifying the economic impact of the entire measurement system

(I) Barry W. Paulson, Economic Analysis of the National Measurement System, September 1977, A report from the 1972-75 Study of the National Measurement System by the NBS Institute for Basic Standards p1-37.

This report summarised the results of studies on the economics of measurement conducted by NBS between 1966 and 1975 Expenditure on measurement related activity in 1963 was found to be $36 billion or 6% of GNP and the principal users were

1) Government - $ 11.3 billion
2) Trade - $ 4.3 billion
3) New Construction - $ 1.3 billion
4) Elec. Gas & Water Utilities - $ 1.1 billion
5) Aircraft Manufacture - $ 1.1 billion

The report

1) Notes that the costs and benefits of measurement to society may be significantly different from the sum of the costs and benefits to individuals

due to complex secondary effects arising from political and humanitarian goals of society

2) Notes the public (i.e. collective) goods characteristic of measurement and identifies a number of areas where reliance on the private sector could result in a misallocation of resources. This public goods characteristic also creates difficulties in conducting cost-benefit analysis for measurement resource allocation and the report suggests that cost effectiveness analysis i.e. comparing the cost of alternate ways of achieving a specific pre determined goal, may be a more useful analysis.
3) Considers a number of micro studies of the costs and benefits of NBS programs but notes (page 35) that these studies are from the perspective of the physical scientist and the specific measurement function he is concerned with. An alternative approach would be from the perspective of the user and in particular the consumer and notes that measurement problems for the consumer probably encompass most types of physical measurement.

(ii) Pasqual A. Don Vito, Estimates of the Cost of Measurement in the U.S. Economy, November 1984 Planning Report 21 NBS p1-42

This study provided the first comprehensive estimate of the economic role of measurement. Whilst it has been quoted widely for it's estimate of the economic benefit of measurement (3.5% of GDP) the information it provided on measurement intensity in industry sectors was also of great interest.

Survey information was collected on the measurement labour intensity in each industry sector of the US economy i.e. the percentage of labour costs committed to measurement related activities. Measurement costs of the most measurement intensive industrial sectors are shown in Table 1.

Figures for the value added, defined as " the value of goods and services sold less the non labor costs plus certain other items such as profits and indirect business taxes. " were determined by the Bureau of Economic Analysis in the US Department of Commerce for each industry sector. As the cost of labour is typically the largest component of value added Don Vito used the labor component of value added as a surrogate for total value added to obtain the value added from measurement related activities for each sector and summing over all sectors derived that the value added from measurement related activities was 3.5% of GNP.

Table 1. Measurement Costs of Selected Industrial Sectors 1979

Industry Sector	Measurement Labor as a % of total Labor	1979 Value Added ($ million)	1979 Labor Measurement Cost ($ million)
Chemicals	12.5	34,489	4,311
Plastics	16.0	5,972	956
Petrol. Refining	13.3	28,649	3,810
Glass	8.8	5,449	480
Screw Mach. Prod	15.7	10,791	1,651
Engines &Turbines	12.3	5,185	638
Metalwork Mach.	7.3	11,132	813
Spec Industr Mach	7.3	5,813	424
Off. Mach&Comp	16.5	5,651	932
Serv Ind Mach	3.6	5,340	192
Elec Trans, Distrib	9.8	11,623	1,139
House. Appliances	3.4	3,648	124
Radio TV Comm	11.0	13,979	1,538
Electronic Comp	20.5	6,001	1,230
Aircraft	15.7	20,942	3,288
Prof,Scientif Equip	9.2	7,648	704
Optical,PhotoEquip	13.9	8,010	1,113
Telephone Serv	8.9	48,796	4,343
ElecGas Water Util	20.0	48,907	9.781
Auto Services	15.4	25,666	3,953

Notes:

1. The twenty most measurement intensive sectors account for 15% of GNP and 50% of total expenditure on measurement related activity.
2. The total cost of measurement to industry was estimated to be $163 billion in 1984 which represented approx. 2% of sales. Approx. 75% of measurement expenditure is attributable to labor expenditure
3. The sectors with highest measurement expenditure viz utilities, telecom, chemicals and petrol refining have a high legal metrology content.
4. The above figures do not include government expenditure on measurement.

(iii). G M Peter Swann, The Economics of Measurement, Report for the UK National Measurement System Review, June 1999, 1-62

The aim of this discussion paper was to "improve understanding of the Economic role of the NMS, the fundamental rationale for public funding, and contribute to the methodologies for identifying and valuing the economic and social benefits that it generates."
The focus was primarily on the economics of innovation and measurements contribution to this. The methods considered for identifying the benefits of measurement are

1) **Direct Measurement**, by polling beneficiaries
2) **Engineering Economics,** where the economic model is derived from the engineering fundamentals of the measurement

3) **Econometric Studies,** which makes indirect inference of the effect of measurement from correlation with macro-economic data.
4) **Case Studies,** which are particularly useful in identifying externalities and beneficiaries.
5)

However the report does not get into the detail of quantifying benefits.

(iv) Department of Trade and Industry National Measurement System Policy Unit, Review of the Rationale for Economic Benefit of the UK National Measurement System, November 1999, 1-159

This review was limited to the economic impact of the peak metrology organizations. The methodology employed was derived from endogenous growth theory and in particular the impact of technology. The impact of metrology was derived from metrology related patents as a percentage of total patents.

(v)Geoffrey Williams, The Assessment of the Economic Role of Measurements in a modern society, European Measurement Project, Summary of Final Report April 2002, 1—42

The specific contribution of the European Measurement Project was to provide a framework for studying the economic processes that determine the adoption and diffusion of measures and measurement techniques, and the effect they have on economic activity. The study focussed on the role of measurement in underpinning technologies that drive growth of GDP. The methodology used was similar to that in the DTI report above. Making an assumption that 1% of industrial costs are spent on measurement in the EU, it found that expenditure on measurement in the EU, excluding legal metrology and social expenditure, was 0.96% of GDP.

7.2Trade Measurement System

Whilst there have been many studies of the national measurement System there have been few studies of the trade measurement system. Poulson (12) noted that many of the studies of the NMS had been from the perspective of the physical scientist and suggested that

> "An alternative approach would be from the perspective of the user and in particular the consumer"
> and notes "that measurement problems for the consumer probably encompass most types of physical measurement."

The following papers address the Trade Measurement System References: Stiefel (10) Knapp (39, 40), Measurement Canada (43), Birch (69) Butcher (26)

(i) S.Wayne Stiefel, Management Assistance for Weights and Measures Progress, Measuring Inaccuracy's Economic Distortion, presented at the 58th National Conference on Weights and Measures 1973

This paper addressed the issue of the economic impact of trade measurement compliance programs and in particular the monetary value of under or overcharging

("economic distortion") caused by measuring instrument inaccuracies. The method used had three components

1) Obtaining from Census data the value, for each census division in each State, of commodities sold at the different points in the commerce chain.
2) Estimates of the fraction of these commodities being sold by class of measuring device or by packaging
3) A measure of the performance of devices taken from weights and measures inspection reports.

It was assumed for simplification that measuring device errors followed a normal distribution and non-compliance was calculated for deviation from the MPE. The data for (3) was still being collected. There was also a discussion about whether the economic distortion should be related to the extent to which an instrument was outside the MPE, or the total inaccuracy of the instrument.

(ii) R.G. Knapp, Case study of the proportion of Gross National Product (GNP) subject to legal metrology measurement standards, (1997) 2 page note.

Surveys conducted by Measurement Canada inspectors in the 1980's resulted in the development of a data base on the number and location of all classes of trade weighing and measuring instruments and the mean annual value of commodities and services (e.g. freight charges) traded over each class of instrument.

The data obtained in 1989-1990 from 159,000 0f the 300,000 instruments in service indicated that the total value of goods traded over all classes of trade weighing and measuring instruments totalled $C203 billion in 1989/90 or 32% of GNP. This did not include pre packaged goods or utility metering

(iii) R.G. Knapp, Case study of the efficiency and effectiveness of Weights and Measures verification and reverification, (1997) 2 page note.

Combining the information from the above study with information gathered on instrument compliance rates Measurement Canada were able to estimate for each class of instrument annual "dollars at risk" i.e. the sum of short and over-measure.

When these figures were related to the cost of verification and reverification activity it was found that for each dollar spent on regular periodic inspection 11.4 dollars of non complying measurement was corrected. By targeting inspection activity towards those instruments with higher dollars at risk this "benefit/cost" ratio increased to 28.7.It was also found that on average total trade measurement inequity was comprised of 65% short measure and 35% over measure.

On average each inspector on an annual basis discovered and corrected about $2 million of total measurement inequity.

(iv)Measurement Canada's Assessment and Intervention Strategy for Canada's Marketplace, September 1999, p 1-61

This paper describes Measurement Canada's Marketplace Intervention Model that was developed to focus limited resources on those areas where the return to the taxpayer was greatest and to ensure accuracy and equity in the market place.

The scope of transaction covered by the model includes traditional measurement of quantity of commodities (weights & measures), the sale of electricity and gas and

quality measurements and grading that determine the unit price but excluding measurements used for collecting excise or taxes.

The Model analyses and scores each of Canada's trade sectors. with respect to their economic significance, dependent party vulnerability and metrological practices. These scores are then used for negotiating with stakeholders a level of intervention in the sector that is aligned to internationally accepted standards and includes national compliance sampling. In some cases sectors where combined e.g. when no additional measurements took place downstream as with pre packed goods in the food manufacturing and wholesaling sectors.

The model scores each sector using six indicators viz.

1. Reliance on trade measurement
2. Economic significance of the sector
3. Economic risk to the vulnerable party
4. Dependence of the vulnerable party to receive accurate measurement
5. Compliance of trade measurement devices in the sector
6. Consistency and conformance of those devices with established standards.

Six cumulative levels of intervention were defined in the Model viz

1. Traceability of measurement standards
2. Establish rules for accurate measurement of products
3. Establish mechanisms to enforce 2
4. Establish mechanisms for dispute resolution
5. Establish metrology rules for measurement devices
6. Establish mechanisms for device performance disputes.

(v) Birch, J A, The Role of Metrology in Economic and Social Development. Presented at a seminar on the Role of Metrology in Economic and Social Development held in Braunschweig, Germany.1998, Published in Conference Proceedings

This paper reported on estimates from Australian National accounts data of the value of trade measurement transactions in the Australian economy. The total value of trade measurement transactions was estimated to be approx. 60% of the GNP which as it included pre packaged goods and utility metering is consistent with the figure found by Measurement Canada.

VALUE OF TRADE MEASUREMENT TRANSACTIONS IN THE AUSTRALIAN ECONOMY $A MILLIONS 1990-91

Sector	Commercial	Retail	Export	Taxes	Freight
Agriculture	20,474		5,599		
Mining	28,886		14,639		
Manufacturing					
Food, Beverages	34,974	47.487	7,891		
Chemicals, Petroleum	23,485	17,201	3,012	9,433	
Basic Metals	21,446		11,281	1,197	
Paper Products	14,793		373		
Wood Products	7,829		556		
Non Metallic Products		751	221		
Textiles	4,049		2,279		
Reticulated Services					
Electricity	8,121	16,747			
Gas	1,526	2,788			
Water		586			
Freight					
Road					5,187
Rail					2,583
Total	173,099	84,804	45,851	10,530	7,770
% of total	54	26	14	3	2

TOTAL VALUE OF TRADE MEASUREMENT TRANSACTIONS $A 322,000 MILLION

Note: The value of retail transactions were only 26% of the total which raises the question as to whether the trade measurement system is only for consumer protection or for ensuring the integrity of the entire system.

(vi) Tina Butcher, Office of Weights and Measures, NIST, Economic Impact of Weights and Measures in US, January 1998, 1 page

An estimate was made of the total value of weights and measures transactions in the USA in 1996 using government and industry data. It was found that weights and measures regulations impact on transactions involving $4.13 trillion (54.5%) of the $7.57 trillion US GDP (1996).

