KPMG Consulting

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Potential Economic Impact Of The CIPM Mutual Recognition Arrangement

Final Report

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Executive Summary

In October 1999, an arrangement between leading National Metrology Institutes (NMIs) was signed under the auspices of the Comité International des Poids et Mesures (CIPM), and coordinated by the Bureau International des Poids et Mesures (BIPM), for the *Mutual recognition of national measurement standards and of calibration and measurement capability (CMCs) issued by national metrology institutes*. The *Mutual Recognition Arrangement* (MRA) provides for the formal recognition of national measurement standards and calibration capabilities, and is expected to become the basis for wider agreements related to trade and commerce (e.g., WTO). Currently, the MRA covers relationships between 48 NMIs, as well as nearly 40 so-called designated institutes that also participate.

The current study examines the MRA from the perspective of discussing its potential economic impact, both on the NMIs and other organizations. Specifically, the goals are:

- To study the economics of central coordination of multilateral relationships between individual national metrology institutes (NMIs). This part of the study focuses on the gains in cost-efficiency for NMIs as a result of multilateral relationships, centred on BIPM's coordinative role, in comparison to the costs of a system of bilateral relationships without central coordination.

- To study the MRA's potential impact on economic efficiency as a facilitator of reductions in technical barriers to trade. Here, the study looks at the role of metrology in international trade, focusing on the importance of designing appropriate institutions to reduce technical barriers to trade (TBT), and the potential impact that the MRA might have in this regard. To contextualize the potential impact of lowering TBT in monetary terms, data is presented to highlight trade patterns between MRA signatory nations. A review of the limited literature on valuing technical barriers to trade is also presented.

- To present a set of arguments that might be useful in ensuring that potential economic benefits associated directly with the MRA are actually realized. These arguments are offered with the aim to enhance the important role that BIPM might play in helping to promote the MRA, and thereby increase its potential for positive impact.

The study provides both a theoretical and empirical examination of the MRA, and by extension, of BIPM's role as facilitator. This examination suggests that the MRA is properly viewed as an institution that structures relationships between NMIs as they engage in the production of mutual recognition. BIPM is viewed as a necessary organization to support the MRA, particularly as it provides a credible, neutral, international voice in support of the relationships between NMIs, and in relationships with other actors (such as trade organizations). Most importantly, the study provides an empirical examination of the expected impact of the MRA by employing a Survey of NMI Directors, to gauge their impression of the current impact of the MRA, and its expected future impact on other organizations. The Survey is supported by a set of interviews conducted with leading organizations around the world involved in the field of metrology, or in trade

governance. In addition, trade data is presented to highlight the 'order of magnitude' potential impact that reducing technical barriers to trade would have for MRA signatory nations.

The key findings of the Study are as follows:

- Based on information gathered in the NMI Survey, it is reasonable to suggest that the MRA results in a notional saving of approximately 75k € in the cost of establishing and maintaining mutual recognition with one other NMI compared with the cost of the same thing pre-MRA.
- The results also indicate that the total notional saving to the community of NMIs is in the order of 85M € per annum, at present levels of cost and comparison activity. The associated conclusion is that the cost of establishing mutual recognition on the scale currently achieved would have been prohibitively expensive in the absence of the centrally coordinated MRA.
- A conservative order-of-magnitude estimate of the MRA's potential role in reducing technical barriers to trade internationally is presented, suggesting that the MRA might confer significant benefit to signatory nations. It is suggested further that strategies for realizing this potential be pursued by BIPM at the international level and by NMIs at the domestically.
- Results of the NMI Survey indicate:
  - 75% of respondents have a 'positive' or 'very positive' impression of benefits due to *mutual recognition of calibration by a greater number of countries;*
  - 79% of respondents have a 'positive' or 'very positive' impression of benefits due to *mutual recognition of national measurement standards by a greater number of countries;*
  - 63% of respondents have a 'positive' or 'very positive' impression of benefits due to *lower costs of ensuring mutual recognition;*
  - 96% of respondents have a 'positive' or 'very positive' impression of benefits due to *centralized coordination of mutual recognition at the international level;*
  - 88% of respondents have a 'positive' or 'very positive' impression that the MRA will benefit *accredited calibration and testing laboratories;*
  - 79% of respondents have a 'positive' or 'very positive' impression that the MRA will benefit *legal metrology organizations;*
  - 39% of respondents have a 'positive' or 'very positive' impression that the MRA will benefit *written standards organizations; and*
  - 76% of respondents have a 'positive' or 'very positive' impression that the MRA will benefit *government regulators.*

- The long-term realization of the potential benefits of the MRA is likely to require a proactive role for BIPM and the NMIs in promoting the MRA, specifically as this relates to organizations charged with the responsibility for governing international trade (i.e., international trade bodies, and domestic trade representatives). It is argued that this proactive role is necessary to promote a positive balance between the costs and benefits of MRA membership over time.

- There is a widely held view that BIPM's 'promotional' role, internationally and in support of domestic NMIs, can only be based on its credible, neutral, international voice. It is also well accepted that BIPM's credibility is a function of its ability to speak from a position of scientific expertise, and that BIPM must maintain its scientific credibility over time, in order for it to establish and promote the MRA specifically, and metrological issues more generally worldwide.

1.0 Introduction

Reliability of the international measurement system is enhanced through continual effort by the world's national metrology institutes (NMIs) to base measurements and measurement uncertainties on universally accepted units, normally those of the International System of Units (SI). It is important for individual nations, through their NMIs, to compare national measurements and establish their mutual equivalence, not only in an effort to enhance measurement capabilities, but also as a means to reduce technical barriers to international trade. The extent to which an NMI can secure the mutual equivalence of national measurement standards and calibration capabilities, within known uncertainties, is thus a contributing factor to its nation's ability to engage in global trade.

Historically, mutual equivalence has been determined through an NMI's participation in bilateral agreements, or in regional multilateral agreements and organizations (RMOs). In October 1999, however, the importance of metrological equivalence was extended to a fully international spectrum with the signing of an arrangement for the *Mutual recognition of national measurement standards and of calibration and measurement capability (CMCs) issued by national metrology institutes*, under the auspices of the Comité International des Poids et Mesures (CIPM), and coordinated by the Bureau International des Poids et Mesures (BIPM). Known as the *Mutual Recognition Arrangement* (MRA), it provides for the formal recognition of national measurement standards and calibration capabilities, and is expected to become the basis for wider agreements related to trade and commerce (e.g., WTO).

The key objectives of the MRA are to:

- establish the degree of equivalence of national measurement standards maintained by NMIs;
- provide for the mutual recognition of calibration and measurement capability issued by NMIs; and,
- thereby provide governments and other parties with a secure technical foundation for wider agreements related to international trade, commerce and regulatory affairs.

The explicit goal of the MRA is to extend the recognition of the degree of equivalence of national measurement standards, derived from the results of key comparisons, to all signatory NMIs.[1] In addition, the MRA provides an opportunity for participating institutes to recognize the validity of calibration and measurement capabilities issued by other participating institutes, for specified quantities and ranges.

The MRA extends mutual recognition to the international level by coordinating key comparisons between RMOs. Recognition is thereby acknowledged within known uncertainties between NMIs

[1] *Appendix 1 lists the signatories to the MRA.*

through traceability to the key comparison reference value, as governed by the CIPM. Practically, calibration and measurement capabilities of a given NMI are recognized first through the local RMO, and are then extended to all RMOs – and hence to all NMIs – through the coordinative efforts of the Joint Committee of the Regional Metrology Organizations and the BIPM (JCRB).

The value of the MRA to a given NMI can thus be defined as the benefits of more broadly accepted measurement equivalence, and/or the costs avoided in ensuring mutual recognition through a centralized cooperative system such as the MRA, versus a decentralized system characterized by a series of bilateral relationships directly with other NMIs, or with other non-local RMOs. Looking at signatory nations more broadly, the benefits of the MRA extend to the reduction of technical barriers to trade, thereby enhancing domestic and international economic activity; it is this combined value that the current study investigates.

1.1 Study overview

KPMG Consulting LP has been retained by the Bureau International des Poids et Mesures (BIPM) to conduct a study on the potential economic impact of the Mutual Recognition Arrangement (MRA), signed on 14 October 1999. The study focuses on two specific impacts: economic impacts that might affect individual national metrology institutes as a result of membership in the centrally coordinated multilateral MRA, and impacts that might result from the MRA's role in the reduction of technical barriers to trade. To investigate these potential impacts, the study has three objectives:

- To study the economics of central coordination of multilateral relationships between individual national metrology institutes (NMIs). This part of the study focuses on the efficiency effects for NMIs as a result of multilateral relationships, centred on BIPM's coordinative role, in comparison to the costs of a system of bilateral relationships without central coordination.

