Economic impact of equivalence of measurement standards

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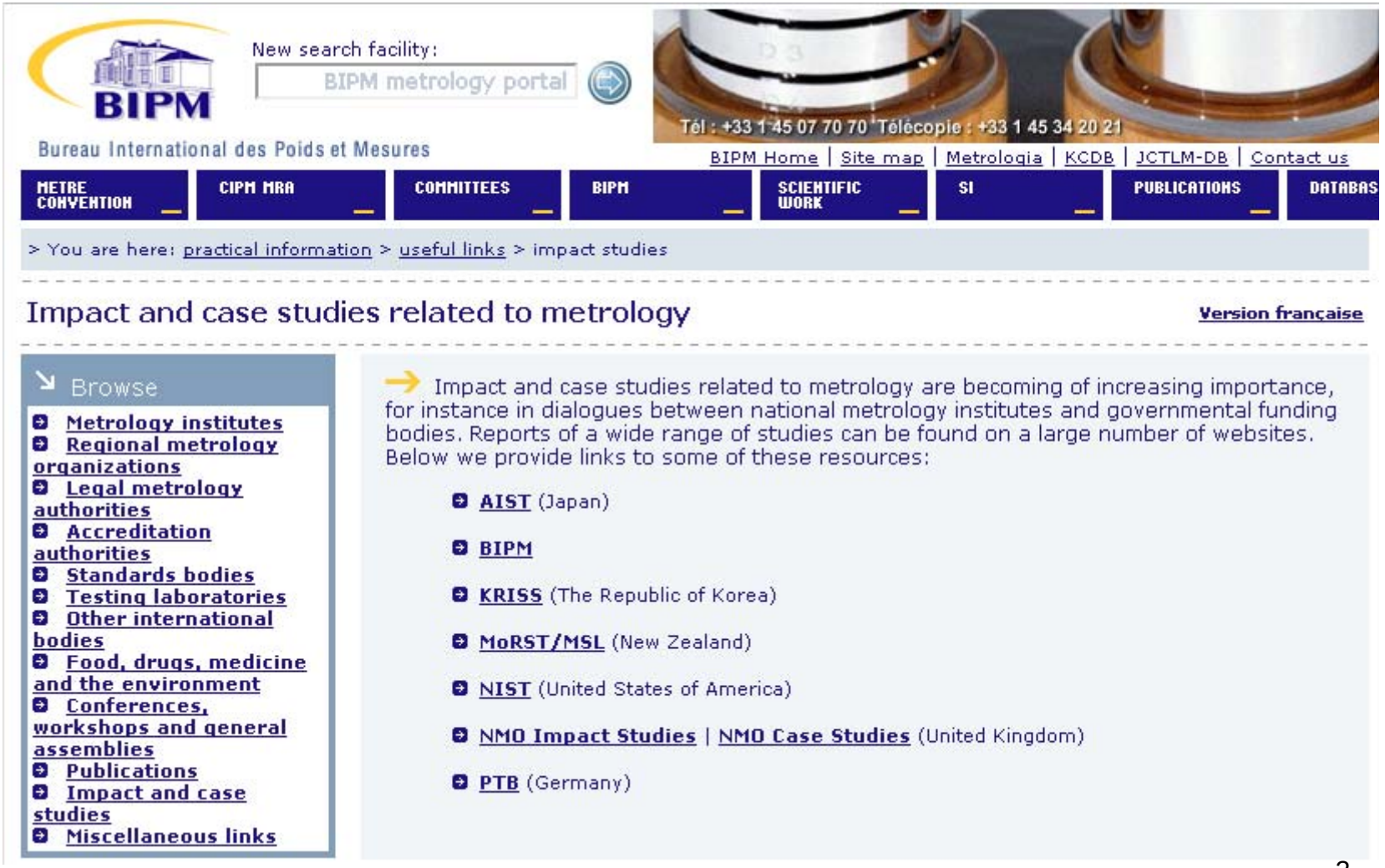
2. Modeling
3. Empirical investigation

Links to the past studies on the BIPM website



BIPM

Bureau International des Poids et Mesures

New search facility:

BIPM metrology portal

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BIPM Home | Site map | Metrologia | KCDB | JCTLM-DB | Contact us

METRE CONVENTION | CIPM MRA | COMMITTEES | BIPM | SCIENTIFIC WORK | SI | PUBLICATIONS | DATABAS

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Impact and case studies related to metrology

Version française

Browse

- Metrology institutes
- Regional metrology organizations
- Legal metrology authorities
- Accreditation authorities
- Standards bodies
- Testing laboratories
- Other international bodies
- Food, drugs, medicine and the environment
- Conferences, workshops and general assemblies
- Publications
- Impact and case studies
- Miscellaneous links

Impact and case studies related to metrology are becoming of increasing importance, for instance in dialogues between national metrology institutes and governmental funding bodies. Reports of a wide range of studies can be found on a large number of websites. Below we provide links to some of these resources:

- AIST (Japan)
- BIPM
- KRISS (The Republic of Korea)
- MoRST/MSL (New Zealand)
- NIST (United States of America)
- NMO Impact Studies | NMO Case Studies (United Kingdom)
- PTB (Germany)

Economical impact measure, How ?