7.3 Programs of Metrology Authorities.

A number of studies have considered the economics of specific programs of metrology authorities. Three that have some relevance to legal metrology are considered below

References: TASC, cholesterol standards (34), INMS, primary standards (50), KPMG, MRA (94)

(i)TASC Inc., The Economic Impact of NIST Cholesterol Standards Program, NIST Planning Report 00-4, September 2000, 1-51

This study of the provision by NIST of cholesterol standards to industry identifies four levels of economic impact in the supply chain that delivers medical services to the consumer viz,

1. .Lower production costs for manufacturers of cholesterol measuring systems
2. Reduced transaction costs between manufacturers and clinical laboratories
3. Lower costs for clinical laboratories in maintaining quality control systems
4. Higher quality medical services for consumers

The study did not attempt to quantify the benefits to consumers, however the economic impact on industry resulted in a social rate of return of 154% and a benefit to cost ratio of 4.47

(ii) Institute for National Measurement Standards: Economic Impact Study, Conducted by KPMG Consulting September 2001,1-74

This study was designed to provide an objective measure of the current and expected impact of the maintenance of primary standards by INMS activities on the Canadian economy. The market maintenance impact (pure public good) dimension of was measured by using the cost of annual registration for ISO 9000 & 14000 as a measure of organizations willingness to pay for maintenance of primary standards which provided a known uncertainty of measurement and by extension traceability to national standards (ISO proxy Model)

The core economic benefits of this INMS function were identified as;

1. Market Maintenance (Public Good), which took the form of reduced transaction costs. Estimated currently, at a lower bound, as $18.9 million annually
2. Quality of Life (Public Good) associated with social welfare benefits (not quantified)

Comment: Whilst maintenance of national standards supports the quality standards, charging the full cost of quality registration to this activity seems excessive.

(iii) KPMG, Potential Impact of the CIPM mutual Recognition Arrangement, April 2002, 1-127

This study examined the potential economic impact of the CIPM Mutual Recognition Arrangement (MRA) and its methodology was of particular interest due to the development by OIML of a MAA. It considered the economic impact in terms of

1. The gains in cost efficiency for National Metrology Institutions (NMIs) in establishing mutual recognition multilaterally through central co- ordination rather than bilaterally.
2. Economic efficiency resulting from reductions in technical barriers to trade (TBT).

Based on information provided by a survey of NMIs it was estimated that there was a notional saving to participating NMIs of 75K Euros per annum in the cost of establishing and maintaining mutual recognition and the total notional saving to the community of NMIs was of the order of 85M Euros.

The study notes that a measure of the extent to which TBT might be limiting or raising the costs of trade has yet to be estimated by the WTO, OECD, the World Bank or other parties. However studies indicate that the reduction of non-tariff barriers to trade can be expected to result in as much as 10% net benefit. Based on the value of

the trade between nations participating in the MRA as over $4 trillion, it is noted that a one-tenth per cent increase in trade values would translate into an increase in value of over $4billion, amongst the 28 nations that are considered, and this is viewed as a conservative estimate of the benefit.

Comment: No estimate appears to have been made of the correction factors that should be made for the percentage of trade effected by TBT and the extent to which the TBT is measurement related. These factors could markedly reduce the benefit.

7.4 Trade Measurement Industry Sectors

A number of studies have been conducted on the economic impact of measurement in trade measurement industry sectors. A sample of these are reviewed to identify particular aspects of their economic impact.

References: Gallaher and ors, utility industry (33), Baker, natural gas industry (82), Lange, bulk weighing (107), Kelly, Draft Survey (110)

(i) Michael P. Gallaher, Stephen A. Johnston and Brendan Kirby, Changing Measurement and Standards Needs in a Deregulated Electric Utility Industry, May 2000, NIST Planning Report 00-2, p 1-165

The objectives of this study were to identify the additional measurements and standards needed to capture the full benefits of wholesale and retail deregulation of the Electric Utility Industry and the economic impacts of not meeting those needs. The needs will arise from

1. Increased growth in the number and complexity of transactions
2. Increased number of market players and their information needs
3. A shift from reliance on voluntary agreements among formerly integrated utilities to explicit contracts among many providers of different services.

It is estimated on the basis of survey responses from a sample of industry experts that the economic impact of prospective opportunities that may be lost by not meeting these needs ranges from $US3.1 to $US 6.5 billion

Measurement and standards will be needed to support market transactions by helping ensure interoperability among equipment and systems provided by different vendors, by providing reliable and precise information for contracts and dispute resolution, and by developing pricing systems that reflect proper incentives.

The electric power industry represents approx, 2.5% of the US Gross Domestic Product and 1998 had retail sales of $217 billion.

The components in the retail cost of supplying electricity are

generation	75.6%
transmission	2.5%
distribution	5.6%
market transactions	16.3%.

Real time pricing in a competitive market has potential for significant savings by reducing peak demand. However there are potential costs associated with deregulation viz

1. Increased transaction costs to support market transactions.
    -Transaction costs include contracting, metering, communication and processing of information, billing and dispute resolution These costs account for 11% of the cost of supplying electricity.
2. Increased bulk transmission requirements
    - caused by competitive markets increasing the average distance electricity is transported.
3. Increased monitoring costs to support system reliability and power quality
4. Potential decrease in overall system reliability and power quality.
    - these changes could significantly increase costs to industry

Generally there is potentially a trade off between cost of power supply and its reliability and power quality. A role of measurement may be to provide the infrastructure to allow the supply of electricity with different levels of reliability or power quality to different groups of customers.

(ii) Paul Baker, The economics of measurement in the natural gas industry, December 2001, 1-25

This study examined measurement issues within the gas supply chain in the EU from the transport stage to delivery to the final consumer. The gas market in the EU is moving towards increased market liberalisation which calls for "interoperability" and "simplification" of rules. Increasing gas-to-gas competition and this new market environment is creating additional demand for measurement services.

The study drew on interviews with measurement experts from the natural gas industry, manufacturers of gas measurement equipment and national metrology institutes. However due to an absence of available quantitative data on measurement activities in the gas sector it was not possible to make even selective estimates of the "economic" costs and benefits of measurement activities in the gas sector.

(iii) J.C. Lange, High Capacity Belt Weighers for Iron Ore, OIML Seminar on Testing of Bulk Weighing Installations, April 1985 p 1-14

This paper describes the upgrading of the belt conveyor weighing system in the port of Narvik in northern Sweden to reduce the uncertainty of measurement from 0.5% to 0.2%.The cost of the extra equipment was 5 million FF and the increased annual return to the exporter due to the reduced uncertainty was 8.6 million FF.

Comment: the basis of the benefit was that the exporter overfilled to ensure no short measure, and the reduction in uncertainty reduced the overfill.

(iv) John P. Kelly, Trade by Draft Survey or by Belt Weighing, *OIML Bulletin* 126, 51-55, March 1992

Cargo draft surveys continue to be used for determining the traded quantity of international and national shipments of bulk materials and commodities. This method has a measurement accuracy significantly less than obtained using belt weighers.

7.5 Regulatory Measurements

Many of the economic studies on regulatory measurements have been focussed on these measurements as technical barriers to trade and have rarely evaluated the

benefits of these measurements. A few items in the bibliography have addressed the issue and are summarised below.

References: Semerjian (35) de Bas, emission measurements (83), Birch, vehicle load control, traffic control, (67), Kleppan Resource control in Fishing industry (113)

(i) Hratch G. Semerjian and Robert L. Watters Jr., Impact of measurement and standards infrastructure on the national economy and international trade, *Measurement* 27 (2000) 179-196

This paper described a number of programs in the Chemical Science and Technology Laboratory of NIST which were directed at providing the metrology infrastructure to meet regulatory requirements. These included development of reference materials for the automobile industry and for sulphur content in fossil fuels, radiopharmaceutical standards and the chemical and physical properties of alternative refrigerants to CFC.

The economic impact of these programs, conducted by external consultants are usually retrospective studies which have provided benefit-cost ratios or social rate of return which have been consistently high.

(ii) Patrick de Bas, The economics of measurement of emissions into the air, June 2002, 1-21.

This study was conducted for the European Measurement Project and considered the economic impact of measurements used in the control of air emissions in the cement industry. Production of cement in Europe has an estimated value of 10 billion euros and it is estimated that the total cost of measurement are at most one per cent of the total cost of production of cement and benefits at the trade level are very small. The principal benefit is improved relations with (local) government and reduced community health risk

Due to the multiplicity of pollutants that are involved in air emissions the economic impact study focussed only on the main components viz NO(X), SO(2) and dust. The study describes the methodology developed by the WHO for quantifying the impact of air pollution on health, the most important cost being the cost of delivering care. However this study does not attempt to relate the costs to the gained benefits to society from reduced emissions.

(iii) Birch, J A (1998) The Role of Metrology in Economic and Social Development. Presented at a seminar on the Role of Metrology in Economic and Social Development held in Braunschweig, Germany. Published in Conference Proceedings

This paper highlighted the significant economic and social benefits that can be obtained from the use of metrology in regulatory control. Two examples were provided

The first related to the maintenance of public highways which is a major expenditure for governments in both developing and developed countries.

The use of vehicle load weighing devices to control overloaded vehicles can provide significant saving. As the damage to road structures increases as the fourth power of the load, detecting a 10% overload can reduce road damage by nearly 50%.

The social (and economic) benefits of legal metrology are most clearly demonstrated by their impact on road fatalities. Over the last twenty years road fatalities in Australia have decreased from 3700 to less than 2000 (Figure 1) per year despite an increasing population and increased car ownership. Whilst improved roads, driver education and compulsory seat belts have all made a significant contribution, legal measuring instruments viz. radar speed devices and breathalysers have also contributed to this decline (Figure 2). These measuring devices greatly increased the probability of apprehension and there was a high degree of community confidence in the accuracy of the measurements

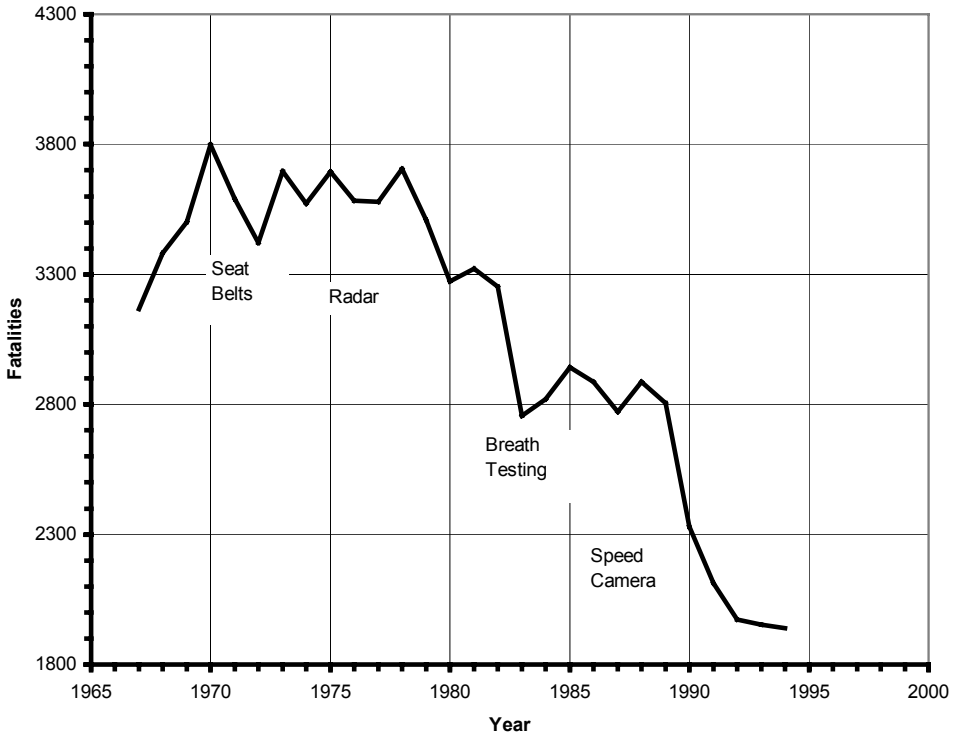

Figure 1. Road Fatalities in Australia

Determining the economic benefit of these reduced fatalities requires a monetary value to be placed on a life. Stiglitz (8) notes " that is virtually no limit to the amount that could be spent to reduce the likelihood of an accident on a road. Yet at some point a judgement must be made that the gain from further expenditure is sufficiently small that additional expenditures are not warranted." Issues that have been considered are whether the value is age dependent or based on prospective earning capacity. Different studies in the USA have produced results in the range of between $2 million to $8 million (in 1997 dollars)

In Australia one study conducted in the State of Victoria estimated the saving to the community over a three year period from a reduction in road fatalities of 380 was approximately $1.6 billion. The economic benefit to Australia in reduced injuries and fatalities over the last twenty years would be in excess of $5 billion per year to which legal metrology would have made a significant contribution by changing drivers' behaviour indicating that legal metrology is a most cost effective support of social engineering.

The World Disaster Report (117) highlighted the importance of road accident control for developing countries. The report estimated that 70% of road fatalities occur in developing countries and that the current cost of traffic accidents in these countries was roughly the level of all international aid. A major study has forecast that with the rising number of cars, particularly in developing countries, by 2020 road fatalities will be the third highest cause of global death and disability, just behind clinical depression and heart disease.