- To study the MRA's potential impact on economic efficiency as a facilitator of reductions in technical barriers to trade. Here, the study looks at the role of metrology in international trade, focusing on the importance of designing appropriate institutions to reduce technical barriers to trade (TBT), and the potential impact that the MRA might have in this regard. To contextualize the potential impact of lowering TBT in monetary terms, data is presented to highlight trade patterns between MRA signatory nations. A review of the limited literature on valuing technical barriers to trade is also presented.

- To present a set of arguments that might be useful in ensuring that potential economic benefits associated directly with the MRA are actually realized. These arguments are offered with the aim to enhance the important role that BIPM might play in helping to promote the MRA, and thereby increase its potential for positive impact.

The potential economic impact of the MRA is considered in both theoretical and empirical terms. The study is based on the tenets of economic theory, which inform a discussion of the pertinent

aspects of the MRA, including its role in conferring benefits through the creation of mutual recognition, establishing cooperative outcomes in the relationships between NMIs, and stimulating second-order effects by creating welfare gains through the reduction of TBT. In addition, a review is presented of standard approaches to measuring empirically the benefits of institutions such as the MRA, and to measuring the benefits of reduced technical barriers to trade. A survey is designed and implemented to measure the effect of the MRA on its signatories (i.e., NMIs), and on associated public and private sector activities including trade, commerce, and regulatory affairs. The goal of the empirical study is to measure – or establish a reasonable estimate of – the impact that the MRA has on economic activity currently, and its expected impact in the future.

By extension, a measure of the MRA's impact also offers an opportunity to interpret the economic role that BIPM plays in the international metrology community. As such, the empirical methods used in the study (i.e., NMI survey, and interviews with leading organizations), are designed to help isolate the benefits associated with BIPM's unique role in international metrology. This interpretation supports insight and arguments about the implications of the MRA for BIPM.

1.2 Outline of the Report

The Report is presented in four sections:

- Section 1.0 Introduction
  An overview is presented to outline the objectives of the study, and to provide a summary of the Mutual Recognition Arrangement and its economic role.

- Section 2.0 Economics of the Mutual Recognition Arrangement
  The specific economic role of the MRA is developed, with a focus on establishing an institutional response to creating mutual recognition and cooperation between NMIs, and the second-order effects of the MRA on other actors in the (possible) reduction of technical barriers to trade.

- Section 3.0 Measuring the MRA's Potential Impact: Empirical Results
  Economic impact of the MRA is measured through the use of the NMI Survey. The survey addresses the impact on NMIs of reduced transaction costs and the value of membership in the MRA, as well as the potential value or importance of reduced technical barriers to trade. In addition, validating interviews are conducted with a number of leading organizations, in order to enhance understanding of the MRA's economic role (and that of BIPM).

- Section 4.0 Implications for BIPM
  The concluding section of the study provides an analysis of the survey and interview results in the context of what they imply for BIPM, including a set of arguments about the importance of future strategies to ensure that the potential benefits of the MRA are fully realized.

2.0 Economics of the Mutual Recognition Arrangement

BIPM generates many forms of economic benefit through its various activities. The current study, however, focuses only on the economic impact of the MRA, and by extension, BIPM's role in potentially generating economic benefit through MRA governance. As such, the following discussion centres on the specific forms of economic activity that are affected by the MRA – namely, the relationships that exist between NMIs, and the expected impact that the MRA has, or could have, on the reduction of technical barriers to trade.

We explore the impact of the MRA by using a conceptual framework that supports three core arguments about the economic role of the MRA and BIPM.

1. The MRA is viewed as an institutional response to the problems inherent in coordinating relationships between otherwise competitive organizations. Because of the special nature of measurement standards as public goods, and the associated economic challenges with their production and maintenance at the international level, the MRA is viewed as a response to the requirement for central coordination in the creation of a truly international metrological system. The extension to this argument is that BIPM, de facto, represents a suitable and necessary organization to act as the coordinator in structuring relationships between NMIs in the MRA.

2. The MRA is the institution through which NMIs collectively produce mutual recognition. Mutual recognition establishes multilateral acceptance of measurement standards and CMCs by other NMIs in a manner that replaces former regionally- or bilaterally-based systems of recognition. The argument presented in the study is that this confers a first-order benefit to signatory NMIs, in that their national standards and CMCs are recognized by a greater number of actors post-MRA, than pre-MRA, and that there is a cost-efficiency associated with this when measured in terms of central coordination.

3. The MRA is an institution upon which *other* actors may base economic strategies. These other actors stand to reap second-order benefits, most notably due to a likely role in the reduction of technical barriers to trade. In the study, we trace this impact in a general sense, by suggesting the importance of the MRA will be exhibited through the potential for a much broader acceptance of testing and conformity assessment procedures internationally, if the MRA is recognized appropriately. This argument is supported by a review of estimates of potential monetary effects.

To frame these arguments, we provide the following brief review of the economic rationale and role for the MRA, and the BIPM.

2.1 Economic Foundation and Role of the MRA

This section discusses the economic foundation and role of the MRA – and by extension the BIPM – in three regards: it represents a necessary institutional response to defining a cooperative outcome between NMIs in the creation of mutual recognition; it is supported by a specific organization (the BIPM) in a way that enhances the probability of a positive outcome for the MRA; and it provides a basis upon which other forms of economic strategy may rest, notably efforts to reduce TBT. In what follows, we describe the specific role of the MRA (and BIPM) in a manner that isolates key assumptions, arguments, and inferences that are subsequently explored in the empirical examination. And while this discussion is couched in terms of economic theory, it is a relatively "non-technical" description. Having said this, a more "technical" discussion of the economic foundation of the MRA is provided in Appendix 2.

2.1.1 The MRA as a Necessary Institution

The MRA is properly viewed as an *institution*, in that it structures the behaviour of NMIs in their collective aim at creating mutual recognition of national measurement standards and CMCs. In this way, mutual recognition is the primary outcome of the relationship between NMIs in the MRA, i.e., it is the good being produced. The institutional character of the MRA is important, as it not only provides the underpinning for mutual recognition, it does so in response to the fundamental economic nature of the international metrology system.

For any given NMI, its raison d'être is to establish and maintain its nation's measurement standards (and associated CMCs). These measurement standards then act as the primary reference point for all forms of activity that require, in one way or another, traceability to measurement standards, including many varied forms of scientific and commercial activity.2 Schematically, this notion is represented in Figure 1, where traceability to the NMI is shown throughout stylized classes of commercial technology and development.

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2 *This point has been made numerous times elsewhere, and need not be developed further here (see for example Semerjian and Watters 2000).*

Figure 1	Schematic representation of traceability and economic development

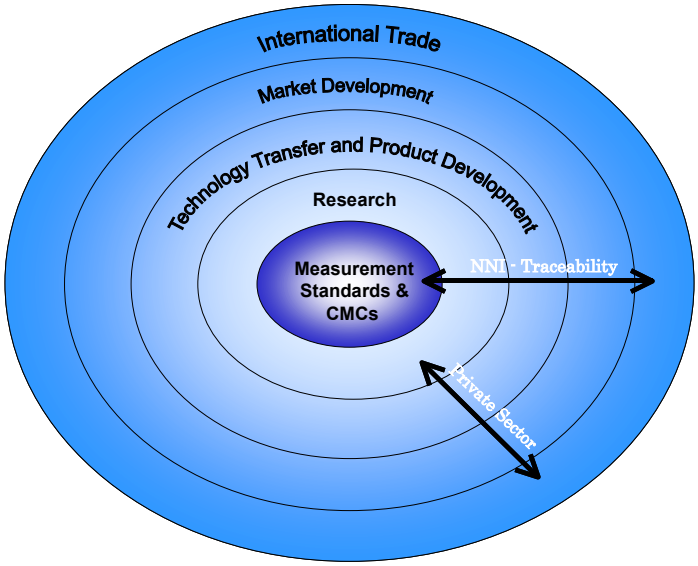

Figure 1 also implies that private sector activity is not involved in establishing measurement standards and CMCs for traceability. This is due to the nature of standards as *public goods*, whose provision must be established through collective (government) action.[3] The reason for this is that standards act as a mutual reference point for *all economic actors*, and their maintenance must be governed in a manner that allows for equitable access. Were this not the case, for instance if standards were privately held, the "owner" of the standard could use it to gain economic advantage at the expense of other actors. The ubiquitous international response to the public good nature of national measurement standards has been the establishment of public NMIs.

Similarly, the value of the international metrology system is a function of comparability between the different capabilities of NMIs in realizing, scientifically and technically, the equivalence of each other's national standards and CMCs. Increasingly, this involves direct comparison between NMIs, as opposed to traceability to singular international artefacts; it is thus desirable to maintain a system of *mutual recognition* where nations are effectively prevented from using measurement standards as competitive tools. As with the creation and maintenance of national standards, the creation and maintenance of international mutual recognition must be done collectively, in order to avoid situations of opportunistic behaviour by a given nation in its relations with others. Recognition, almost by definition, requires mutual consent. The MRA, by establishing the equivalent of "rules of the game" for NMIs, creates an institution that structures the efficient and equitable creation and maintenance of mutual recognition.