Methodologies : Top-down

Employing macro data or “top-down” approaches are common methodologies. Considering externality of measurement technologies, estimation by macro analysis becomes larger proxy.

Ex.

Contribution of measurement to the economy;

3.5 % of the GNP

Source: *Estimates of the Cost of Measurement in Twenty Major Sectors of the U.S. Economy, NBS, 1984*

1 to 6 % of the economic indicators (GNP, market growth…) are mentioned as the contribution of measurement in the past reports and policy papers.

Economical impact measure, How ?

Methodologies : Bottom-up

Considering specific character of measurement activities, bottom up approach may be employed by using following indicators.

Numbers of

- **calibration certificates (both in NMI and calibration/testing laboratory)**
- **accreditations which request traceability of metrology (e.g. ISO 9001)**
- **patents related to metrology**
- **document standards related to metrology**

They will reflect “lower bound” estimation.

Some of them are also employed for “scale up factor” for macro analysis.

	EU
NMI Turnover	552,249
Legal Metrology	na
Accreditation Services Turnover	44,850
Certification Costs to Industry	1,940,852
Instrumentation Demand	46,836,000
Internal Spending in Industry[1]	33,915,276
Social Spending	na
Total	83,289,227
% GDP	0.98

Source: ***The assessment of the economic role of measurements and testing in modern society, G Williams, 2002***

Economical impact measure, How ?

Methodologies : Case study

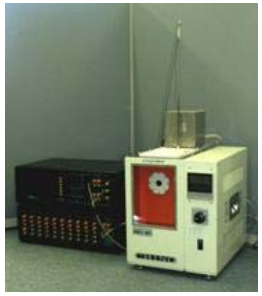
Innovations driven by new measurement technique are also interested subject. Estimation of the “input” to the specific project is more quantitative. Outcomes may be accumulated as the market growth, market share among the legacy products, etc. However, it is not easy as the market size or its share are time dependent subjects. In some reports, correlation of products, exponential approximation in time scale are employed.

Economical impact measure, How ?

Methodologies : Case study

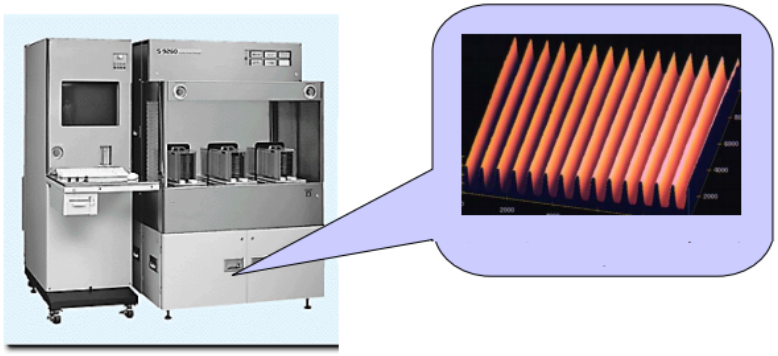
Thermometric standard contributions to tympanic thermometer is 20 % of its annual market of 4 billion Yen (After estimation).

Source: ***Case Studies on Outcomes Produced by Temperature Standard, NMIJ/AIST, 2004***



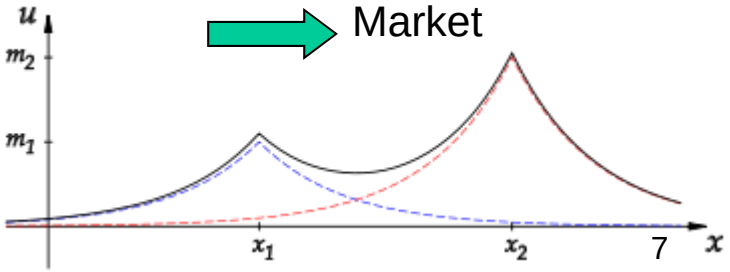
Nan scale line width standard would have improved semiconductor productivity of 122 ROI

Source: ***Economic Impact of Publicity Funded R&D: A methodological aspect -Measurement standard for nanotechnology -, NMIJ/AIST, 2005***



National Traceable Reference Materials Program will give $49M impact (Prediction).