(iv)R. Kleppan, E. Koren, T. Myklebust and B. Schultz, Resource Control by use of belt weighers in the fishing industry, *OIML Bulletin*,38 24-28, October 1997.

The Norwegian fishing industry is important to the economy of the country and to ensure sustainability landed quantities of different species are controlled by weight. Control of the pelagic sector (herring and mackerel) is carried out by in-line weighing systems. Use of belt weighers has reduced the uncertainty in determining fish weight from 10-20% to < 2%.

7.6 International Recommendations

There is an extensive literature on the economics of standardisation some of the key publications are included in the bibliography (119, 120, 121, 126, 132). The issue is relevant to the development by OIML of International Recommendations and the OIML Certification System.

Economists have often viewed standards as an impediment to free markets by reducing competition. However there is increasing recognition of market failure due to externalities and lack or asymmetries of information. Standards can assist in correcting these failures as well as providing inter-changeability and compatibility both nationally and globally.

Forselius (126) provides a Return On Investment (ROI) model for involvement in standards committees activities which may also be of interest to OIML members.

Time does not permit any detailed analysis of the literature, however the bibliography provides a guide for interested members.

8. Quantifying the economic benefits of Legal Metrology

The studies summarised in Section 7 provide some guidance on the quantification of the economic benefits of legal metrology.

The NBS studies (12,17) on the national measurement system provided valuable information on the intensity of measurement expenditure in industry sectors in the US economy and indicated that many of the highest measurement expenditures occurs in the trade and legal metrology sectors e.g. Government, trade, utilities, telecommunications. The estimated measurement expenditures used in the DTI (UK) studies and the European Measurement Project (EMP) studies are markedly less than those found by NBS and the difference is highly significant to any economic analysis of the legal metrology system.

The DTI and EMP studies highlighted the importance of knowledge in innovation and economic growth, and role of scientific metrology in contributing to this knowledge base. They quantified this contribution using information from measurement related patents. Other studies (141,142,144) have emphasised spill-over effects from basic research that diffuse through industry by increasing the human knowledge base. Legal metrology would contribute to this increasing knowledge and associated social benefits through the development of International Recommendations and it's compliance and enforcement programs (c.f. sec 5.2)

8.1 Trade Measurement System

The Canadian studies reported by Knapp identified the value of commodities and services measured over trade measurement instruments and these studies were consistent with the values estimated by NSC for Australia and OWM (NIST) for USA. The studies reported by Knapp also provided a benefit cost ratio for reverification activities and noted the predominance of short measure over over-measure.

The studies in Section 7.3 also identified significant economic benefits from maintaining and developing standards and from international harmonisation of metrology through Mutual Recognition Arrangements.

Finally the industry studies in section 7.4 identified the significant economic benefits from reducing the error of measurement through improved measurement capability.

However what has not been analysed is the economic (or social) benefit provided by the States intervention in trade measurement transactions. In particular what " economic distortions" (Stiefel ref 10) would occur if these measurements were left to the market without any intervention by the State i.e. no legislative requirements, no pattern approval of measuring instruments, no enforcement etc.

Both the history of weights and measures and the problems arising from asymmetry of information (c.f. Gresham's Law) would seem to indicate that under such a regime the errors of measurement and their bias would be significantly greater, resulting in increased "economic distortions". These distortions would primarily arise from use of measuring instruments" not fit for

purpose", manipulation of larger effective errors, and lack of third party inspection and enforcement, resulting in an increase in short measure, disputation and transaction costs (c.f. 157).

Estimating the dollar value of these distortions would require more detailed information about the value and distribution of errors in measuring instruments. However whilst Stiefel assumed a normal distribution of errors for his study the information provided by Knapp found a strong bias towards short measure. There is also a need to clarify whether the economic distortion is the extent of errors outside the legal MPE's or of all the errors of measurement (Stiefel ref 10).

An indication of magnitude of such economic distortions resulting from the withdrawal of the State, is provided by noting that the annual value of trade measurement transactions in modern industrial societies is about 50% of GDP (ref 26, 40, 69) and an increase in the average error of measurement of 0.1%, would create an "economic distortion" of.05% of GDP. Such an amount is significantly greater than the expenditure by governments in maintaining the national trade measurement systems.

8.2 Trade Measurement Authority Programs

Trade Measurement Authorities need economic analysis of their programs to assist them in prioritising their resource allocation. However as mentioned earlier in this report analysing only a segment of the trade measurement system can overlook spill-over benefits. This can be particularly important when comparing government versus private operation of a program.

Knapp (39,40) has reported significant benefit to cost ratios for reverification activities by Measurement Canada in 1989-1990.This analysis required the development of a significant data base covering the operation of trade measurement instruments. This was facilitated by Canada having a single national authority for trade measurement, however privatisation of these programs in some countries will make it difficult to obtain this detail.

The assessment and Intervention Strategy currently used by Measurement Canada whilst not using the same degree of detail as in the Knapp study is a co-operative strategy with stakeholders that should markedly increase the trust and confidence in the system.

The information on the value of trade measurement transactions in the papers by Stiefl (10) Birch (69) and Butcher (26) provides valuable guidance in determining the economic significance of sectoral programs.

8.3 Mutual Acceptance Arrangements

The Mutual Acceptance Agreement for pattern approval testing, currently being developed by OIML will have a significant economic impact by eliminating multiple testing of instruments and facilitating the early entry of new instruments to the market place. Quantifying the benefits of this agreement requires information on the current degree of multiple testing, the fees and other

costs associated with the testing and the value of trade measurement instruments sold annually. This information is currently not available.

OIML is also considering developing an MAA for pre-packaged goods. This is a sector were there is significant technical barriers to trade and the value of goods traded globally is far greater than measuring instruments. Such an MAA should have a very significant economic impact.

8.4 Regulatory Metrology

Quantifying the benefits of regulatory metrology is far more difficult due to a large component of social benefit and public goods. In addition we need to distinguish between the value of the regulation and the contribution made by legal metrology. The principal benefits of regulatory metrology were described in Section 4.2 and the benefits of legal metrology to society were described in Section 5.

Some studies (35, 69, 113) have shown high social rates of return, however the issues are often complex and quantification can be difficult (83).Arrow in his eight principles for the appropriate use of cost benefit analysis for environmental, health and safety regulation, whilst they relate to regulation rather than regulatory metrology, highlight this complexity viz.

1. Is useful for comparing the favourable and unfavourable effects of policies
2. Decision makers should not be precluded from considering the economic costs and benefits of different policies in the development of regulations. Agencies should be allowed to use economic analysis to help set regulatory priorities.
3. Benefit cost analysis should be required for all major regulatory decisions
4. Agencies should not be bound by strict benefit cost tests. Factors such as equity within and across generations may be important
5. Benefits and costs should be quantified wherever possible with uncertainties.
6. External review of regulatory analysis
7. Economic assumptions used should include the social discount rate, the value of reducing risks of premature death and accidents and the value associated with other improvements in health.
8. Distributional consequences should be identified.

In many cases cost effective analysis rather than benefit – cost analysis will be found to be more appropriate.

9. Developing Countries

There is little literature on the economics of metrology in developing countries. This despite the challenges to developing countries to develop, modernise and globalise their metrology systems to provide their economies with the social and economic benefits of modern metrology

Birch (76) noted the importance of an effective trade measurement system for the responsibilities of the government of Papua New Guinea viz;
"In this regard it is worth noting that:
-Mineral products contribute 70%of PNG export income and 17% of government revenue
-PNG has recently changed its taxes on alcohol and tobacco from an ad valorem tax to taxes based on weight and volume
-There is a proposal to develop the PNG natural gas deposits and export the gas to Australia by a high pressure gas pipeline
All of these sources of government revenue and national income rely on accurate and consistent measurement."

The study by Lange (107) on high capacity weighing and by Kelly (110) on draft surveys are particularly relevant to these issues. Birch (67 and sec 7.5) has also drawn attention to the use of vehicle load weighing devices to control damage to roadways. This is an important issue in many developing countries.

The UNCTAD specialist workshop on commodity exports of LDC's held in 2002 (95) recognised the importance of measurement infrastructure for developing countries in the Chairpersons summary report in the following terms

"25. An adequate measurement system (both in quantitative and qualitative terms) has been often overlooked although it is essential in accurate valuation of goods. It also reduces transaction costs and disputes, improves collection of government revenues controls fraud and improves export earnings. Experts supported the development of an international system and urged international organisations to contribute to its mainstreaming."

And also recognised the importance of national and/or regional testing laboratories to assist developing countries to access global markets.

"24. Experts have stressed the lack of quality control infrastructures such as laboratories and inspection companies, which makes it difficult for countries to fulfil requirements of SPS and TBT Agreements. In this context, the establishment and/or upgrading of national bureaus of standards as well as regional testing laboratories was recommended. Rules of origin were also often difficult to understand and satisfy."

Introducing regulatory metrology for environmental, health and safety control is also a challenge for these metrology authorities. As noted in sec.7.5 the World Disaster Report (117) has highlighted the importance of road accident control for developing countries. The report estimated that 70% of road fatalities occur in developing countries and that the current cost of traffic accidents in these countries was roughly the level of all international aid. A major study has forecast that with the rising number of cars, particularly in developing countries, by 2020 road fatalities will be the third highest cause of global death and disability, just behind clinical depression and heart disease.

The OECD report (118) has noted that an effective road safety program needs a combination of three things: campaigns to raise public awareness of the risks associated with poor road user behaviour, a stringent enforcement regime and a consistent penalty system. Legal metrology can make a significant contribution to such a program.

However economic analysis is only one of the tools necessary for metrology authorities in developing countries to set priorities for the development of their national system. Birch (70) has described the analysis by the Asian Development Bank of their experience in capacity building with governments of developing member countries and their guidelines for effective development, which could equally be applied to the metrology systems.

In particular they have considered the extent to which the ADB programs have supported the efficiency and effectiveness with which government institutions fulfil the key functions of policy formulation, legal framework, development and enforcement, the delivery of public infrastructure and services, the mobilisation and management of financial resources for these purposes and collaboration with private institutions for equitable and sustainable development. The ADB regards inadequate capacity as one of the most consistent constraints to sustainable development.

The ADB conducted an Interdepartmental Review on Technical Assistance Operations and found that traditionally the Bank had used two principal instruments to tackle institutional weakness viz:

- external consultants to advise the weak institution;
- training the staff of the executing agency.

In both cases underlying structural weaknesses were left unaddressed with the result that significant institutional strengthening did not take place.

An ADB Task on Improving Project Quality found that advisory technical assistance (ADTA) grants for institutional strengthening are often ad hoc and have a short-term narrow focus, concentrating on superficial symptoms of institutional inadequacies and missing key institutional areas in need of strengthening. They also found that there was a tendency to impose recommendations for institutional improvement from the outside rather than develop solutions to problems with the full participation of those affected.

Finally an informal review by the ADB Strategy and Policy Office of both loan and technical assistance financed capacity building support has identified the following specific inadequacies -

- prior sector and institutional analyses, and related needs assessments are not undertaken rigorously;

- capacity building technical assistance projects are often one shot deals rather than part of a longer term exercise and plan which is essential given the nature of capacity building;

- tangible measures of project success are readily identified, monitored, followed up or evaluated;

- there tends to be an over emphasis on training and hardware supply and inadequate attention to more important capacity variables such as policy, strategy, management ability, systems and redesigned work processes;

- inadequate attention is given to the active involvement of higher management of the institution concerned and to creating internal resources to sustainably manage the capacity building process;

10.Conclusion

As demonstrated in Section 8 the value of trade measurement transactions, the accuracy and consistency with which they are performed industry expenditure on this activity and the cost of (government) programs to maintain and enforce trade measurement systems provide the basic data for quantifying the costs and benefits of trade measurement. However this quantification requires data on the operation of the system that in most cases is not available and may become more difficult to obtain as trade measurement control is privatised.

However IT systems do provide the opportunity to obtain this information, which also has significant value in setting sectoral priorities for control of the system.

Regulatory metrology is more difficult to quantify because of its significant social benefits, however as demonstrated in section 8.4 the social rates of return can be quite high and provide some compensation for uncertainty.

Both lack of time and available data has limited the final result that were obtained from this brief five week study. A number of further studies that could be pursued include:

1) A more detailed study on in-service accuracy of trade measurement instruments in both developed and developing countries.
2) More detailed information on the value of goods measured in trade measurement transactions, particularly in emerging and developing economies.
3) A more detailed study on trade measurement in global trade in commodities. This would be of particular importance to developing countries and could also consider the draft survey issue.
4) A study on the benefits of the OIML MAA's for pattern approval certification and pre-packaged goods. A first step in such a study would be obtaining an estimate of the level of global trade in these products.
5) A study on the economic benefit of OIML Technical Committee work in developing International Recommendations.
6) A study of the economic value of regulatory measurements in developing countries. Road traffic control e.g. radar speed devices and breathalysers would seem to be an appropriate area of study.