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[3] *Please see Appendix 2 for a technical description of public goods.*

Prior to the signing of the MRA in October 1999, NMIs' recognition of each other was limited to a regional basis through RMOs, or to special relationships or arrangements directly between NMIs. Simply put, the MRA formalizes the objective comparability between RMOs, thereby extending comparability – and mutual recognition – between signatory NMIs. Institutionally, the MRA establishes the means by which this takes place, and can be summarized as follows (text of MRA):

> *To put the criteria for mutual recognition on an objective footing, the arrangement calls upon: (a) the results of a set of key comparisons carried out using specified procedures which lead to a quantitative measure of the degree of equivalence of national measurement standards; (b) the operation by each NMI of a suitable way of assuring quality; and (c) successful participation by each NMI in appropriate supplementary comparisons. Together, these three procedures demonstrate to participating institutions the degree to which each may have confidence in the results reported by others, and so promote mutual confidence between them.*

That the MRA establishes a formal system for mutual recognition is not surprising, given that it is in the collective interest of NMIs to establish an independent and objective means to avoid any form of opportunistic or competitive behaviour that would see one NMI gain at the expense of another. The rules of conduct, including a formal dispute resolution mechanism, are thus suitable (and expected) for the purposes of mutual recognition. These rules are also required due to the voluntary nature of the MRA itself. As an *arrangement*, as opposed to legally binding *agreement*, the MRA is structured on the basis of voluntary membership. As a result, the MRA is akin to a club designed to produce a collective good for its members – namely mutual recognition. The cost of membership is individual participation according to the institutional rules, with the benefits being the realization of mutual recognition and associated (potential) benefits in structuring the behaviour of other economic actors (i.e., reducing TBT).

The success of the MRA thus rests on its ability to structure the behaviour of signatory NMIs in their collective pursuit of mutual recognition. By promoting objectivity and neutrality in inter-NMI relationships, the MRA thereby enhances the credibility with which NMIs submit their technical/scientific capabilities (through reporting of deviations from reference values and uncertainties), effectively lowering the costs of recognizing other NMI's capabilities. In part, this rests on traditional scientific and technical expertise; in part, it rests on the design of mechanisms to 'prove' credibility, including quality systems.

2.1.2 The Requirement for Organizational Support: BIPM

In most instances, institutions are also characterized by a requirement for administrative or organizational support to ensure that intended outcomes are met. Just as the NMIs are charged nationally with the responsibility of governing the process of creating and maintaining domestic standards and CMCs, so too is there a requirement for international governance; this is the role played by the BIPM (on behalf of CIPM).

The requirement for organizational support to the MRA, as reasonably supplied by BIPM (as secretariat to the CIPM), is seen in four regards:

- Experience and Credibility – BIPM provides considerable expertise and credibility to the process of inter-NMI mutual recognition. This is due to two factors. First, the BIPM is an expert, either by direct involvement in or association with, the science of metrology. As such, BIPM is credible when it comes to structuring intercomparisons between NMIs (either at the level of key references, or for CMCs) and involvement in interpreting metrological results. Second, it has considerable historical experience in structuring international metrological relationships. For the MRA, this implies a natural role as Chair of the JCRB, upon which the institutional structure of ensuring mutual recognition rests.[4]

- Neutrality – The issue of neutrality is closely related to that of credibility. In order for the relationships between NMIs to be productive, national interest or rivalry must be tempered. And even though it is scientific and technical credibility and accuracy amongst NMIs that contributes to this neutrality most directly, it is also important that a neutral body provide any requirement for organizational support. As an international organization without direct association or allegiance with national interests, the BIPM is well situated to play this role. In particular, this would be vital in instances of dispute resolution (which, to date, has yet to be necessary).

- Administration – In a practical sense, the MRA needs administrative support. For the most part, this administrative support involves the organization of key and supplementary comparisons, and the publication of results from the comparisons and acceptance of CMCs, in the Key Comparison Database. This administrative support is provided by BIPM.

- International organization – The promotion of mutual recognition between NMIs extends beyond the direct impacts on NMIs themselves, to other organizations affected by measurement standards and CMCs (e.g., accreditation laboratories, trade bodies, regulatory agencies). At the international level, the promotion of the MRA involves (possible) communication and association with other international organizations (e.g., ILAC, WTO, EU), and requires a credible, neutral, international organization to represent, in part, the interests of the metrological community. As we discuss below, this is a suitable (and expected) role for BIPM.

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[4] It is important to note that the experience and credibility of BIPM is, in part, a function of its own scientific capabilities. These capabilities, however, have been a subject of discussion over the past several years. As such, we address this issue in the empirical section of the study.

2.1.3 Impact on other actors: Isolating the potential for reducing TBT and lowering costs of trade

The MRA makes explicit reference to the importance of its results to potentially "provide the technical basis for wider agreements related to trade, commerce and regulatory affairs, signed by the competent authorities in each country or region." Indeed, it is accepted by signatories to the MRA that the second-order impacts on commerce and regulatory affairs – especially as structured through international trade – represent the greatest expected economic benefit of the MRA.[5]

And yet this impact is not necessarily guaranteed, simply by virtue of mutual recognition between NMIs. This is due to one reason: signatory NMIs are not the national organizations charged with the responsibility to govern trade relations. As a result, the broader effect of the MRA will be realized only by its mediation through other actors. To appreciate the importance of this statement, we outline the stylized role that NMIs (and measurement standards and CMCs) play in governing trade relations, with a specific emphasis on the role of technical barriers to trade (Note: a technical discussion of the economics of TBT is presented in Appendix 2).

Technical barriers to trade result from the asymmetric, or costly, application of standards or assessment procedures to establish the conformity of traded commodities with regulations. As such, TBT impose costs on trading partners, possibly to the extent of preventing trade altogether; trade regulations that deal (in)directly with measurement and/or traceability, are of particular relevance to the MRA.

The importance of traceability to national standards determined and held by NMIs can be viewed as follows. Consider a firm whose product requires accurate measurement to guarantee its conformance to some set of voluntary or mandatory specifications (or standards/regulations), including those that might be set for product quality/safety reasons, or to govern the accuracy of quantity. To reveal the conformity of its product, the firm will measure the product (or have it measured by a third-party), and report the results. As required by the International Vocabulary of Metrology (VIM), the results must be consistent with the definition of traceability, as:

> *...the property of the result of a measurement or the value of a standard whereby it can be related to a stated reference, usually national or international standards, through an unbroken chain of comparisons, all having stated uncertainties (ISO1993 as quoted in Semerjian and Watters 2000).*

Typically, the firm will establish traceability by ensuring that an accredited calibration laboratory calibrates its measurement instruments. The calibration laboratory, in turn, ensures traceability

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[5] *It is important to emphasize that measurement standards, CMCs, and other forms of NMI activity (such as service provision and technology transfer), also have significant impacts on domestic commercial and regulatory practices, independent of international trade. For the current study, however, we do not investigate these benefits, and rather focus only on the inter-organizational dimensions of the MRA, and their possible effects on trade relations.*

through comparison to derived or basic measurement standards, either directly with the NMI, or as mediated through an accreditation body (often a national government agency). As such, the chain of unbroken traceability is linked to the NMI.

Consider now that the firm intends to export the same product into another country. If the importing country requires conformance to some set of voluntary or mandatory standards (either the same or different from domestic ones), the firm must report its measurement results. *Acceptance* of these results, in turn, determines the cost of trade. One of three scenarios is likely:

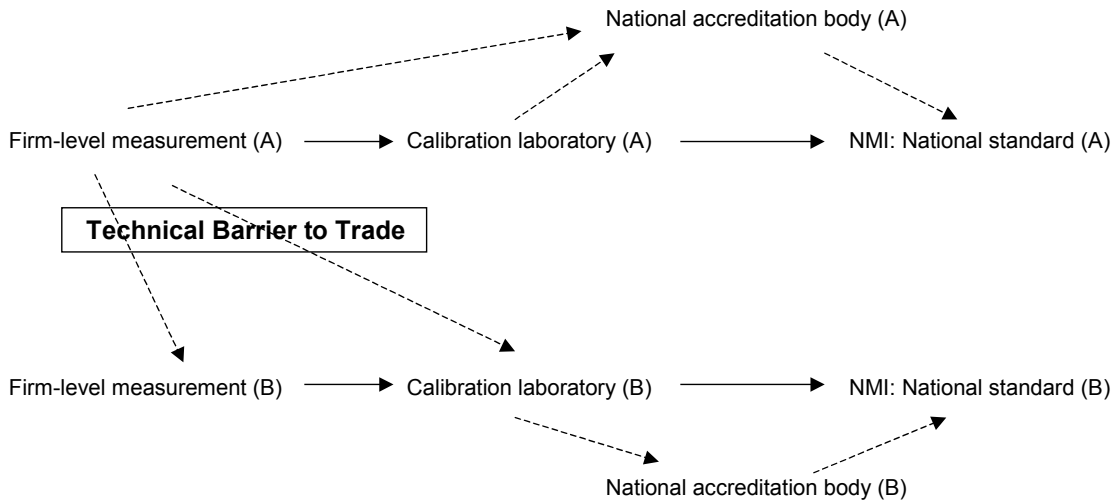
- Field-level measurement conformity – The importing country requires that the firm re-measure its product in accordance with importing procedures and regulations, possibly by a measuring body local to the importing country. This is the most costly scenario, in that the product is re-measured from the field level.