Source: ***The Economic Impact of the Gas-Mixture NIST-Traceable Reference Material, NIST, 2002***



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New approach for estimating the economic impact

Modeling

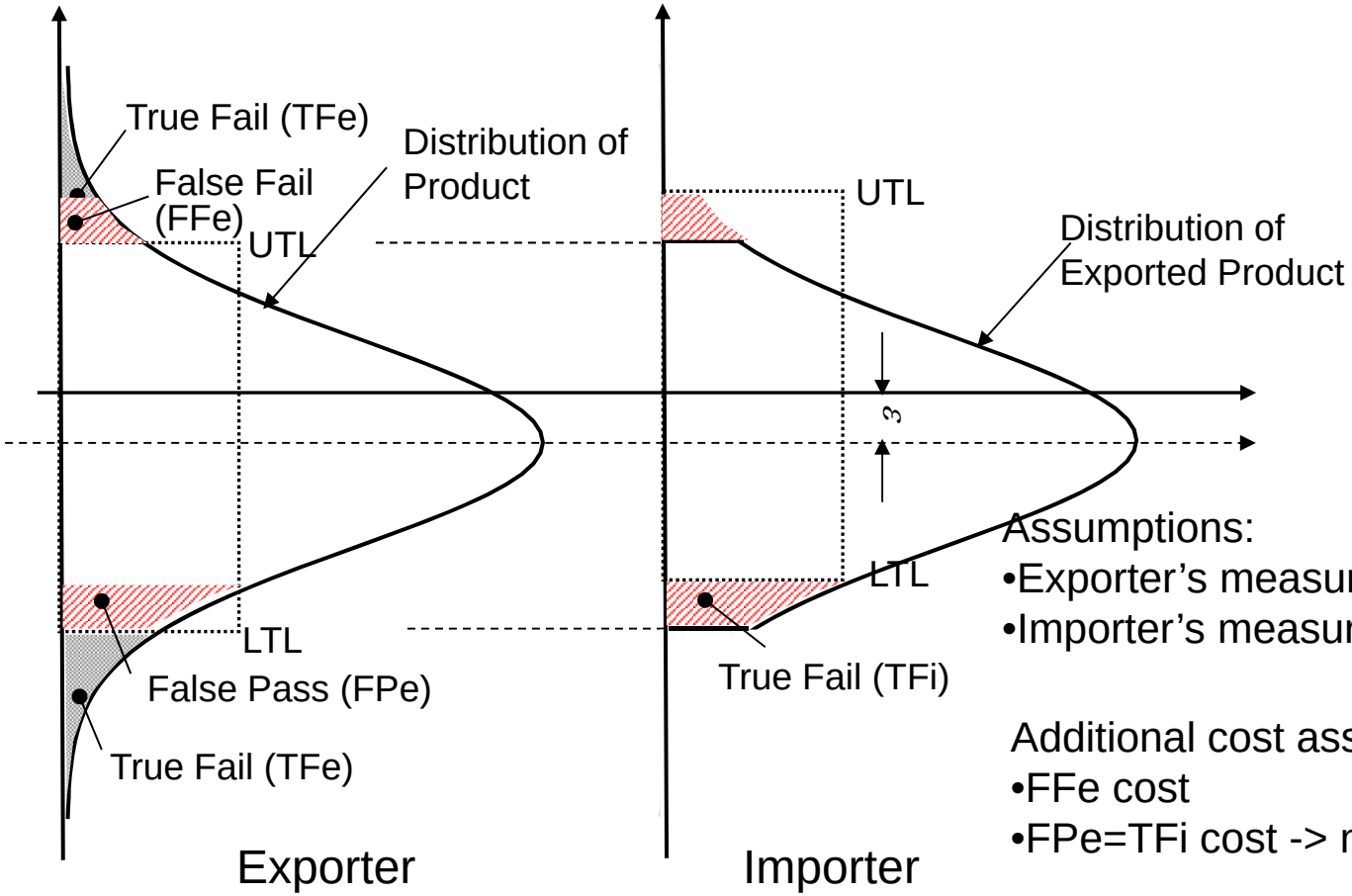
•To simplify, two concerned relationship (exporter and importer) is picked up

•If there is deviation between metrology standards of the exporter's and importer's, there must be additional cost associated.

•Associated cost may be categorized for False Fail and False Pass

•Economical impact can be assumed those additional cost

Effect by the Deviation between Importer and Exporter



Assumptions:

- Exporter's measurement has deviation ε
- Importer's measurement is correct

Additional cost associated:

- FFe cost
- FPe=TFi cost -> much heavier damage

Economical Impact: FFe+FPe

New approach for estimating the economic impact

For further investigations, what we need is…

- Distribution of the product associated with measurand (quality)
  - **Which is usually confidential parameter**
- Deviation of measurement standard ε, fact or assumption
  - **Which is obtained from KCDB**
- Associated costs may be calculable statistically.