From the response I have received from CIML members, the bibliography in the study is seen as a valuable tool for pursuing further studies. I will be placing copies of all of these studies in the BIML information Centre and I would hope that members would continue to identify further studies that could be added to this resource.

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Attachment 2

Review of the Literature

This review highlights issues in some of the key publications in the bibliography (numbering has been kept the same) which are relevant to the economic and social analysis of legal metrology. A major issue is the quantification of the economic and social benefits of (legal) metrology.

9. R.D. Huntoon, Concept of a National Measurement System, *Science,* 158, 67-71,October 1967

This paper notes that "The National Measurement System evolved in this country with little formal recognition as a system (but) is now being examined in this way" and details the magnitude and scope of the system viz.

1. Estimated 20 million measurements a day (in USA)
2. Those industries that account for two-thirds of the GNP ($400 million)invest annually about $14billion of operating expenditure and 1.3 million man years in measurement activity
    1) About $25 billion invested in measuring instruments and increasing at $4.5 billion per year

And notes that

"If we judge the value of a service by what the user is willing to pay for it, then the value of the National Measurement System to the nation is in excess of $15 billion a year."

The paper notes that the nationwide need for a complete and consistent system of physical measurement, properly co-ordinated with those of other nations requires;

1. The ability to make accurate, reliable, precise and compatible measurements in terms of a common language of units and methodology.
2. A systematic and readily accessible body of accurate, reliable, precise and consistent data on the properties of materials in different environments and for information, reference materials and conceptual knowledge that will make possible the effective use of such data.

10. S. Wayne Stiefel, Management Assistance for Weights and Measures Progress, Measuring Inaccuracy's Economic Distortion, presented at the 58th National Conference on Weights and Measures 1973

This paper addressed the issue of the economic impact of trade measurement compliance programs and in particular the monetary value of under or overcharging ("economic distortion") caused by measuring instrument inaccuracies. The method used had three components

4) Obtaining from Census data the value for each census division in each State of commodities sold at different points in the commerce chain.
5) Estimate of the fraction of these commodities being sold by class of measuring device or by packaging.
6) A measure of the performance of devices taken from weights and measures inspection reports.

It was assumed for simplification that measuring device errors followed a normal distribution and non compliance was calculated for deviation from the MPE. The data for (3) was still being collected. There was also a discussion over whether the economic distortion should be related to the extent to which an instrument was outside the MPE or the total inaccuracy of the instrument.

11. Raymond C. Sangster, Final Summary Report Study of the National Measurement System 1972-75, NBSIR 75-925, December 1976,1-35

This study was conducted by the NBS Institute for Basic Standards on the structure and operation of the US system.

The U.S. National Measurement System is defined as comprising all of the activities and mechanisms-intellectual, operational, technical and institutional –used by the country to produce the physical measurement data needed to create the objective, quantitative knowledge required by our society. This knowledge is used to describe, predict, communicate, control and react in many aspects of our personal and social lives, science and technology. The structure was seen as having five levels

6. The conceptual system that defines measurement quantities and units
7. Basic technical infrastructure that provides the tools and techniques to implement the conceptual system
8. Realized measurement capabilities, that allows the measurement of specific quantities to known accuracies
9. The institutional dissemination and enforcement network
10. End-use measurements, which all other levels of the system exist to support

This study was one of the first to attempt an economic analysis of the national measurement system. The report conducted for NBS summarises a macroeconomic study that was conducted of the cost of labour and equipment used for making measurements in each of 78 major industry group in the US. Labour costs were estimated from staffing schedules and job analysis sheets in the period 1967-1972 and expenditure on measuring equipment from the 1963 Input-Output model of the U.S. economy.

Measurement was found to cost and estimated 6% of GNP of which 85% was for labour. The study emphasised that measurement is part of the knowledge or information sector and stressed the importance of examining the relation of measurement information to the information sector as a whole. It is that a weakness of the study is that it was conducted from the perspective of the physical scientist and the specific measurement function he is concerned with. An alternative approach would be to focus on the user of measurement, and further notes that the standpoint of consumers has been almost untouched by the study and that the perspective of consumers would make it easier to explore secondary impacts of costs and benefits of measurement for the society as a whole.

12. Barry W. Poulson, Economic Analysis of the National Measurement System, September 1977, A report from the 1972-75 Study of the National Measurement System by the NBS Institute for Basic Standards p1-37

This study was one of the first to attempt an economic analysis of the national measurement. The report conducted for NBS summarises a number of previous studies on economic aspects of the US national measurement system and particularly

the 1963 NBS study on measurement intensity for industry sectors which measured the cost of labour and equipment used for making measurements and the 1972-75 economic analysis of the system conducted by the NBS Institute of Basic Standards. The report is divided into four parts viz.

1. Economic characteristics of measurement
2. Measurement in the US economy
3. Economic analysis of costs and benefits of measurement in the Private Sector
4. Economic analysis of costs and benefits of measurement in the Public Sector

The National measurement System is seen as having five interacting levels viz.

1. 1.Conceptual system of measurement phenomena, quantities and units
2. Basic Technical infrastructure
3. Realized measurement capability
4. Dissemination and enforcement network
5. Organizational input-output transactions in the market place

The report emphasises that measurement is a component of the information sector and identifies a number of economic characteristics of measurement viz

1. Measurement is a form of information that is used as an input in production and in transactions by both buyers and sellers
2. Improved measurements may not yield benefits in an economic sense, in particular it will depend on the extent to which it satisfies wants or maximises profits.
3. Costs and benefits of measurement to society may be significantly different from the sum of the costs and benefits to individuals due to complex secondary effects arising from political and humanitarian goals of society

The report notes the public (i.e. collective) goods characteristic of measurement and identifies a number of areas where reliance on the private sector could result in a misallocation of resources. This public goods characteristic also creates difficulties in conducting cost-benefit analysis for measurement resource allocation and the report suggests that cost effectiveness analysis i.e. comparing the cost of alternate ways of achieving a specific pre determined goal, may be a more useful analysis.

The report considers a number of micro studies of the costs and benefits of NBS programs but notes (page 35) that these studies are from the perspective of the physical scientist and the specific measurement function he is concerned with. An alternative approach would be from the perspective of the user and in particular the consumer and notes that measurement problems for the consumer probably encompass most types of physical measurement. The report notes (page 14)

"that an analysis of the total measurement system, especially in a quantitative benefit-cost mode, is bound to failure: Since a modern society could not function without a systematic way of acquiring measurement data, the value of having a measurement system is incalculable."

14. J.S.Hunter, The National System of Scientific Measurement, *Science,*210, 869-873, November 1980

This study notes:

"The NBS estimates that the taking of measurements of all kinds costs 6 percent of the gross national product. It was estimated that in 1977 the federal government alone spent $690 million on the collection of data, and that approximately 43 percent of the data was generated by or for the environmental agencies. If the direct cost of making measurements is large, the indirect cost of making poor measurements must be huge." And concludes as follows;

"The responsibility for and control of the nation's measurement systems is poorly centralized. It is possible that this diffusion is healthy for the development of viable measurements. Further, it is probably impossible to coalesce the nation's diverse measurement requirements into any single pattern. But clearly the quantity of the scientific measurements now required by our measurement-intensive laws and regulations are piling up, while many of the desirable physical and statistical characteristics of good measurement methods and associated measurement systems are being given short shrift. The result is that the quality of many scientific measurements is suspect. The time appears ripe for a review of the adequacy of our present approach to scientific measurement."

17. Pasqual A. Don Vito, Estimates of the Cost of Measurement in the U.S. Economy, November 1984 Planning Report 21 NBS p 1-42

This report provides the first comprehensive estimate of the economic role of measurement. It estimates of the cost of measurement and the value added (defined as the value of goods and services sold less non-labour costs plus certain other items such as profits and indirect business taxes).The cost of labour is typically the largest component of value added.

Using value Department of Commerce, Bureau of Economic Analysis figures for value added by each of the 81 industry sectors of the US economy, estimates of value added by measurement were calculated using survey estimates of measurement labour intensity (the labour component of value added was used as a surrogate for total value added)

The average value added from measurement related activities for all sectors of the U.S. economy was then estimated to be 3.5 per cent of GNP. (See 49, 50 & 59 for comments on this analysis.)

For the twenty most measurement intensive sectors, that collectively contributed 15 per cent of GNP, their measurement related activities were 13.4 per cent of their contribution to GNP and 50 per cent of the total economy expenditure on measurement related activities.

The total cost of measurement to industry (capital plus labour expenditure) was $163 billion in 1984, approximately two per cent of sales.

Of the twenty most measurement intensive sectors in 1979 electricity gas and water utilities had more than twice the measurement cost of any other sector and also contributed the greatest added value. Other major contributors were chemical and

chemical products, petroleum refining and related products, telephone and telegraphic services, electric transmission and distribution and glass and glass products all of which have a significant trade metrology component.

22. Gregory Tassey, The functions of technology infrastructure in a competitive economy, Research Policy, 20, 1991, 345- 361

Tassey defines infratechnologies (22)

"Infratechnologies are a varied set of "technical tools" that include measurement and test methods, artefacts such as standard reference materials that allow these methods to be used efficiently, scientific and engineering data bases, process models and the technical basis for both physical and functional interfaces between components of systems technologies such as factory automation and communications"

and he notes that an industry's technology will comprise elements with a high proprietary character while others will offer little private return. These latter components comprise generic technology and infratechnology and they are the components where under-investment is likely to occur and for which government support is desirable.

It is noted that these non proprietary technologies have a high degree of public good and appropriability and they tend to diffuse in a highly disaggregated manner to industry. This creates difficulties in measuring the productivity impacts of these technologies.

Four components of the delivery system of government supplied infratechnologies are analysed viz;

1. Underlying research base that provides the basic scientific principles and knowledge from which specific applications are derived.
2. Product and process development, particularly those effecting product reliability, quality and cost
3. Market development by contributing to performance standards that assist takeup of the technology
4. Dissemination or diffusion by reducing transaction uncertainties.

Case studies on the impact of infratechnologies on industrial growth are provided and were found to be comparable with the social rates of return of industrial innovations by private firms and with returns from other government research.

28. Gregory Tassey, Standardisation in Technology-Based Markets, NIST, June 1999, 1-21

Views standards as striking a balance between the requirements of users, the technological possibilities and associated costs of producers, and constraints imposed by government for the benefit of society in general. The function of standards are to provide;

1. Quality/reliability
2. Evaluated information
3. Compatibility/interoperability
4. Variety reduction to attain economies of scale.

And notes that;

1. The unavailability of standards at different points in a technologies life cycle can result in large economic inefficiency.
2. Multiple standards may exist for prolonged periods, limiting economies of scale
3. Standardisation over a technology life cycle has a dynamic character
4. The process of standardisation frequently must be managed as a system.

29. Gregory Tassey, Lessons learned about the methodology of economic Impact studies: the NIST experience, *Evaluation and Program Planning* 22 (1999) 113-119

This paper considers how the basic tools of economic impact assessment need to be modified when applied to infratechnologies. The knowledge gained is used for project management, strategic planning and policy analysis. The quantitative metrics used are Net Present Value, Benefit-Cost Ratio, Social Rate of Return & Adjusted Internal Rate of Return all of which need to be assessed for their applicability to specific projects. Examples are provided of technical outputs and qualitative and quantitative economic outcomes of a range of projects.

Outcomes for measurement standards projects are primarily in improvement in industry wide infrastructure and in stimulating new product or service commercialisation. However both the research projects and their benefits may be spread over a long period of time greatly affecting the benefit-cost ratios and net internal rates of return and this is compounded by the difficulties in identifying benefits and outcomes for these types of projects.

30. Gregory Tassey, R&D Trends in the U.S. Economy: Strategies and Policy Implications, April 1999,NIST Planning Report 99-2, 1-52

Thos paper provides a detailed analysis of technology policy needed to support long term economic growth. Strategy must be based on a much more pervasive technology-intensive sector which will require greater investment in generic technology and technology infrastructures.