- Calibration-level conformity – The importing country requires that the calibration laboratory to which the firm is linked, be assessed for conformity with the importing country's own calibration system. Here, the cost of conformity assessment is at the level of the calibration laboratory, although this cost is likely to be passed on to the firm.

- Mutual recognition – The importing country accepts the measurement information as reported by the firm (and then judges conformity against the importing regulations). Here, there is no additional measurement cost for trade, and it is assumed that this is the preferred solution for the firm and its clients. The acceptance of measurement by the importing country may be established through mutual recognition arrangements between countries, at various levels of the traceability chain.

The acceptance of measurement reports by the importing country determines, in large part, the measurement-related costs of trade (for the firm directly, and in aggregate across firms and industries, for the exporting country). In situations where the measurement-related costs are positive, these are referred to as technical barriers to trade, and run from simple increased costs, to situations where the costs prevent trade from occurring at all. This relationship between the requirement for traceability and the costs of trade between country's A and B is represented in Figure 2.

Figure 2 **Traceability and technical barriers to trade**



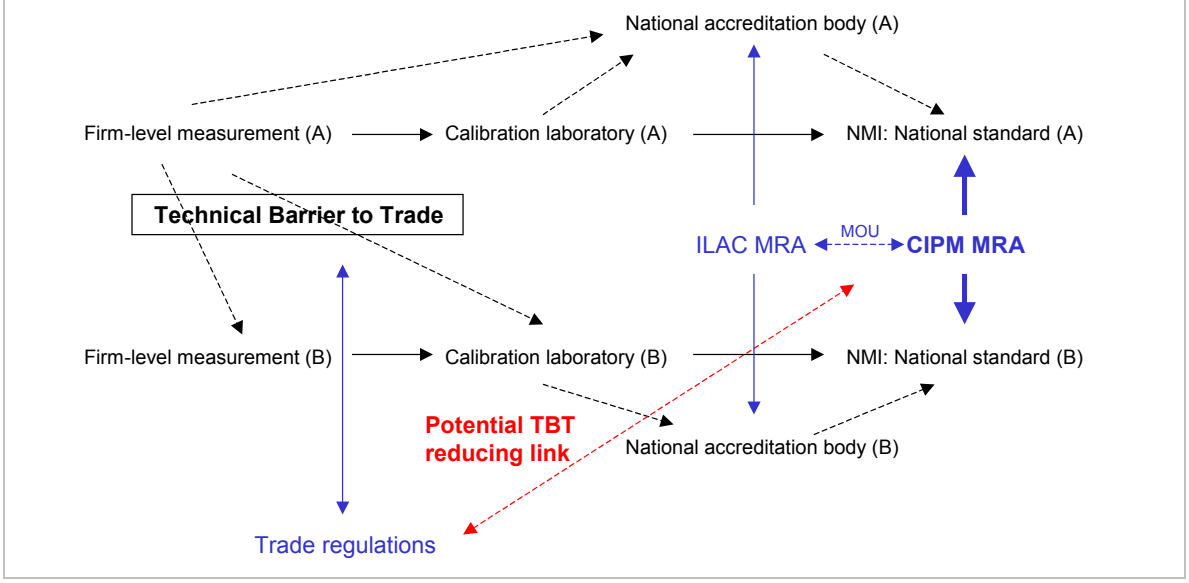
The pursuit of the preferred solution to the elimination of TBT and the reduction of measurement-related costs of trade, involves the institution of mutual recognition arrangements. Indeed, as promoted in the World Trade Organization's TBT Agreement:

> *Article 6.1 – ...Members shall ensure, whenever possible, that results of conformity assessment procedures in other members are accepted, even when those procedures differ from their own, provided they are satisfied that those procedures offer an assurance of conformity with applicable technical regulations or standards equivalent to their own procedures. It is recognized that prior consultations may be necessary in order to arrive at a mutually satisfactory understanding regarding, in particular:*
>
> *Article 6.1.1 – adequate and enduring technical competence of the relevant conformity assessment bodies in the exporting Member, so that confidence in the continued reliability of their conformity assessment results can exist; in this regard, verified compliance, for instance through accreditation, with relevant guides or recommendations issued by international standardizing bodies shall be taken into account as an indication of adequate technical competence.*
>
> *Article 6.3 – Members are encouraged, at the request of other members, to be willing to enter into negotiations for the conclusion of agreements for the mutual recognition of results of each other's conformity assessment procedures.*
>
> *Article 9.1 – Where a positive assurance of conformity with a technical regulation or standard is required, Members shall, wherever practicable, formulate and adopt international systems for conformity assessment and become members thereof or participate therein.*

The promotion of "international systems for conformity assessment" is directly related to a desire to reduce (the costs of) TBT. Institutionally or organizationally, this involves the negotiation and implementation of mutual recognition systems, each associated with a distinct 'step' in the traceability system. Clearly, the most important of these for the current study is the CIPM MRA at the NMI level, but a similar arrangement at the level of accreditation bodies is also important, as is mediated by the International Laboratory Accreditation Cooperation (ILAC). In addition, a Memorandum of Understanding between CIPM and ILAC was signed in 2002. If the necessary link between trade regulators and bodies such as ILAC and BIPM can be developed, this stands to help reduce TBT. This potential is illustrated stylistically in Figure 3.

The potential role for the CIPM MRA in helping to reduce TBT is clear: by establishing mutual recognition of national standards and CMCs at the highest level, it becomes easier to establish mutual recognition of conformity assessment procedures in trading systems throughout the traceability chain, thereby reducing costs. An important element of this role is that the MRA contributes to the creation of an international "technical infrastructure", characterized by a credible, scientific, objective set of criteria (i.e., metrology itself). Perhaps even more importantly, the coordination and communication of this technical infrastructure is partly the responsibility of the BIPM, and infrastructure benefits from the transparency and accountability created by BIPM at the international level. Indeed, it can be argued that this sort of transparency or neutrality is necessary if trade regulators are to rely on the MRA as part of their strategies to reduce TBT. As such, the reduction of TBT requires cooperation between organizations at all levels of measurement activity, from the firm and laboratory level, to the level of the NMI. Indeed, this is a vital issue, and is discussed at some length in the findings of the current study.

Figure 3 **Traceability, TBT, and mutual recognition: How TBT might be reduced**



3.0 Measuring the MRA's Potential Impact: Empirical Results

To estimate the potential impact of the MRA, the study employs two methodological approaches. First, a survey of NMIs has been conducted to investigate the direct impact on NMIs, and to gather information on NMIs' view of the importance of the MRA in other settings, such as the reduction of TBT. Second, detailed interviews were conducted with Directors of leading signatory NMIs, with individuals directly involved in the governance of trading relationships between states, and with individuals directly involved in the measurement industry, or in industries where measurement is particularly important.[6] The 'results' of the interviews are integrated into the discussion of implications for BIPM, presented in Section 4.0 of this Report.[7]

The empirical study was designed to offer key information is two main regards. First, it provides a current and retrospective view of the MRA's impact on NMIs since its inception in 1999. This information is important as it highlights the pattern of activity that has emerged as NMIs work to establish the results of key comparisons and acceptance of CMCs, which are the basis for mutual recognition. Second, and arguably of more importance, the empirical study suggests a set of key issues that must be addressed in order for the MRA to achieve its expected impact, particularly as this relates to the reduction of TBT. Both the survey and the interviews were paramount in revealing what these issues are, and how the MRA – and BIPM more specifically – might respond.

3.1 NMI Survey Results

Directors of the 48 signatory NMIs were requested to participate in a web-based survey, the main purpose being to assess their impression of the impact of the MRA. The survey, shown in Appendix 4, was composed of three key sections: demographics, current NMI activity, and benefits to the NMI and other organizations as a result of participating in the MRA. The 'demographic' section allows respondents to be categorized on the basis of characteristics such as size and budget. The 'current activity' section reveals the impact of the MRA, specifically as this

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6 Note: As a secondary 'add-on' to the original parameters of the study, an attempt was made to survey a number of industry trade associations in selected sectors about the costs their members face as a result of measurement-based technical barriers to trade (i.e., automotive, telecommunications, aerospace, biotechnology, agri-food, medical devices and pharmaceuticals). The response rate to this survey was too low to permit useful interpretation of the results in the current Report. It is possible, however, that a detailed examination of industry's strategies and responses to TBT, including a direct measure of TBT costs, might form the basis of future research.