KCDB (Key comparison database)

BIPM
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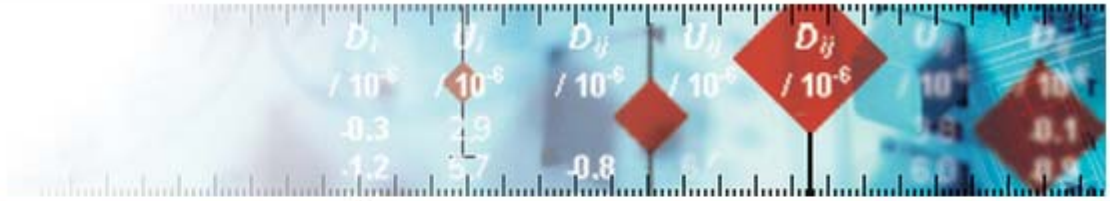


Home | Key and supplementary comparisons | Calibration and Measurement Capabilities - CMCs

Key and supplementary comparisons - Results

KCDB

↘ CCM.M-K1

- Information
- Pilot / Contact
- Participants
- Results
  - 1 kg
- Print out

↘ Related links

- KCDB Statistics
- KCDB FAQs
- CIPM MRA
- JCRB
- Find my NMI
- Metrologia

CCM.M-K1

↘ Results

Laboratory individual measurements | Equivalence statements | Degrees of equivalence | Graph(s) of equivalence

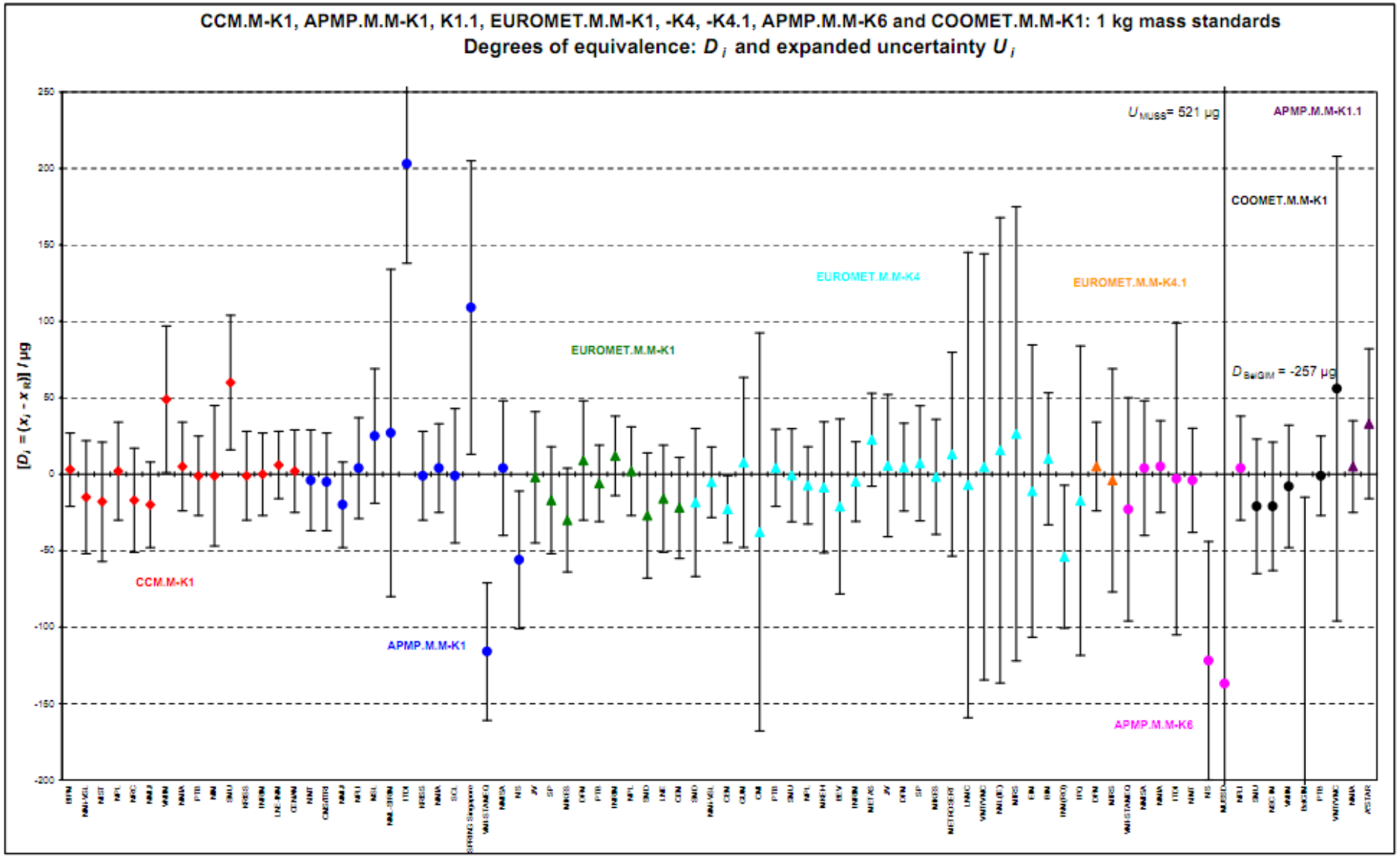
CCM.M-K1, APMP.M.M-K1, EUROMET.M.M-K1, EUROMET.M.M-K4, EUROMET.M.M-K4.1, APMP.M.M-K6, COOMET.M.M-K1, and APMP.M.M-K1.1