Market failure occurs in a range of technology based industries including

1. emerging technologies that entail high-risk and long gestation periods but create new markets with significant added value
2. systems technologies that provide infrastructure to many product and service technologies and thereby drive growth in major economic sectors.
3. enabling or multi-use technologies which benefit multiple segments of an industry or group of industries, but encounter economies of scope and diffusion investment barriers.
4. infratechnologies which leverage investment in both development and use of proprietary technologies, but which require distinct competencies to develop and common ownership (such as standards) to effectively use.

One significant negative impact of these market failures arises from the fact that many of to-day's most important technologies have complex system structures, which require equally complex interfaces to enable market entry by small and medium

suppliers and system optimisation by users. Without the needed infrastructure, inefficient industry structures evolve.

33. Michael P. Gallaher, Stephen A. Johnston and Brendan Kirby Changing Measurement and Standards Needs in a Deregulated Electric Utility Industry, May 2000, NIST Planning Report 00-2, p 1-165

The objectives of this study were to identify the additional measurement and standards needed to capture the full benefits of wholesale and retail deregulation of the Electric Utility Industry and the economic impacts of not meeting those needs. The needs will arise from

1. Increased growth in the number and complexity of transactions
2. Increased number of market players and their information needs
3. A shift from reliance on voluntary agreements among formerly integrated utilities to explicit contracts among many providers of different services.

It is estimated that the economic impact of prospective opportunities that may be lost by not meeting these needs ranges from $US3.1 to $US 6.5 billion

Key areas in which the value of measurements and standards are increasing in the electric power industry are

1. Competitive metering of energy generation and ancillary services at the supplier and customer level
2. Monitoring bulk power flows and transactions
3. Monitoring transmission and distribution system conditions
4. Communicating and controlling generation, transmission and distribution systems.
5. Monitoring power quality along these systems and in customer facilities
6. Assessing system conditions and contract compliance through the use of advanced diagnostic tools.

The electric power industry represents approx, 2.5% of the US Gross Domestic Product and 1998 had retail sales of $217 billion.The components in the retail cost of supplying electricity are

- generation 75.6%
- transmission 2.5%
- distribution 5.6%
- market transactions 16.3%.

Real time pricing in a competitive market has potential for significant savings by reducing peak demand. However there are potential costs associated with deregulation viz

1. Increased transaction costs to support market transactions.
   -Transaction costs include contracting, metering, communication and processing of information, billing and dispute resolution These costs account for 11% of the cost of supplying electricity.
2. Increased bulk transmission requirements
   -caused by competitive markets increasing the average distance electricity is transported.

3. Increased monitoring costs to support system reliability and Power quality
4. Potential decrease in overall system reliability and power quality.
   -these changes could significantly increase costs to industry

Generally there is potentially a trade off between cost of power supply and its reliability and power quality. A role of measurement may be to provide the infrastructure to allow the supply of electricity with different levels of reliability or power quality to different groups of customers.

34. TASC Inc.,The Economic Impact of NIST Cholesterol Standards Program,NIST Planning Report 00-4,September 2000, 1-51

This study identifies four levels of economic impact in the supply chain that delivers medical services to the consumer viz,

1. Lower production costs for manufacturers of cholesterol measuring systems
2. Reduced transaction costs between manufacturers and clinical laboratories
3. Lower costs for clinical laboratories in maintaining quality control systems
4. Higher quality medical services for consumers

Surveys of manufacturers and clinical laboratories were undertaken to provide conservative estimates of the economic impact on the first three levels viz,

Performance Metric	Lower Bound Est.
Net Present Value 1999 $	$3,573,812
Social Rate of Return	154%
Benefit-cost-ratio 1999 $	4.47

39. R.G. Knapp, Case study of the proportion of Gross National Product (GNP) subject to legal metrology measurement standards, (1997) 2 page note.

Surveys conducted by Measurement Canada in the 1980's indicated that the total value of goods traded over all classes of trade weighing and measuring instruments totalled $C203 billion in 1989/90 or 32% of GNP. This did not include pre packaged goods or utility metering

40. R.G. Knapp, Case study of the efficiency and effectiveness of Weights and Measures verification/reverification, (1997) 2 page note.

Combining the information from the above study with information gathered on instrument compliance rates Measurement Canada were able to estimate for each class of instrument annual "dollars at risk" i.e. the sum of short and over-measure.

When these figures were related to the cost of verification and reverification activity it was found that for each dollar spent on regular periodic inspection 11.4 dollars of non-complying measurement was corrected. By targeting inspection activity towards those instruments with higher dollars at risk this "benefit/cost" ratio increased to 28.7.It was also found that on average total trade measurement inequity was comprised of 65% short measure and 35% over measure.

On average each inspector on an annual basis discovered and corrected about $2 million of total measurement inequity.

41. KPMG, Recommended Structure for a Marketplace Intervention Model for Trade Measurement, Report prepared for Measurement Canada, February 1998,1- 38

This report developed a model for ranking trade measurement sectors on basis of need for regulatory intervention and determining the most appropriate level of intervention by Measurement Canada for each sector. Ranking of the sectors was based upon assessment of the following factors

1. Reliance on trade measurement as the basis for commercial transactions
2. Economic significance of the sector
3. Potential economic risk to the vulnerable party in trade transactions
4. Dependency of the vulnerable party on the counter party to ensure accurate measurement
5. Compliance Rates
6. Measurement consistency and device conformance to established standards.

Stakeholder consultations were undertaken to confirm the appropriate level of intervention.

43. Measurement Canada's Assessment and Intervention Strategy for Canada's Marketplace, September 1999, p 1-61

This paper describes Measurement Canada's Marketplace Intervention Model that was developed to focus limited resources on those areas where the return to the taxpayer was greatest and to ensure accuracy and equity in the market place.

The scope of transaction covered by the model includes traditional measurement of quantity of commodities (weights & measures), the sale of electricity and gas and quality measurements and grading that determine the unit price but excluding measurements used for collecting excise or taxes.

The Model analyses and scores each of Canada's trade sectors. with respect to their economic significance, dependent party vulnerability and metrological practices. These scores are then used for negotiating with stakeholders a level of intervention in the sector, that is aligned to internationally accepted standards and includes national compliance sampling. In some cases sectors where combined e.g. when no additional measurements took place downstream as with pre packed goods in the food manufacturing and wholesaling sectors. The model scores each sector using six indicators viz.

1. Reliance on trade measurement
2. economic significance of the sector
3. economic risk to the vulnerable party
4. dependence of the vulnerable party to receive accurate measurement
5. compliance of trade measurement devices in the sector
6. consistency and conformance of those devices with established standards.

Six cumulative levels of intervention were defined in the Model viz

a. Traceability of measurement standards
b. Establish rules for accurate measurement of products
c. Establish mechanisms to enforce 2
d. Establish mechanisms for dispute resolution
e. Establish metrology rules for measurement devices
f. Establish mechanisms for device performance disputes.

50. Institute for National Measurement Standards: Economic Impact Study, Conducted by KPMG Consulting September 2001,1-74

This study was designed to provide an objective measure of the current and expected impact of INMS activities on the Canadian economy. The current economic impacts were calculated through "bottom up"case studies. The market maintenance impact (pure public good) dimension of INMS primary standards is measured by using the cost of annual registration for ISO 9000 & 14000 as a measure of organizations willingness to pay for maintenance of primary standards which provides a known uncertainty of measurement and by extension traceability to national standards (ISO proxy Model) Three core economic benefits of INMS functions are identified

1. Market Maintenance (Public Good),which take the form of reduced transaction costs. Estimated currently, at a lower bound, as $18.9 million annually
2. Quality of Life (Public Good) associated with social welfare benefits (not quantified)
3. Direct Benefits to Industry/Consumers (Private Goods). Estimated currently at $140.8 million annually with future additional expected benefits over the next five years for new thrust areas of $340.6 million, mainly arising from deregulation of the Ontario electricity market.

52. Department of Trade and Industry, White Paper, Measuring up to Competition, 1989

This UK Government White Paper made explicit the rationale for government funding of the national measurement system viz

"Since a measurement standard will typically be used by a very wide range of individuals and firms, the investment necessary to develop and maintain it will yield benefits which accrue to all. The private benefits to be obtained from committing funds to work on measurement standards are therefore overshadowed by the broader benefits they confer on the user community as a whole-a strong disincentive to investment by individual private firms. If left to itself, therefore, the private sector can be expected to devote fewer resources to the development of measurement standards than is desirable from the point of view of the economy as a whole."

The benefits to the economy were

1. Facilitating free and open trade
2. Encouraging innovation and the spread of new technology
3. Promoting quality

53. J.S.Metcalfe and R.D.Smellie, Maintenance Activities and the National Measurement System, October1991, 1-32

This paper has a interesting discussion on metrology standards and public goods viz, Page 22 Metrology Standards and Public Goods

33. The public good rationale requires closer scrutiny. A public good is defined in terms of two important economic characteristics:

(a**) Non-rivalry in consumption**. A public good is used but not consumed in the sense that an unlimited number of users can have equal access to it without the stock of that 'good' being depleted. Apart from marginal dissemination costs it costs no more to supply many customers as it does to supply a single customer. It is therefore argued that the good should be available to all who value it. Off air broadcasting is a prime example of a non-rivalrous public good: no additional broadcasting costs are involved when more individuals tune to the appropriate signal. Knowledge in general has this public good property, one individual's knowledge of relativity theory is not at the expense of anybody else's knowledge.

(b) **Non excludability** Access to the public good cannot be limited or monitored to identify who users are. From this it follows that rational users have no incentive to truthfully disclose the values they individually place on the public good. If it is provided they can make use of it. The inability to control access to the good and the difficulties inherent in valuing its benefits makes it impossible to charge for public goods, allowing users to free-ride. From this it follows that private provision through a market cannot be achieved, the demand side of the market is said to fail.

34. These two characteristics define a pure public good. However, whilst the non-rivalry condition is always present that of non-excludability need not be. Excludability varies along a spectrum with degrees of impurity whereby there is potential for partial or complete excludability. The degree of excludability is vital to the case for public provision by non-market methods.

35. It is the pure, non-excludable public good argument which generates strong conclusions about public provision. Such a good or service should be made available to all individuals willing to pay the costs of dissemination and its production should be financed from general taxation. In principle it should only be provided if the total value all users place on its use exceeds the costs of provision, although in practice there is no way of knowing what user valuations are. Lacking a market to assess demand and willingness to pay it is impossible to assess an appropriate supply of the public good. Underprovision or overprovision are likely to be the norm and there is no simple basis for making investment and production decisions. While there are many different kinds of public good those which flow from the generation of knowledge and information are particularly relevant to the current discussion.

36. The Dobbie report (1989)* accepted the pure public good argument in its appraisal of the MNS concluding,

"Except in a minority of instances it is neither possible nor desirable that a price should be charged for the use of measurement standards". (para. 3.8)

We do not agree. The argument that it is impossible to charge is valid only for pure public goods. More generally it does not follow that if a method of charging could be devised it would be undesirable to use it. At root the argument for public provision is practical, not substantive, and hinges on the degree of excludability which can be imposed.

37. When excludability is enforceable quite different principles can operate. For example, whilst off air broadcasting is a pure public good, satellite and cable TV turn it into an impure one with a strong excludability regime. Off air broadcasting has to be financed from licence revenue and advertising, cable and satellite TV charge customers directly in proportion to the services they consume. In general the excludability problem can be dealt with in one of two ways:

(a) Embodying the public good in a private good with strong proprietary properties. The book, the record or tape are each examples of how public goods in the form of knowledge and entertainment services are made excludable. The sale of hard copies of British Standards (specification standards produced by the British Standards Institute) provides a more direct analogy from the world of engineering.

(b) Building the provision of the public good around a club arrangement. Cable and satellite TV achieve this as does any concert theatre. A barrier to access is created and with it the basis for charging for the provision of the service.

38. These points are substantiated in Annex 5 of the Dobbie Report (part 2) entitled 'Economic Rationale for Government Funding of Work on Measurement Standards'.

After a thorough review of the non-rivalry and excludability issues the annex notes the situations where charging may be feasible. In particular, where the user community are dependent on researchers who have built a sophisticated facility for the provision of calibration and other services,... "the organization which developed the standard will be able to levy a charge on the use of the standard... Such a charge will finance the development and maintenance (our emphasis) of the standard" - to which the rider is added that limits to charges are set by the cost of users developing the expertise and knowledge themselves (p.7). With this view we agree entirely.

The fundamental point is this. Access to standards knowledge is not open, as a general rule it is gained through buying calibration services provided by the NAMAS accredited laboratories and ultimately traceable back to national standards institutes.

These institutes have a strong comparative advantage in the support and development of standards. Measurement services provide access to their expertise and identify the customers: a basis for charging therefore exists.