7 A list of Interviewees is presented in Appendix 5.

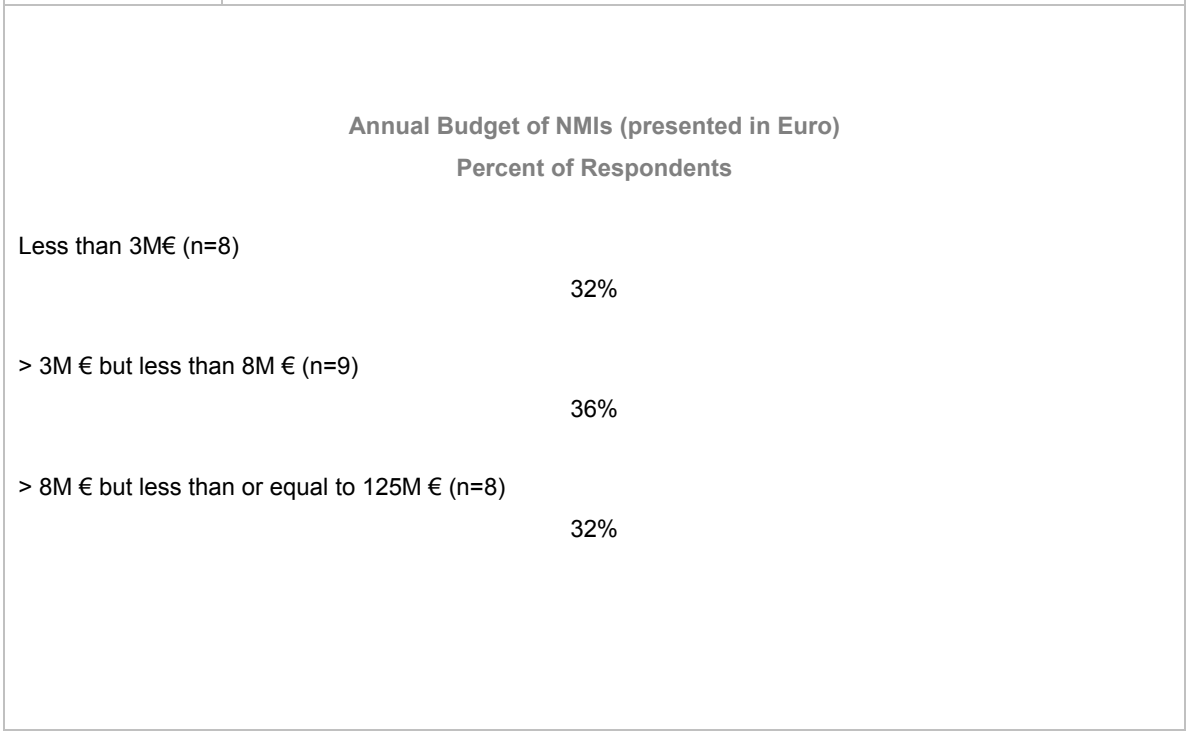
relates to the conduct of key comparisons. The 'other organizations' section reveals Directors' interpretation of the broader (future) impact of the MRA.

The question-by-question results of the survey are presented below. A total of 26 NMI Directors (or their representatives) chose to participate in the survey. Responses are reported in aggregate, as confidentiality was guaranteed as a condition for participation in the survey.

Q1. In local currency, what is the annual budget of your NMI?

The results indicate that approximately one-third (32%) of the respondents to the web-based survey have an annual budget of less than 3M€, one-third (36%) have an annual budget of greater than 3M€ but less than 8M€, and one-third (32%) have a budget greater than 8M€ but less than or equal to 125M€. Reported budget size ranged from a low of 250,000 € to a high of 125M €, with the average budget being approximately 16M €.

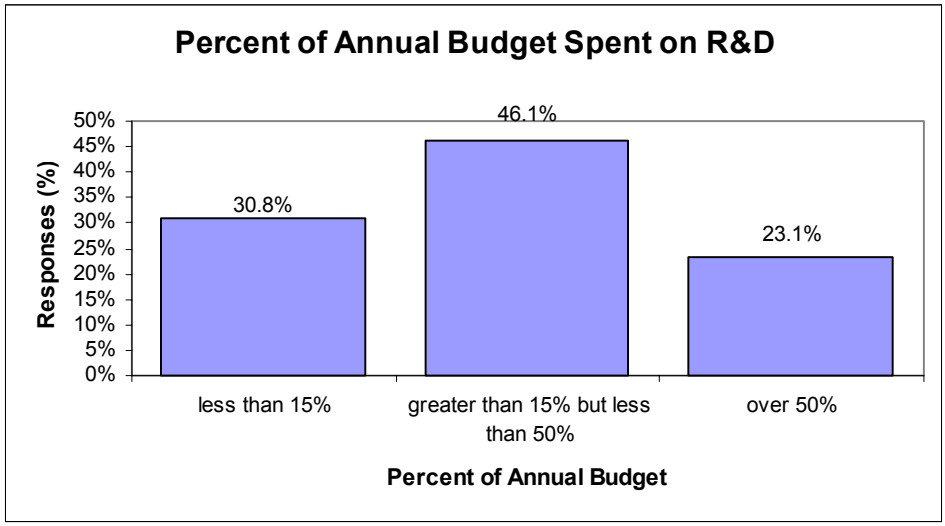
Figure 4	NMI annual budgets



Q2. Expressed as a percentage of your NMI's total budget, how much is spent annually on research and development?

On average, NMIs spend approximately 32.5% of their annual budget on research and development. The figure below provides a more detailed breakdown, and reveals that 30.8% of NMI respondents spend less than 15% of their annual budget on R&D, 46.1% spend more than 15% but less than 50% of their budget on R&D, and 23.1% spent over fifty percent of their budget on R&D.

Figure 5 **Annual spending on R&D**

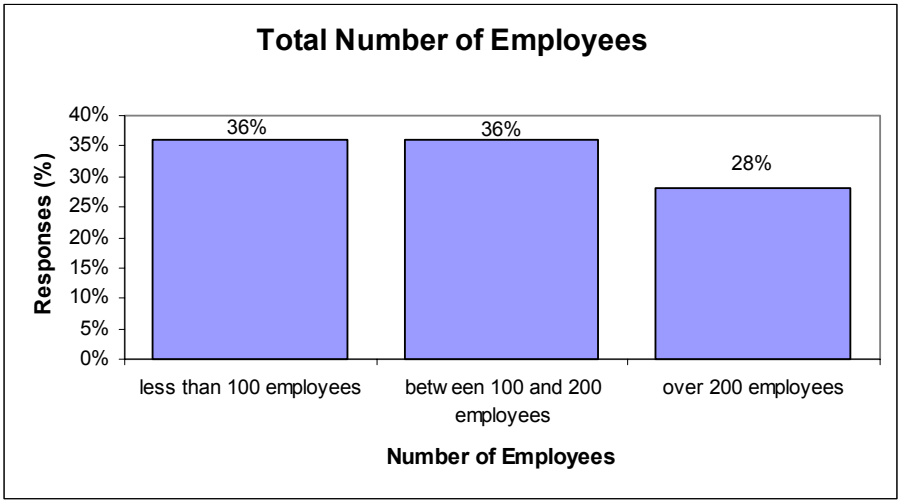


As a percent of the total NMI annual budget, approximately 42% of respondents spent less than 1M € on R&D, 19% spend between 1M € to 2M € on R&D, and the remaining 39% spend over 2M € on their annual budget on R&D.

Q3. How many employees work at your organization?

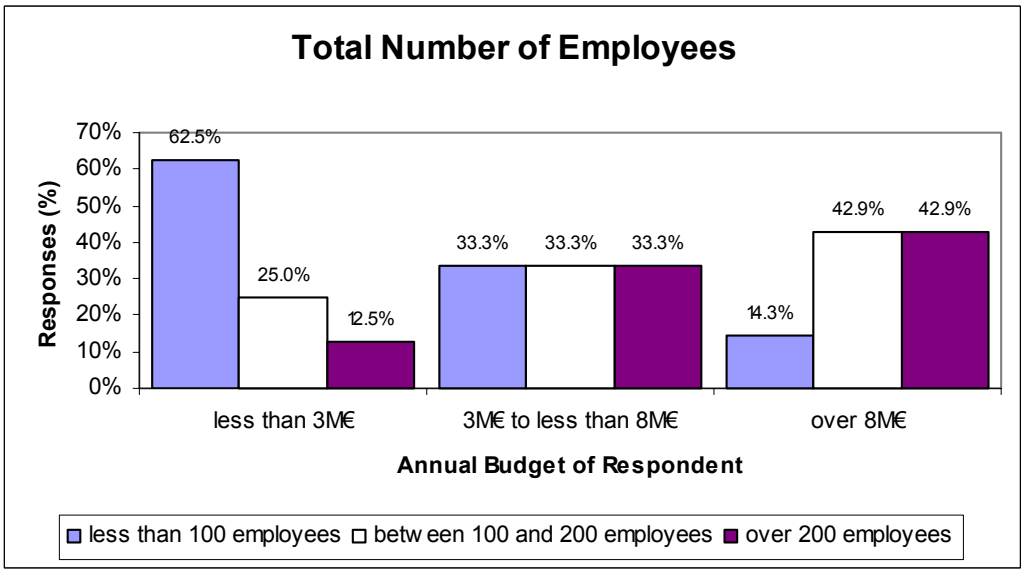
The average number of employees working at an NMI is 184. Figure 6a below provides a more detailed breakdown of the total number of employees.