MEASURAND : Mass
NOMINAL VALUE : 1 kg

- **Key comparison CCM.M-K1**

$x_{(rep)i}$: reported result obtained as the difference between the measurement of the mass standards carried out by laboratory *i* (being evaluated as the average mass of two 1 kg artefacts) and the nominal value 1 kg
u_i : combined standard uncertainty of $x_{(rep)i}$

KCDB (Key comparison database)



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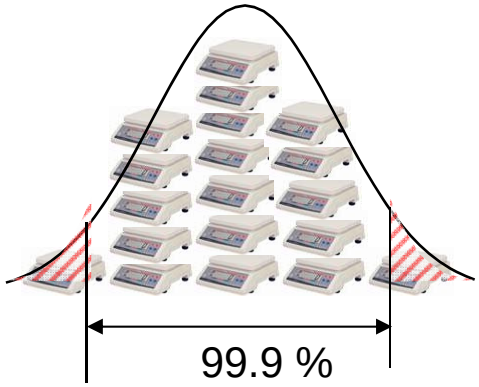
Case study of Japanese automated balance

Following assumptions and interviews were employed for case study in Japanese automated balance provider

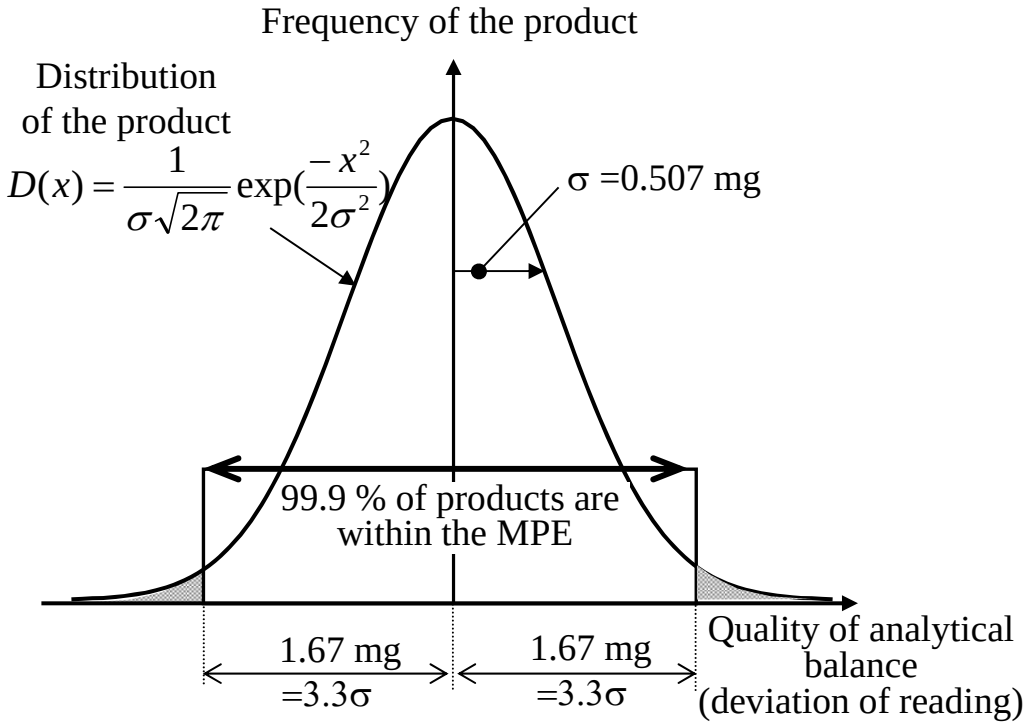
As they do
- All products are tested (not sample test).
- Test failed product is rejected.

Interviewed parameters to Japanese precision balance provider and their answer
- LTL, UTL (correspond to the specification of the balance, equivalent to OIML F1 class)
- Present rejection rate. This will derive product distribution (with assumption of normal distribution)

Automated balance production and inspection



99.9 % of products satisfy the regulation (OIML requirements: 1/3 of Class F1 tolerance = +/- 5 mg at 1 kg)



If Japanese metrology standard shifts ε, associated failures are expressed

- False Fail (FFe)