Raising revenue from calibration services is not the only option, it may be noted. In particular, R&D club arrangements are a further way of identifying users who benefit from work in the NMS. NEL, for example, has a number of clubs with instrument makers to disseminate generic information on principles of measurement. These clubs are 50% funded by DTI and cover 14% of total programme costs.

1. Department of Trade and Industry, 1987, Review of DTI Work on Measurement Standards., Part I.

55. Jeremy Klein, Edward Stacey, Christopher Coggill, Mick McLean and Mary Sagua, Measuring the Economic Benefits from R&D: results from the mass, length and flow programs of the UK national measurement system, *R & D Management,*26, 1, 5-15, 1996

This paper rejects the Don Vito analysis (13) as follows:

"DonVito (1984) aimed to measure the value added (contribution to GNP) from measurement-related activity in the US. He first surveyed US industry on a sector-by-sector basis and determined the cost of measurement-related activities as a proportion of sales. He then multiplied these proportions by the value added for each sector in order to calculate the 'value added by measurement'. He deduced that the cost of measurement was $163 billion in the US and that the average value added from measurement was 3.5% of GNP.

In our view, the use of the labour ratio as a measure of the proportion of GNP affected by measurement activity is questionable because it measures costs or activities rather than benefit. It is only necessary to observe that improvements in the efficiency of making measurements would lead to a reduction in cost of measurement activities, resulting in a reduction in the value added from measurement if calculated using Don Vito's method. In fact, improved measurement technologies should increase the value added by measurement. Furthermore, the high economic value for measurement which results from this method has tended to be used uncritically as a justification for correspondingly high levels of government support."

Recognising the difficulty in calculating the value of the national measurement system a more focussed investigation of the marginal effects of reduced expenditure on particular parts of the national measurement system is adopted. This approach was driven by the political imperative of convincing policy makers.

The study limited its approach to direct impacts, excluding any indirect benefits. The main value creation mechanisms investigated were;

1. Traceability to primary standards
2. Generating new measurement technologies which are turned into products & services
3. Using leading edge metrology to support advanced products.
4. Providing an expert service to industry to diagnose and solve measurement related problems
5. Providing leadership in frontier technologies through workshops, training courses and collaborative clubs

This analysis was then applied to the impact of not funding in 1993 a number of measurement infrastructure projects in mass, length and flow at a cost saving of 5 million pounds. On the basis of industry surveys it was found that the industry sectors affected had an annual output of 212 million pounds and a trading profit of 46 million pounds and the effects of the cuts would be to reduce growth in these sectors from 3.79% to 3.07% per annum. The split of economic value between the mechanisms was found to be

- Traceability 5%
- Commercialisable Products 2%
- Leading-edge calibrations 8%
- Consultancy 54%
- Leadership 30%

56. Jeremy Klein, Measuring the Economic Benefit from R&D: The Case of the National Measurement System, Science in Parliament, 53, 2, 1996, 25-27.

This paper criticised the Don Vito analysis in the following terms

"We were hampered initially by some unfortunate assumptions in the metrology community: A questionable American study from the mid-80s had attempted to measure the value of measurement standards by looking at the costs to industry of making measurements. Though the fallacy of estimating output value from input costs should be obvious, the conclusion that the "value added by measurement" in the US economy was 3.5 per cent. of GDP, some $163bn, had become accepted inter alia as a justification for high levels of government support. Furthermore, the 1989 UK White Paper had nurtured the belief that the NMS produces benefits which, although substantial, are neither tangible nor quantifiable."

57. G M Peter Swann, The Economics of Measurement, Report for the UK National Measurement System Review, June 1999, 1-62

The aim of this discussion paper was to "improve understanding of the Economic role of the NMS, the fundamental rationale for public funding, and contribute to the methodologies for identifying and valuing the economic and social benefits that it generates."

His analysis of the economics of measurement provides a number of useful ideas including

i) That measurements are located both inside organizations and as part of an exchange between organizations
ii) That the economics of measurements that are done to meet regulatory requirements and to facilitate trade have similarities with the economics of standards Whereas the economics of measurements that are done to increase efficiency in production have similarities with the economics of investment.
iii) The pool of feasible measurements determines the size of the pool of measurable product characteristics.

He provides a detailed discussion of the rationale for public funding which he identifies three reasons

i) market failure
ii) regulating private monopolies
iii) new industry development

Three generic causes of market failure are identified

i) Externalities

For which a detailed discussion is provided on their importance and why they arise. The discussion highlights that focussing on the "bottom line "value of measurements will have difficulty in assessing spill-over benefits and provide an incomplete measure of the economic benefits. This will result in private sector projects appearing to having a higher measured benefit/cost ratio than public sector projects.

Pure public goods are discussed and the ability to internalise spill-overs by charging the beneficiaries.(see also ref 52). However this is difficult where benefits are spread widely.

Externalities highlight the difficulty in identifying the customer for measurement

ii) where economic activities are subject to **increasing returns**

iii) Asymmetric information

Those who control measurement technologies will not have an incentive to create measurement technologies that demonstrate failings.(This is dealt with in detail in ref 130). A discussion is provided of four generic approaches to evaluating the benefits of measurements, viz

1. **Direct Measurement**, by polling beneficiaries
2. **Engineering Economics,** where the economic model is derived from the engineering fundamentals of the measurement
3. **Econometric Studies,** which makes indirect inference of the effect of measurement from correlation with macro-economic data.
4. **Case Studies,** which are particularly useful in identifying externalities nd beneficiaries.

58. Department of Trade and Industry National Measurement System Policy Unit, Review of the Rationale for Economic Benefit of the UK National Measurement System, November 1999, 1-159

This review by PA Consulting Group for DTI was limited to the peak technical and organisational metrology infrastructure organisations that are funded by the UK Government i.e. NPL, NEL, LGC & NWML and contractors under competitive tender arrangements. The determination of the benefits was limited to an industrial perspective and it was found that measurement as a whole delivers impact into the economy of 0.8% of GDP.

A key idea in the economic analysis is that of knowledge stock. Economic impact methodology, rather than cost benefit analysis, is used to quantify the contribution of a particular activity to the overall activity in an economy. Using an analysis that growth of total factor productivity (TFP) is a function of various sources of knowledge or technology they

- Allocate a proportion of GDP growth to TFP growth
- Allocate a proportion of TFP growth to knowledge growth
- Allocate a proportion of knowledge growth to metrology inputs

From the literature on endogenous growth and technology inputs

- Around 20-25% of growth in GDP comes from changes in technology or TFP growth
- Around 60% of domestically available knowledge comes from domestic sources
- From patent count which identified metrology related patents as 10% of all patents

59. Steve Brown, Ian Bradley, Fiona Williams & Geoff Williams, Improving the Mapping Measurement Impact Model, National Measurement Partnership Conference, 1999, 1-8

Using an improved version of the method developed by Klein and ors (46) the model delivers an economic benefit measure which estimates for each project funded by DTI

the value of the additional benefit, in terms of increased gross profit, that UK industry can expect to gain as a result of the project

The value creation mechanisms used are the same as in 46 with an additional mechanism

57. Representing UK interests on international bodies.

The three main data inputs to the model are:

1. Financial data about the industries affected
2. An assessment of the impact on industries of the projects
3. Strength of the interaction mechanism for each project

Using small scale equations for impact profiles across the sectors and applying appropriate discounting techniques a present value figure is derived as a measure of the overall economic effect over a particular time frame.

60. Department of Trade and Industry, Quinquennial Review of the National Weights and Measures Laboratory at Teddington, September 2000,p 1-32

This review focussed on organisational issues, particularly with respect to the changing role of national Legal metrology authorities in the wider European market, and there was little economic analysis of the contribution of NWML to the UK economy.

There was recognition of the need to maintain a UK Centre of Excellence in Metrology, to maintain a good regulatory system for the benefit of consumers and UK industry and to continue the policy, legal and regulatory activities to sustain open and competitive markets.

The need to continuously measure outcomes to ensure optimum resource allocation was recognised

63. Steven Brown, Ian Bradley, Paula Knee, Fiona Williams & Geoffrey Williams, Measuring the Economic Benefits from R&D: Improvements in the MMI Model of the United Kingdom National Measurement System, June 2002, (Forthcoming in *Research Policy*)

Following Tassey (21,22) the paper considers metrology as an underpinning or infratechnology supporting the development and use of new techniques and products. They are likely to have similar benefits to industrial standards (129) through reduction of transaction costs, avoidance of replication of effort and encouragement of international trade.

The Mapping Measurement Impact (MMI) Model assesses publicly funded research through a forward looking econometric approach as distinct from the more common retrospective case study assessments.

They define the UK National Measurement System as a set of publicly funded programs which aim:

"To maintain and develop, at the national level, an infrastructure that ensures measurement in the UK is valid, fit for purpose, consistent and internationally recognised. This infrastructure exists primarily to promote the UK's economic competiveness and support regulatory needs"

NOTE: this is a much narrower definition of the National Measurement System than that first put forward by Huntoon (9) and defined by Sangster (11) and the global measurement system proposed by Birkeland (86)

64. Shelley Charik, John Francis, Paula Knee and Ray Lambert, Setting Research Priorities for a National Measurement Programme: The Biggest Bang for the Tax-Payers Buck,2002 NCSL International Workshop and Symposium, p 1-12

DTI provides 50 million pounds to a wide range of UK metrology organisations through a customer -contractor relationship which is assessed on the efficiency of delivery of the funded program. This paper considers analytical tools for measuring the prospective effectiveness of programs in delivering quality of life benefits, including consideration of uncertainty budgets as a factor in determining value for money.

The paper describes a Mapping Measurement Impact (MMI) tool developed to measure for industrial metrology the increase in business profit or value adding resulting from metrology. The MMI provides a projected Economic Benefit Measure (EBM) representing the 10year cumulated additional growth as a measure of the metrology impact.

The MMI approach was applied primarily to metrology in high technology applications and it underemphasized the role of measurement in underpinning continuous improvement across industry (the pervasive effect of the system).

Due to modelling and bias problems with the MMI model other alternatives are being considered that are more transparent and less ambitious. One alternative is to consider sectoral measurement intensities as a proxy indicator for the influence of measurement.

In considering quality of life, monetary values are derived using an economic equivalents model (EEM) based on surveys of public willingness to pay and the value of a statistical life (VOSL) estimated by road traffic accident prevention analysis. A table of economic equivalents for aspects of QOL is provided.

Finally the paper provides information on Decision Conferencing (DC) procedures which integrates the analytical data and expert judgement to assess funding proposals.

67. Birch, J A, Legal Metrology in Support of Economic and Social Development Presented at the First APEC Conference on Standards and Conformance held in Manila. 1996, Published in Conference Proceedings.

This paper detailed some qualifications to the Don Vito analysis (13) viz.

"Any discussion on the role of metrology in economic development needs to consider the economic impact of measurement. The most commonly quoted figure is that measurement related activities add 3.5% to the gross national product of industrialised

nations. This figure was derived from labour and capital expenditure in the US economy in 1979[3].

However I have five qualifications about this economic analysis:

1. With the introduction of mutual recognition of measurement and testing there will be a significant reduction in expenditure on measurement related activities resulting in a reduced contribution to gross national product and a reduction in added value. However from the point of view of the metrologist the mutually recognised tests and measurements would have greater value than the multiple tests and measurements.

2. It is assumed that all measurements are fit for purpose. However a percentage of measurements are wrong or misleading. We need a complementary survey on the cost of bad measurement.

3. Only labour and capital inputs are considered. However the greater part of measured growth in industrialised countries arises from technical progress. The development of measurement systems and technologies makes a significant contribution to technical progress. Indeed measurement has been described as the hallmark of the remarkable advance in understanding the physical universe in modern times[4].

4. The economic analysis does not include the benefits from confidence in the measurement system which minimises disputation and transaction costs. Poulson[5] in his 1977 Economic Analysis of the National Measurement System said:

   "Economic analysis of the total measurement system, especially in a quantitative benefit-cost mode is bound to failure, since modern society could not function without a systematic way of acquiring measurement data, the value of having a measurement system is incalculable."

5. The analysis does not take account of the social benefits that arise from the application of metrology. A significant social benefit arises from legal measurements for the control of health and safety, environment and police traffic control. In addition the application of metrologv in community activities provides a significant social benefit, in this regard sport is particularly measurement intensive.

On balance, taking account of these issues should significantly increase the total benefits obtained from measurement. The clarification and quantification of these issues is important not just to give metrology its due but more importantly to underpin decisions by governments on investment in metrology."

This paper also highlighted the economic and social benefits of legal measuring devices-breathalysers and radar speed measurements-in reducing the road toll in Australia.