Figure 6a	Number of employees



The average number of employees working for the responding NMI organizations, broken down by size of the organization, is presented in the figure below.

Figure 6b	Number of employees broken down by annual budget of respondent



According to respondents, the average percent of employees would be classified as follows:

a. Research scientific staff 34.6 %

b. Technical scientific staff 40.3 %

c. Managerial staff 6.8 %

d. Administrative support staff 13.2 %

e. Business development staff 5.5 %

Impact of the MRA

Q4. Which RMO(s) is your NMI a member of?

Figure 7a reveals that close to two-thirds (62%) of respondents were members of EUROMET. Some respondents may be members of more than one RMO.

Figure 7a **RMO membership**

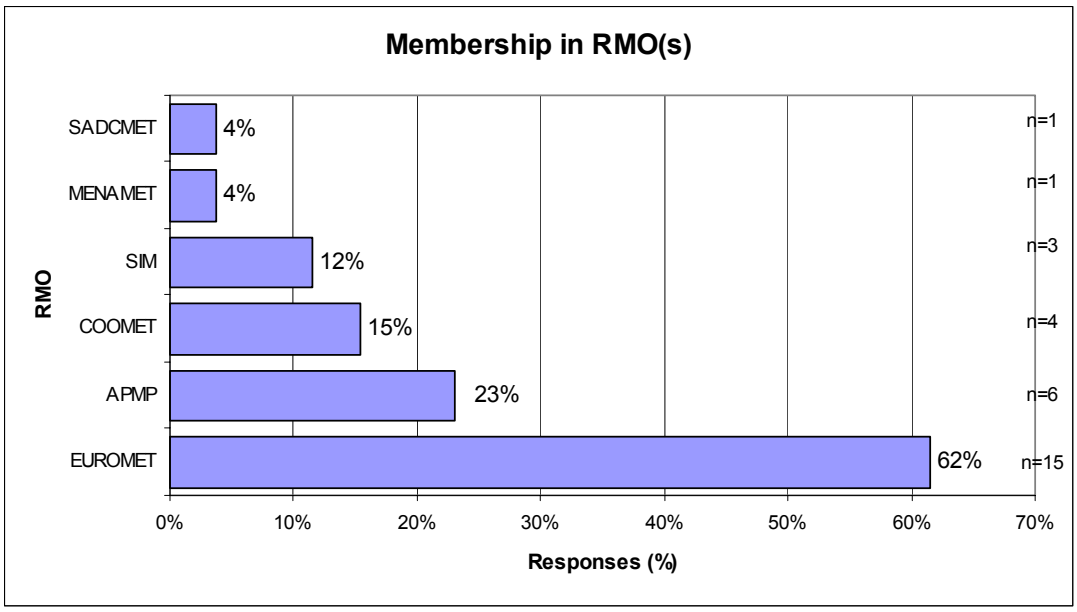
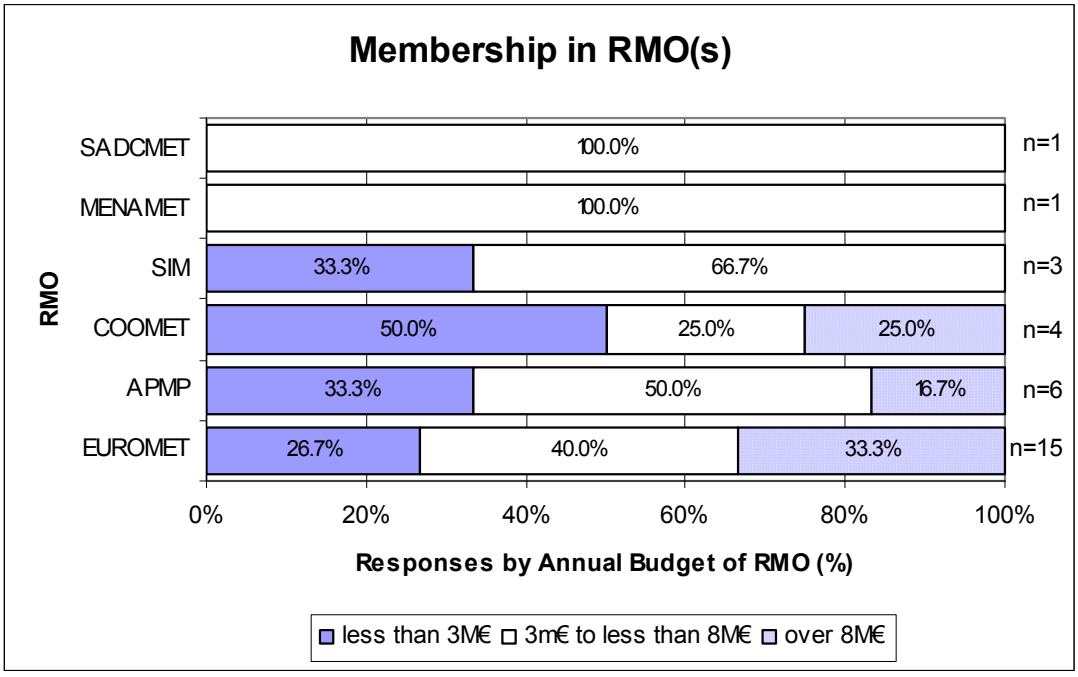


Figure 7b reveals the size, based on annual budget, of the responding NMI that indicated they are members of the RMOs.

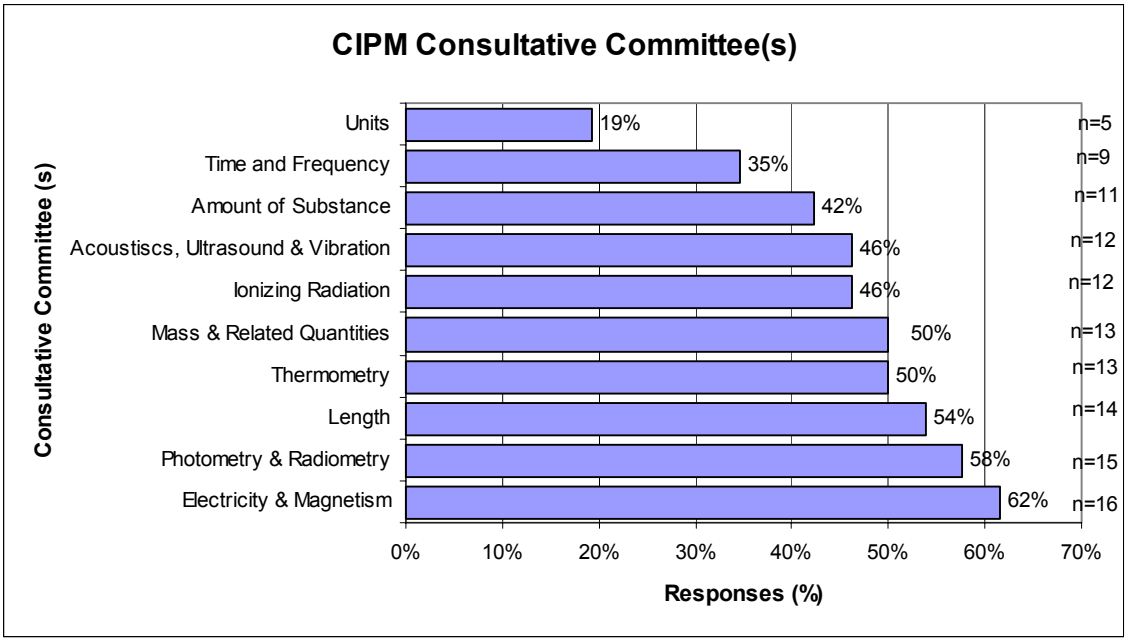
Figure 7b **RMO membership broken down by annual budget of responding NMI**



Q5. Which CIPM Consultative Committee(s) is your NMI a member of?