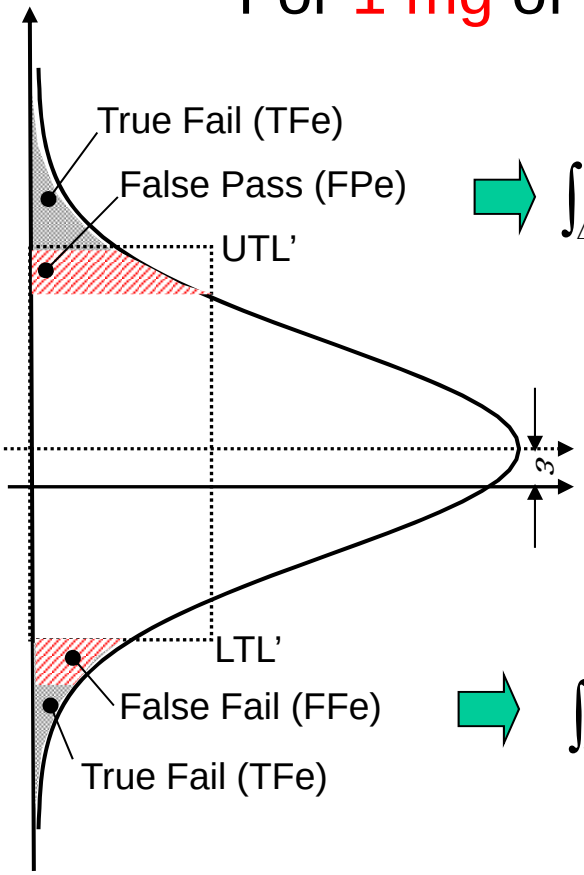
$$\int_{-\Delta}^{-\Delta+\varepsilon}\frac{1}{\sigma\sqrt{2\pi}}\exp(\frac{-x^2}{2\sigma^2})dx$$

- False True (FTe)

$$\int_{\Delta}^{\Delta+\varepsilon}\frac{1}{\sigma\sqrt{2\pi}}\exp(\frac{-x^2}{2\sigma^2})dx$$

Simulation of the impacts

For 1 mg of ε shift corresponds,



$$\int_{\Delta}^{\Delta+\varepsilon} \frac{1}{\sigma\sqrt{2\pi}} \exp\left(\frac{-x^2}{2\sigma^2}\right) dx$$

0.048 % of product

Causes compensation cost
More serious

Total export turnout of automated balance of Japan: 140M Euro (2009, 187G Yen)*
13M Yen economic imapct
(lower bound)

Causes proportional cost

$$\int_{-\Delta}^{-\Delta+\varepsilon} \frac{1}{\sigma\sqrt{2\pi}} \exp\left(\frac{-x^2}{2\sigma^2}\right) dx$$

0.025 % of product

Exporter

Total export turnout of automated balance of Japan: 140M Euro (2009)*
Source from Japan Measurement Instruments Federation

Simulation of the impacts

For x mg at 1 kg of ε shift corresponds,

ε	FP %	FF %	Total impact
0.5 mg	0.48	1.001	197M Yen
0.1 mg	0.025	0.048	13.8M Yen
0.05 mg	0.014	0.02	6.6M Yen
0.01 mg	0.0033	0.0036	1.3M Yen
2 μg	0.0007	00007	0.26M Yen

Stability of IPK: 1 kg 50 μg

CCM.M-K1, Mass Standards: 1 kg *u*R = 2.2 μg

* Based on the total export turnout of automated balance of Japan: 140M Euro (2009)
Source from Japan Measurement Instruments Federation
The loss does not include extra cost for compensation, penalty, etc.