68. Birch, J A, The Scope of Legal Metrology and its role in Economic and Social Development. Presented at an ASEAN Workshop on Legal Metrology held in Surabaya, Indonesia, 1997, Published in Workshop Proceedings.

This paper estimated that the total annual value of trade measurement transactions in Australia was $A 300 million or about 60% of the GNP about 25% of this value was in the retail sector.

The paper also noted that the benefits to industry, commerce, government and consumers of an effective trade measurement system were manifold and included

1. Consumer Protection.
2. Providing a level playing field for commercial transactions.
3. Facilitating effective stock control.
4. Reducing disputation and transaction costs.
5. Providing control of Fraud.
6. Ensuring full national benefit is obtained for commodity exports.
7. Ensuring full collection of government taxes based on measurement.

69. Birch, J A, The Role of Metrology in Economic and Social Development. Presented at a seminar on the Role of Metrology in Economic and Social Development held in Braunschweig, Germany, 1998, Published in Conference Proceedings

"Significant economic and social benefits can be obtained from these legal measurements. Their application to public highways provides an example of their cost effectiveness. Development and maintenance of public highways is a major expenditure for governments in both developing and developed countries.

The use of vehicle load weighing devices to control overloaded vehicles can provide significant saving. As the damage to road structures increases as the fourth power of the load, detecting a 10% overload can reduce road damage by nearly 50%.

The social (and economic) benefits of legal metrology are most clearly demonstrated by their impact on road fatalities. Over the last twenty years road fatalities in Australia have decreased from 3700 to less than 2000 (Figure 2) per year despite an increasing population and increased car ownership. Whilst improved roads, driver education and compulsory seat belts have all made a significant contribution, legal measuring instruments viz. radar speed devices and breathalysers have also contributed to this decline (Figure 2). These measuring devices greatly increased the probability of apprehension and there was a high degree of community confidence in the accuracy of the measurements. One study conducted in the State of Victoria estimated the saving to the community over a three year period from a reduction in road fatalities of 380 was approximately $1.6 billion. The economic benefit to Australia in reduced injuries and fatalities over the last twenty years would be in excess of $5 billion per year to which legal metrology would have made a significant contribution. Legal metrology has been most effective in changing drivers' behaviour. The choice for governments is expensive civil engineering aimed at avoiding accidents or cost effective social engineering using legal metrology devices."

76. Birch, J A, The Role of Legal Metrology in Economic and Social Development in Papua New Guinea. Seminar at the Department of Trade and Industry, Port Moresby, PNG, 2September 2001, 1-13.

This paper noted the importance of an effective trade measurement system for the responsibilities of the government of Papua New Guinea. Viz;

"In this regard it is worth noting that:

- Mineral products contribute 70%of PNG export income and 17% of government revenue
- PNG has recently changed its taxes on alcohol and tobacco from an ad valorem tax to taxes based on weight and volume
- There is a proposal to develop the PNG natural gas deposits and export the gas to Australia by a high pressure gas pipeline

All of these sources of government revenue and national income rely on accurate and consistent measurement."

78. W Schulz and B.Wegner, Messrichtigkeit und Zuverlassigkeit von Strassenzapfsaulen fur dunnflussige Mineralole,PTB Mitteilungen, 104, 2/94.

In this study 3000petrol pumps were examined todetermine the effectiveness of verification and reverification.Only 1% were found outside the MPE but a mean relative deviation of 0.1% was found.

80. Measuring *Man –A Reader*, PTB June 2000, 1-78

This booklet provides excellent descriptions of the application of metrology to a wide range of everyday life situations, most of which are in the field of legal metrology.

81. Geoffrey Williams, The Assessment of the Economic Role of Measurements in a modern society, Summary of Final Report April 2002, 1—42

The study considers the mechanism and extent to which the market can develop and capture new measurement technologies and the role of market failure in providing one example of government involvement.

Other drivers are legal metrology and the need for harmonisation of measurements. In addition constraints on the application of measurement technologies can impede technological progress and international trade.

Direct benefits of measurement are seen in terms of profits to business, improvements in technologies, the growth of trade and social benefits arising from improved environment, safety and quality. However measurement techniques are seen as having little saleable benefit of their own accord and the greatest impact of measurement arises indirectly in the form of externalities and spill-overs. These can arise from making markets work better by reducing transaction costs, by increasing productivity and through innovation.

The paper then considers the role of measurement in underpinning technologies that drive growth. In this regard it is noted that whilst most R& D is carried out in specific sectors the value added is more widely distributed. This is particularly true of measurement R &D.

To quantify the impact of measurement R& D on growth a survey of EU patents in the period 1995-2000 was undertaken and those patents citing measurement activity

as a key input were identified. This was used to provide average estimates of measurement related patents in the total, and from this were derived benchmark estimates of the impact of measurement innovation, viz 0.77%GNP. This is a similar methodology to that used in ref 57.

82. Paul Baker,The economics of measurement in the natural gas industry, December 2001, 1-25.

This study examined measurement issues within the gas supply chain in the EU from the transport stage to delivery to the final consumer. The gas market in the EU is moving towards increasing market liberalisation which calls for "interoperability" and "simplification" of rules. Increasing gas-to-gas competition and this new market environment is creating additional demand for measurement services.

The study drew on interviews with measurement experts from the natural gas industry, manufacturers of gas measurement equipment and national metrology institutes. However due to an absence of available quantitative data on measurement activities in the gas sector it was not possible to make even selective estimates of the "economic" costs and benefits of measurement activities in the gas sector.

82. Patrick de Bas, The economics of measurement of emissions into the air, June 2002, 1-21.

This study considered the economic impact of measurements used in the control of air emissions in the cement industry. Production of cement in Europe has an estimated value of 10 billion euros and it is estimated that the total cost of measurement are at most one per cent of the total cost of production of cement and benefits at the trade level are very small. The principal benefit is improved relations with (local) government and reduced community health risk.

Due to the multiplicity of pollutants that are involved in air emissions the economic impact study focussed only on the main components viz NO(X), SO(2) and dust. The study describes the methodology developed by the WHO for quantifying the impact of air pollution on health, the most important cost being the the cost of delivering care. However this study does not attempt to relate the costs to the gained benefits to society from reduced emissions.

83. Christopher Spencer and Geoffrey Williams, The scope and dimensions of measurement activity in Europe, July 2002, 1-47

This study provides a description of the scope and dimensions of measurement and testing activity in the EU. Funding of NMI's Accreditation Services turnover, certification costs and expenditure on measurement and instrumentation are tabulated for each EU country and internal spending by industry on measurements, based on discussions with industrial users, is estimated at 1% of total industrial costs. Legal Metrology and social spending is not included. Total spending on Measurement in EU is found to be 0.98% of GDP.

Total benefits comprise Application Benefits which are estimated based on econometric estimates of measurement contribution to aggregate final demand (GDP) and Knowledge Spill-overs which are based on econometric estimates of

measurement knowledge contribution to economic growth. Externalities and benefits to society are not estimated. Total benefits are found to be 2.67% of GDP giving a benefit to cost ratio of 2.73

84. Paul Temple and Geoffrey Williams, Infra-Technologies and Economic Performance: Evidence from the United Kingdom Measurement Infrastructure, March 2002, 1-31

The study begins with Tassey's definition of "infratechnologies" (21, 22) and describes the souces of measurement infratechnologies in the UK, both from publicly funded metrology institutions and from industry and accreditation organizations.

The paper notes the importance of infratechnologies to legal metrology in regulating market failure such as the negative externalities of pollution using a methodology based on endogenous growth theory (see ref 57, 79, 144) they provide a benchmark estimate of the aggregate impact of measurement. A key component in this estimate is an average estimate of 11.2% of measurement related patents in the total of all UK patents in particular years.

88. Knut Birkeland, Legal Metrology at the Dawn of the 21st Century, 1999, 1-49.

This strategic study of legal metrology addresses many of the underlying issues of this review. The study defines the concept of a global measurement system in the following terms

"The global measurement system provides a coherent structure which ensures that measurements can be made on a consistent, appropriately accurate, transparent and internationally recognised basis throughout the world. It comprises all activities that provide measurement data as a basis for decisions in many aspects of life - politics, commerce, industry, science, engineering, international trade, human health and safety, environmental and resource protection"

91. J. Kovalevsky, What place for Metrology in France at the beginning of the 21st Century, Summary and Recommendations of a Review of the French Metrology System

This paper notes;

"Metrology, be it primary or legal, is in the heart of a severe international competition. At a time when European harmonisation of regulations is taking place, countries with a strong legal metrology will be the most able to defend their interests successfully."

94. KPMG, Potential Impact of the CIPM Mutual Recognition Arrangement, April 2002, 1-127

This study examines the potential economic impact of the CIPM Mutual Recognition Arrangement (MRA) in terms of

1. The gains in cost efficiency for National Metrology Institutions (NMIs) in establishing mutual recognition multilaterally through central co ordination rather than bilaterally.
2. Economic efficiency resulting from reductions in technical barriers to trade (TBT).

Based on information provided by a survey of NMIs it is estimated that there is a notional saving to participating NMIs of 75K Euros per annum in the cost of establishing and maintaining mutual recognition and the total notional saving to the community of NMIs is of the order of 85M Euros

The study notes that a measure of the extent to which TBT might be limiting or raising the costs of trade has yet to be estimated by the WTO, OECD,the World Bank or other parties. However based on the value of the trade between nations participating in the MRA a saving of $US4billion is conservatively estimated.

95. UNCTAD.,Chairpersons Summary Report, Expert Meeting on Diversification of Production and Exports in Commodity Dependent Countries, Including Single Commodity Exporters for Industrialization and Development, taking into account the Special Needs of LDCs, Geneva 26-28 June 2002

The Chairpersons summary report gave recognition to the importance of measurement infrastructure for developing countries in the following terms

25. An adequate measurement system (both in quantitative and qualitative terms) has been often overlooked although it is essential in accurate valuation of goods. It also reduces transaction costs and disputes, improves collection of government revenues controls fraud and improves export earnings. Experts supported the development of an international system and urged international organisations to contribute to its mainstreaming.

And also recognised the importance of national and/or regional testing laboratories to assist developing countries to access global markets.

24. Experts have stressed the lack of quality control infrastructures such as laboratories and inspection companies, which makes it difficult for countries to fulfil requirements of SPS and TBT Agreements. In this context, the establishment and/or upgrading of national bureaus of standards as well as regional testing laboratories was recommended. Rules of origin were also often difficult to understand and satisfy.

98. World Development Report 2002- Building Institutions for Markets (The World Bank/Oxford University Press 2002), 1-249

This report is interesting for it's lack of recognition of measurement as an institution that facilitates markets and reflects a common failing of policy to overlook measurement. There are a number of case studies in the report where whilst measurement is central to the issue discussed it is neither mentioned or recognised e.g. p18 rice marketing and standardisation, p107 regulation of overloaded trucks and p 154/155 long distance transmission of petroleum by pipeline and transmission of electricity.

107. J.C. Lange,High Capacity Belt Weighers for Iron Ore, OIML Seminar on Testing of Bulk Weighing Installations, April 1985 p 1-14

This paper describes the upgrading of the belt conveyor weighing system in the port of Narvik in northern Sweden to reduce the uncertainty of measurement from 0.5% to 0.2%.The cost of the extra equipment was 5 million FF and the increased annual return to the exporter due to the reduced uncertainty was 8.6 million FF. Zvi Griliches, R & D and Productivity: Measurement Issues and Econometric Results, Science, **237,** 1987, 31-35.

144. Zvi Griliches, R & D and Productivity: Measurement Issues and Econometric Results, Science, 237, 1987, 31-35.

This paper considers the contribution of R&D to productivity and economic growth. It considers the value of patent counts in such studies. Patent statistics have the advantage of relative abundance, ease of access and a reasonably objective legal definition. However the present value associated with patents differ greatly, with the majority of patents being of little or no real value, while at the same time a much smaller fraction of patents is associated with really large economic returns. This makes it difficult to use patent counts as an index of "output" of R&D except, perhaps at a very aggregated level.

147. Paul M. Romer, Endogenous Technological Change, *Journal of Political Economy and Technological Change,*98, S71-102, 1990.

The thrust of this paper is that growth is driven by technological change that arises from intentional investment decisions made by profit maximising agents i.e. endogenous technological change. The distinguishing feature of the technology as an input is that it is neither a conventional good nor a public good; it is a no-rival, partly excludable good.