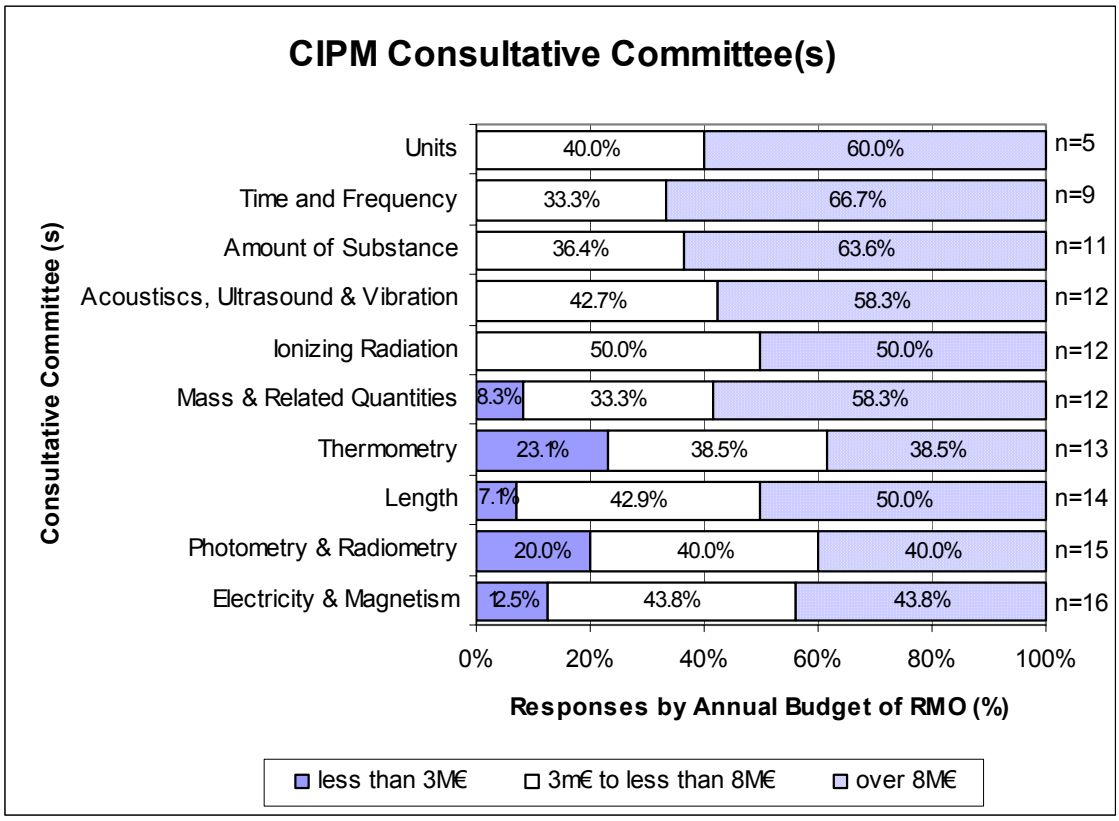
Figure 8a provides a breakdown of the CIPM Consultative Committee(s) that the respondents are members of. NMIs may be a member of multiple Consultative Committees.

Figure 8a	CIPM Consultative Committee membership



The following figure reveals the size, based on annual budget, of the responding NMI that indicated they are members of the various Consultative Committees.

Figure 8b	CIPM Consultative Committee membership broken down by annual budget of responding NMIs



6a) On average, how many international comparisons has your NMI participated in for the past four years? (Note: calendar years are used for ease of international comparison)

The average number of comparisons that were undertaken by respondents during four calendar years (1998 to 2001) is reported. Respondents were also asked to identify which portion of the comparisons that were in direct response to the MRA. The following figures provide the aggregate responses to the total number of comparisons, as well as the number of comparisons undertaken by the size, in this case the annual budget, of the respondent.

Figure 9a	Number of comparisons for all respondents

Number of Comparisons	1998	1999	2000	2001
Local RMO				
	6.6 (n=15)	7.8 (n=19)	6.9 (n=23)	7.5 (n=23)
CIPM				
	9.4 (n=15)	9.6 (n=18)	11.3 (n=19)	13.1 (n=18)
Organizations other than local RMO or CIPM				
	3.8 (n=15)	3.6 (n=16)	4.2 (n=17)	5.0 (n=16)
Of these, how many in direct response to MRA				
	11.7 (n=15)	11.8 (n=19)	16.2 (n=20)	15.5 (n=22)

Figure 9b	Number of comparisons by NMI respondents with an annual budget of less than 3M Euro

	Number of Comparisons
	1998
	1999
	2000
	2001
Local RMO	
	1.0 (n=2)
	1.7 (n=3)
	2.2 (n=6)
	5.5 (n=6)
CIPM	
	2.5 (n=2)
	0.7 (n=3)
	1.3 (n=3)
	5.3 (n=3)
Organizations other than local RMO or CIPM	
	1.5 (n=4)
	1.5 (n=4)
	2.6 (n=5)
	3.6 (n=5)
Of these, how many in direct response to MRA	
	2.3 (n=3)
	2.0 (n=3)
	3.5 (n=4)
	6.5 (n=6)

Figure 9c	Number of comparisons by NMI respondents with an annual budget between 3M to 8M Euro

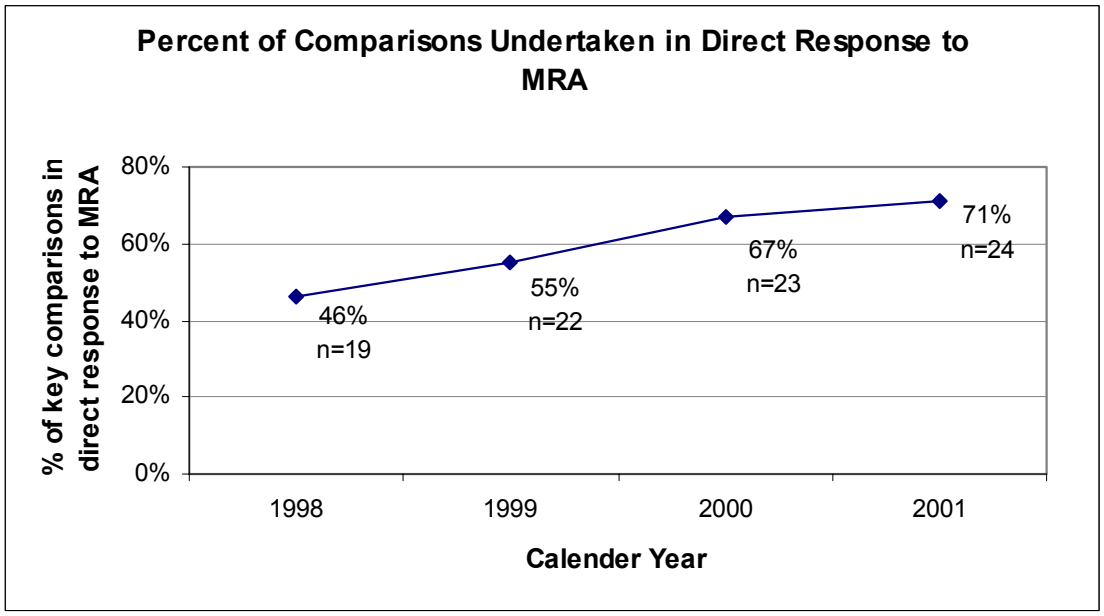
	Number of Comparisons
	1998
	1999
	2000
	2001
Local RMO	
	5.6 (n=7)
	6.4 (n=8)
	6.6 (n=9)
	7.3 (n=9)
CIPM	
	5.0 (n=7)
	5.0 (n=8)
	8.3 (n=8)
	8.0 (n=8)
Organizations other than local RMO or CIPM	
	3.7 (n=7)
	4.1 (n=8)
	4.8 (n=8)
	5.1 (n=7)
Of these, how many in direct response to MRA	
	6.0 (n=7)
	6.3 (n=9)
	11.3 (n=9)
	12.4 (n=9)

Figure 9d	Number of comparisons by NMI respondents with an annual budget over 8M Euro

Number of Comparisons	
	1998
	1999
	2000
	2001
Local RMO	
	11.3 (n=5)
	12.6 (n=7)
	11.8 (n=7)
	10.2 (n=7)
CIPM	
	16.8 (n=6)
	18.6 (n=7)
	20.5 (n=7)
	22.4 (n=7)
Organizations other than local RMO or CIPM	
	6.3 (n=4)
	4.5 (n=4)
	5.3 (n=4)
	6.5 (n=4)
Of these, how many in direct response to MRA	
	25.2 (n=5)
	26.3 (n=6)
	34.0 (n=6)
	31.3 (n=6)