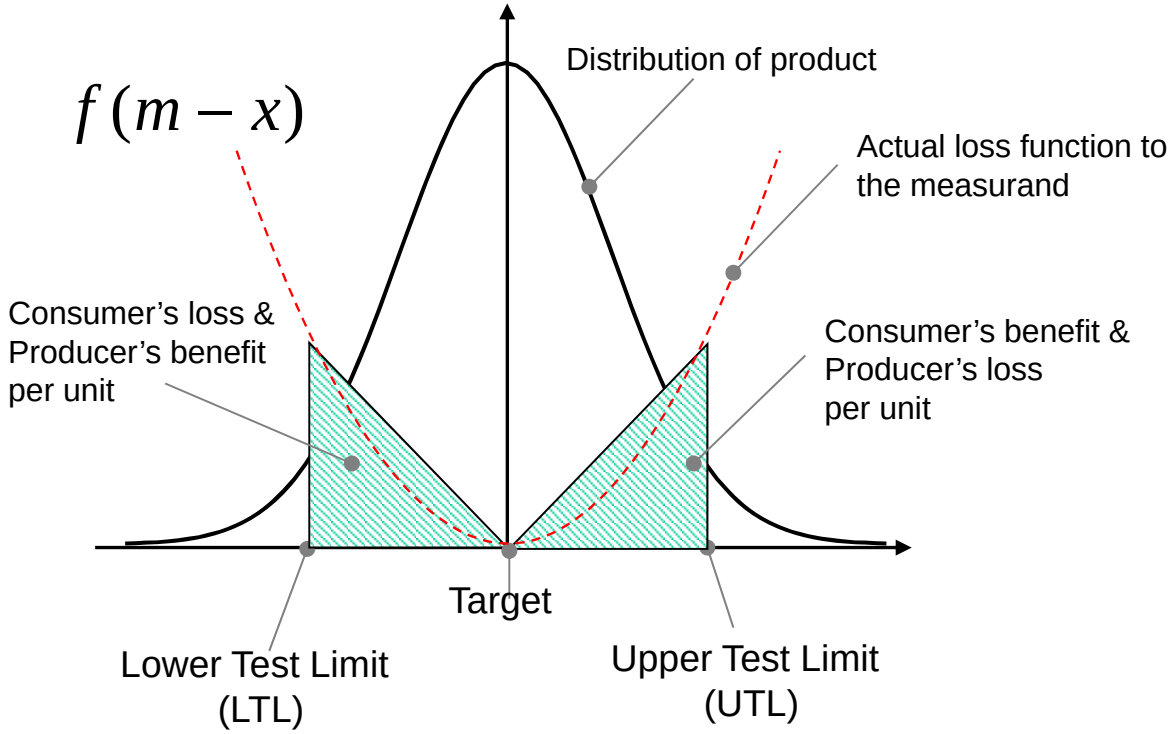
Conclusion I

We can conclude that the Japanese weighing scale industry can enjoy the current equivalence of mass measurement standards at the cost of some thousand to million Euros. In other words, monetary loss of some million Euros to the Japanese weighing scale industry could be decreased if the equivalence of measurement standard among countries is improved.

The discussion above does not include economic impact from the measurement results by the instrument (in this case, a weighing scale) which may deviate from the nominal value in its quality. In practice, economic impact may be larger and more serious if a non-conforming instrument is used in daily transactions. However, this situation is very difficult to assess analytically, because it depends on the goods to be measured. For example, a 1 g deviation in pre-packaged daily goods or in clinical medicines, will have a different economic impact. However, it shall be allowed to calculate the economic impact due to the deviation of measurement standard in individual transactions with the same method, based on individual information and conditions.

Simplified expression of loss function

Pre-packaged product case



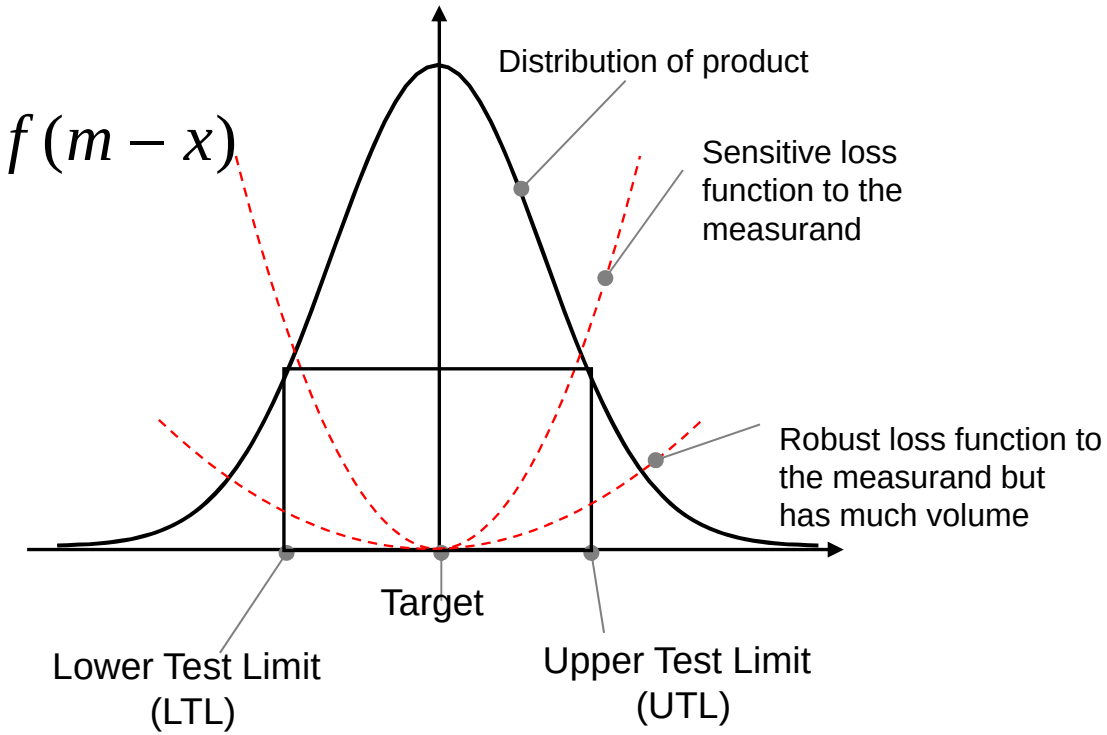
Even if the product passed through the test limits (LTL<product<UTL), there still exist some loss enclosed.

Most simplified such loss can be explained in pre-packaged product as described in the green colour part in the figure (left).

Although per unit loss is proportional to the deviation from the target, associated distribution of product and additional risks such as penalty or rework, the loss function (monetary loss per unit of product) usually shows hyperbolic characteristic to the measurand.