151. Lewis Branscomb ed, *Empowering Technology*, (MIT Press 1993)

This study of technology policy by a former Director of NBS provides some valuable comments on underlying problems of metrology. He notes (page 76-77)

> "Infrastructure or generic technology faces serious constituency problems. While the work is often quite basic, even theoretical, it rarely touches the conceptual frontiers of science. Thus it is too practical and too useful to earn high prestige among academics. At the same time this work is too systematic and too oriented to intrinsic scientific goals to thrill an industry R&D manager. The subject covers the full spectrum of industrial know-how, so it is even difficult to find a disciplinary constituency to support it."

152. Kenneth J. Arrow et al., Is there a Role for Benefit-Cost Analysis in Environmental, Health and Safety Regulation?, Science, 272, 221-222

The paper proposes eight principles on the appropriate use of benefit-cost analysis

1. Is useful for comparing the favourable and unfavourable effects of policies.
2. Decision makers should not be precluded from considering the economic costs and benefits of different policies in the development of regulations. Agencies should be allowed to use economic analysis to help set regulatory priorities.
3. Benefit cost analysis should be required for all major regulatory decisions.
4. Agencies should not be bound by strict benefit cost tests. Factors such as equity within and across generations may be important.
5. Benefits and costs should be quantified wherever possible with uncertainties.
6. External review of regulatory analysis.
7. Economic assumptions used should include the social discount rate, the value of reducing risks of premature death and accidents and the value associated with other improvements in health.
8. Distributional consequences should be identified.

Attachment 3

Glossary of Economic Terms

References

Penguin Dictionary of Economics, 6th edition, 1998
Paul A Samuelson and Richard Nordhaus, Economics,16th edition,1998
Joseph E. Stiglitz, Economics of the Public Sector,3rd Edition, 2000

Adjusted Internal Rate of Return (AIRR). (Tassey (28))
The AIRR is a measure of the annual yield from a project over a given study period, taking into account the reinvestment of interim receipts at a specified rate.

When the reinvestment rate is made explicit, all investment costs are easily expressible as a time-equivalent initial outlay and all non-investment cash flows as a time-equivalent terminal amount.

This allows a straightforward comparison of the amount of money that comes out of a project (its terminal value) with the amount of money put into a project (its present value of investment costs).

Allocative Efficiency
A situation in which no one can be made better off without someone being made worse off. It requires optimal productive, allocative and distributional efficiency. Also known as Pareto Efficiency.

Benefit-Cost Ratio (BCR).(Tassey (28))
Calculated from the same estimates of the present value of benefits and costs as are used for Net Present Value, except that the two values are expressed as a ratio to provide a measure of relative efficiency across projects. As a BCR = I is the break even value, presumably any project with a greater value is a successful project.

Cost Benefit Analysis
Appraisal of a project to determine whether the benefits will exceed the costs. As these benefits and costs may extend over a period of time they need to be discounted at an appropriate rate (see net present value). For government projects, social costs and benefits may be important and there value should reflect the market failure.(see ref 148).

Cost Effectiveness Analysis
Analysis to determine the least cost method of implementing a particular project. Usually used where there are difficulties in comparing costs and benefits.

Deflation
In economic statistics the adjustment of index numbers or economic aggregates to eliminate the effects of price changes. See GDP deflator.

Diminishing Returns
A Law that states that the marginal product of factors declines when they are employed in increasing quantities i.e. that there is an optimum efficiency for the level of application of each factor of production; too little results in diseconomies of scale too much results in diminishing returns.

Endogenous Growth
An endogenous variable is one whose value is determined by other variables within a system. Endogenous growth theory attempts to explain the role of technology or knowledge in economic growth (see Romer ref 144).

Exogenous Variables
Are those variables determined by conditions outside the economy. Changes in the weather e.g. drought, are exogenous.(see Romer ref 144).

Externalities
Activities that effect others for better or worse, without those others paying or being compensated for the activity. Externalities arise when private cost or benefits do not equal social cost or benefits.

External Diseconomies
Situations in which production or consumption imposes uncompensated costs on other parties. Pollution is an external diseconomy (or negative externality).

External Economies
Situations in which production or consumption yields positive benefits to others, without those others paying. Education is an external economy (or positive externality).

Factors of Production
Productive inputs such as labour, land and capital; the resources needed to produce goods and services.

Greshams Law
A law attributed to Sir Thomas Gresham who stated in 1558 that "bad money drives out good" i.e. people will hoard the good money and try to pass off the bad money to someone else c.f. ref 131, 135.

Gross Domestic Product (GDP)
The value at current market prices of the total final output produced inside an economy during a given year. Note that all intermediate goods are excluded. GDP at factor cost is obtained by deleting indirect taxes and adding subsidies. This is the measure of GDP that is used for calculating growth rates.

GDP Deflator
An index of prices which can be applied to the value estimates of the gross domestic product over a time period in order to remove the effects of changes in the general level of prices.

Gross National Product (GNP)
Gross domestic product plus the income from investments abroad less income paid on foreign domestic investment.

Imperfect (or Asymmetric) Information
Imperfect information on the part of consumers can lead to systematic undervaluation of some services. Asymmetry of information occurs when information about a transaction is unequally shared between the parties to the transaction. (ref 130, 131)

Inappropriability
The inability to capture the full monetary value of inventions and innovation, i.e. the private return on investment is significantly less than the social return. This can lead to underfunding and support by government for these activities.

Incomplete Markets
Markets that fail to provide goods or services even though the costs would be less than what buyers are willing to pay.

Macroeconomics
Analysis of the economy as a whole with respect to output, income, prices, employment, fiscal and monetary policy, consumption, investment, the balance of payments and economic growth.

Microeconomics
Analysis of the individual elements in an economy. Deals with the behaviour of individual consumers or firms and focuses on the efficient allocation of resources between alternative uses.

Market Economy
An economy in which resource allocation is primarily determined by supply and demand in markets.

Market Failure
When a market economy fails to allocate resources efficiently.

Monopoly
A market structure in which a commodity is supplied by a single firm.

Natural Monopoly
An industry in which technical factors preclude the efficient existence of more than one producer. Examples would include public utilities i.e. water, electricity, gas where there is a requirement for a network of pipes or cables Thus a single firm can supply the industry output more efficiently than can multiple firms

Net Present Value (NPV).(Tassey (28))
This is an absolute measure of the value or expected value of an R&D project in constant dollar term's. It is calculated by discounting (or inflating) the cost and benefit time series to the reference year and subtracting the present value of costs from the present value of benefits to yield the net present value of the investment. Varying forms of this measure are widely used by industry, where it is often referred to as 'discounted cash flow'. Like most metrics, its use is affected by the selection of a discount rate which is used to adjust the time series of benefits and costs for risk, time preferences of money, and inflation. This selection is not straightforward because of different views with respect to how many of these three factors to include in determining the discount rate.

Normative and Positive Economics
Normative economics is concerned with judgements about "what ought to be" i.e. value judgements or goals of public policy, whereas Positive economics is concerned with propositions which can in principle be verified by observations of events in the real world, without reference to value judgements.

Opportunity Costs
The value of the next best use (or opportunity) for an economic good, or the value of the sacrificed alternative.

Private Goods
Are goods that can be divided up and provided separately to different individuals with no external benefits or costs to others. Private goods can be efficiently allocated by markets.

Productivity
The relationship between the output of goods and services and the inputs of resources (factors of production) used to produce them.

Public Goods
A commodity whose benefits are indivisibly spread among the entire community, whether or not particular individuals desire to consume the public good.

A public good is defined in terms of two important economic characteristics (Metcalfe and Smellie (52))
(a) Non-rivalry in consumption. A public good is used but not consumed in the sense that an unlimited number of users can have equal access to it without the stock of that 'good' being depleted. Apart from marginal dissemination costs it costs no more to supply many customers as it does to supply a single customer. It is therefore argued that the good should be available to all who value it. Off air broadcasting is a prime example of a non-rivalrous public good: no additional broadcasting costs are involved when more individuals tune to the appropriate signal. Knowledge in general has this public good property, one individual's knowledge of relativity theory is not at the expense of anybody else's knowledge.

(b) Non excludability.. Access to the public good cannot be limited or monitored to identify who users are. From this it follows that rational users have no incentive to truthfully disclose the values they individually place on the public good. If it is provided they can make use of it. The inability to control access to the good and the difficulties inherent in valuing its benefits makes it impossible to charge for public goods, allowing users to free-ride. From this it follows that private provision through a market cannot be achieved, the demand side of the market is said to fail.

These two characteristics define a pure public good. However, whilst the non-rivalry condition is always present that of non-excludability need not be. Excludability varies along a spectrum with degrees of impurity whereby there is potential for partial or complete excludability. The degree of excludability is vital to the case for public provision by non market methods.

It is the pure, non excludable public good argument which generates strong conclusions about public provision. Such a good or service should be made available to all individuals willing to pay the costs of dissemination and its production should be financed from general taxation. In principle it should only be provided if the total

value all users place on its use exceeds the costs of provision, although in practice there is no way of knowing what user valuations are.

Risk Assessment
A measure of the risks of a course of action, and the costs and benefits of reducing those risks. Risks differ from uncertainties in that some measure of probability can be attached to them.

Social Capital
Social Capital is an evolving concept as illustrated by the following three definitions (see also "trust" in Introduction).

> Social capital is the total stock of a society's productive assets, including those that allow the manufacture of the marketable outputs that create private sector profits, and those that create non marketed outputs such as defence and education (Penguin Dictionary of Economics 1991).
>
> The social capital of a society includes the institutions, the relationships, the attitudes and values that govern interactions among people and contribute to economic and social development. Social capital, however, is not simply the sum of institutions which underpin society, it is also the glue that holds them together. It includes the shared values and rules for social conduct expressed in personal relationships, trust, and a common sense of 'civic' responsibility, that makes society more than just a collection of individuals. (World Bank 1998).
>
> Social capital is built at the 'level' of families, communities, firms, and national and sub-national administrative units and other institutions. Typically, the idea of social capital is associated with relations in civil society. However, relationships of trust and networks also involve public organizations and institutions. Social capital is embedded in norms and institutions, which include public and legal entities. The focus of analysis may also extend to different groups within civil society such as gender, occupational, linguistic or ethnic groups. (OECD 2001).

Social Benefits
The total increase in the welfare of a society from an economic action.

Social Costs
The total cost to society of an economic activity.

Social Rate of Return (SRR). (Tassey (28))
Calculated as the discount rate that is needed to reduce the time series of net benefits under analysis to zero (i.e., the break even point). Economists often use this metric (which is called the 'internal rate of return' in the corporate finance literature) because, like a Benefit Cost Ratio, it provides an indicator of relative efficiency. One feature that distinguishes. this measure from alternatives, including other rate-of-return measures, is that its value depends solely on the internal characteristics of the project (i.e., selection of a discount rate is not required). When economists use the internal rate-of-return measure to estimate the result from investment in a technology by one firm, the measure is called the 'private' or 'innovator' rate of return, and when this measure is applied to the result from investment in the technology by an entire industry or industries, the term 'social' rate of return is used to denote the fact that an aggregate (as opposed to a single firm) rate of return is being calculated.

Total Factor Productivity (TFP)
An index of productivity that measures total output per unit of total input. The numerator of the index is total output (say GDP) while the denominator is a weighted average of inputs of capital labour and resources. The growth of TFP is often taken as an index of the rate of technological progress.

Transaction Costs
All the costs of enabling exchanges to take place. They include information and negotiation costs which are born by both buyer and seller. These costs are frictions in the economic sphere that limit the efficiency of the price system.

Uncertainty
In economics refers to the situation where the number of possible outcomes exceeds the number of actual outcomes and no probabilities can be attached to each possible outcome (see **Risk**).

Utility
The satisfaction or benefit derived from the consumption of goods or services. There is no way of measuring utility other than indirectly by what individuals are willing to pay. In the private market utility is determined by decisions of individuals. For public goods utility is determined collectively.
Marginal utility is the additional satisfaction gained from consuming a small increment of a commodity. *The Law of Diminishing Marginal Utility* states that as consumption increases marginal utility will tend to decline.

Value
Adam Smith in his *Wealth of Nations* posed the paradox of (economic) value, viz that water that is essential to life has little value, whilst diamonds which have little value in use command an exalted price. This parodox was resolved by noting that the relative abundance of water reduced its marginal utility, i.e. the satisfaction from additional consumption and hence reduces its market price, whereas the scarcity of diamonds limit additional consumption. Hence value is not simply a price but explains how prices come to be what they are.

Value Added
The difference between the value of goods produced and the costs of materials and supplies used in producing them. It measures the value that has been added to the materials and supplies by the processes of production. It consists of the wages, interest, depreciation, rent, and profit components added to the output by a firm or industry.

Welfare Economics
The study of the social desirability of alternative arrangements of economic activities and allocation of resources.