Expected case studies by loss function

High economical impact expected case



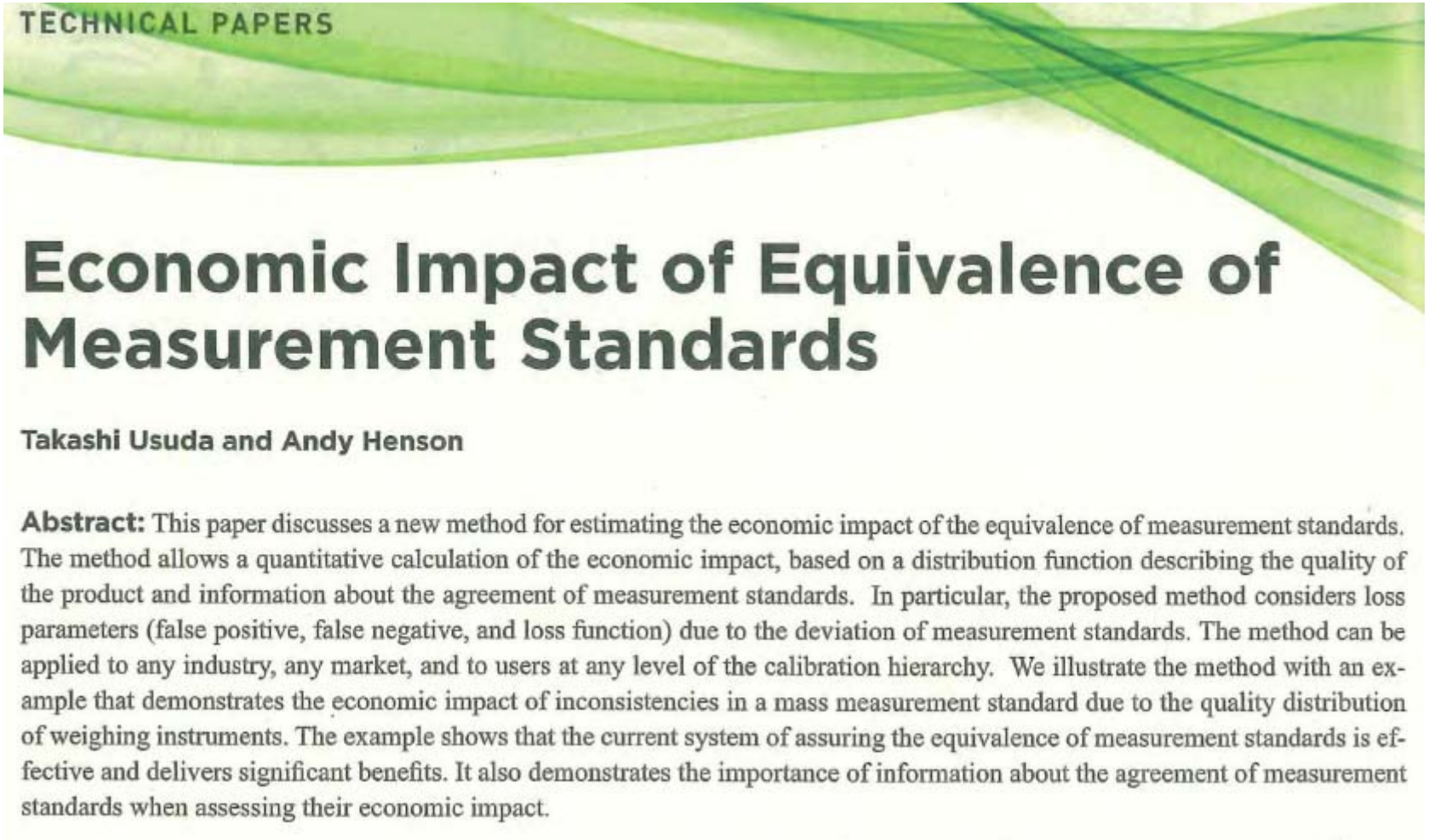
- Sensitive loss function to the measurand
e.g. Clinical medicine

-Robust loss function to the measurand but massive transactions
e.g. Natural gas

The monetary loss due to the deviation of measurement equipment is given by the convolution of and as where $D(x)$ is the distribution of the measurement equipments which lie within MPE of the equipment ($\pm\Delta$)

$$\int_{-\Delta}^{\Delta} D(x) f(m-x)dx$$

For more information



TECHNICAL PAPERS

Economic Impact of Equivalence of Measurement Standards

Takashi Usuda and Andy Henson

Abstract: This paper discusses a new method for estimating the economic impact of the equivalence of measurement standards. The method allows a quantitative calculation of the economic impact, based on a distribution function describing the quality of the product and information about the agreement of measurement standards. In particular, the proposed method considers loss parameters (false positive, false negative, and loss function) due to the deviation of measurement standards. The method can be applied to any industry, any market, and to users at any level of the calibration hierarchy. We illustrate the method with an example that demonstrates the economic impact of inconsistencies in a mass measurement standard due to the quality distribution of weighing instruments. The example shows that the current system of assuring the equivalence of measurement standards is effective and delivers significant benefits. It also demonstrates the importance of information about the agreement of measurement standards when assessing their economic impact.

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