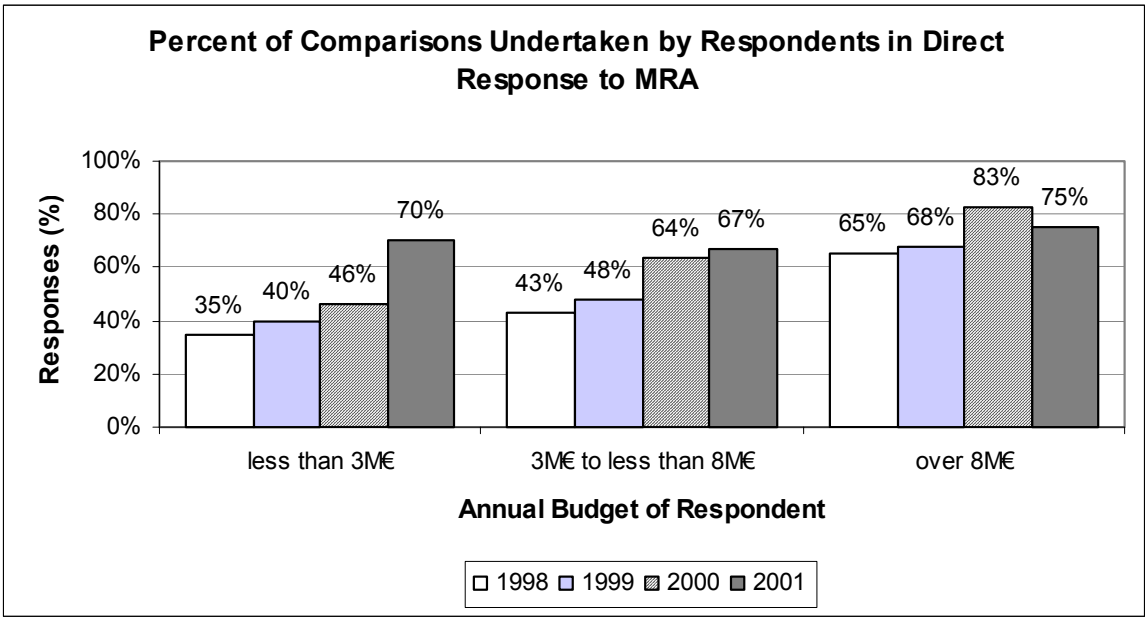
Further analysis, presented in figure 10, shows that the percentage of comparisons undertaken in direct response to the MRA has increased in the last four years from 46% in 1998 to 71% in 2001.

Figure 10 **Percentage of comparisons in response to MRA**



Analysis by size of respondent (annual budget) also reveals that regardless of size, the NMI respondents are undertaking more comparisons in direct response to the MRA. However, it would appear that the smaller NMIs (annual budget of less than 3M€) have experienced a more significant increase.

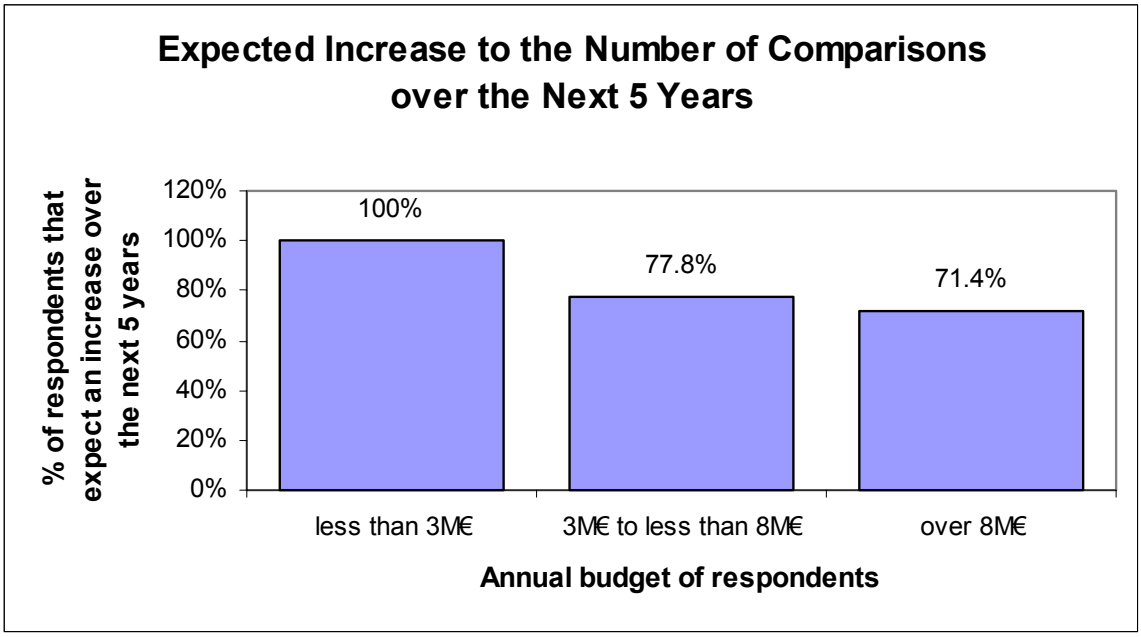
Figure 11	Increase in comparisons, controlled for budget size of NMI



6b) Do you expect this number to change, on average, over the next five years?

The majority of the respondents (84%) expect that the average number of international comparisons that their NMI participates in will increase over the next five years. Further analysis indicates that each of the smaller NMIs (annual budget of less than 3M€) expect the number of international comparisons to increase over the next five years.

Figure 12	Expected increase to the Number of Comparisons over next five years



Why/How?

Verbatim comments explaining why there will be a change in the number of international comparisons are presented below:

- *"We expect the number of RMO inter-comparisons to increase by more than 50% in the next years."*
- *"Due to increasing number of CMC's which I expect to be submitted."*
- *"We are restricted by resources."*
- *"I assume that the number of key comparisons will stabilise but that there will be a growth in the number of supplementary comparisons. There is a risk that the total number will be driven by the capacity of large NMIs to participate rather than by the principle that the performance of each NMI is sampled at a sustainable rate."*
- *"We have participated in about 20 KCs a year since 2000, and allocated almost the same amount of budget to the KC activities. The number of KCs we will participate in is not expected to change over the next five years, considering the resources (budget, man power, etc.) we will put in."*

- *"Increased pressure within the RMO to complete a greater number of key and supplementary comparisons."*
- *"The building-up phase of the MRA and confidence in NMIs' measurement capabilities will continue for some years still. It is a long-term task to cover comprehensively the necessary basis for international equivalence. A further more structured approach to CIPM and RMO key comparisons, supplementary comparisons and bilateral comparisons will have to be developed so that the needs of NMIs be met in an optimal way, allowing especially for the smaller NMIs sufficient opportunities for comparisons responding to the national needs."*
- *"Increase in accordance to RMO projects and new realizations of the SI units which are in progress."*
- *"Start up of new labs. The need to effect inter-comparisons to attain technical competencies and achieve accreditation."*
- *"It is anticipated that the number will increase because APMP will organize more regional inter-comparison to link with the CIPM key comparisons in the coming years."*
- *"The MRA requires to confirm the equivalence of the national measurement standard by participating the BIPM and regional key comparisons."*
- *"There are several time consuming and expensive comparisons in preparation. This will have a significant impact on the budget for the following years."*
- *"Increase of the number of key comparisons may result from introducing new kinds of measurements into the sphere of key comparisons as well as from a possible increase of a number of regional key comparisons."*
- *"Increase burden of MRA-related obligations."*
- *"Increasing SIM and MRA activity."*
- *"Increase the number of RMOs comparisons and subregional comparisons."*
- *"We hope to bring the number of active KC down by long intervals between repetitions."*
- *"After the initial period of the MRA, we expect the number of comparisons to decrease slightly."*
- *"It will probably increase in order to support the CMCs and for covering new fields but the answer is quite different regarding the concerned field."*
- *"While the number of CIPM MRA-related comparisons should taper off in the next few years, this reduction will be offset by the projected growth in standards maintained by CENAM."*

- *"Increase due to (1) supplementary comparisons in the SADCMET region as more countries become signatories and require links to accepted comparison data (2) comparison data possibly required for the submission of additional CMCs/capabilities to both appendices of the CIPM MRA by ourselves."*

Q7. In sum, how much does it cost your NMI to participate in comparisons on an average annual basis for the time period considered above? Please express your answer as percentage of your total budget. Costs include factors such as travel and communication time, dedication of staff's time, direct scientific/technical costs, costs of materials, costs of quality assurance, and so on.

Figure 13 reveals the average percent of the annual budget that is spent on participating in comparisons during four calendar years (1998 to 2001).

Figure 13a	Percentage average annual spending on comparisons by all NMI respondents

	Cost of Comparisons (% Budget)			
	1998	1999	2000	2001
Local RMO				
	4.0% (n=12)	4.1% (n=16)	3.0% (n=19)	3.6% (n=18)
CIPM				
	2.9% (n=13)	2.5% (n=14)	4.4% (n=16)	3.8% (n=14)
Organizations other than local RMO or CIPM				
	2.1% (n=14)	1.3% (n=14)	1.7% (n=16)	1.1% (n=12)
MRA				
	2.5% (n=10)	3.0% (n=13)	7.0% (n=15)	6.7% (n=15)

The results suggest that there has been an approximate increase in spending on comparisons of 4.5%, between the average spending in 1998 and 1999 (11.2%) (i.e., pre official signing of MRA), and the average spending in 2000 and 2001 (15.7%) (i.e., post official signing of MRA).

The following figure provides a further breakdown by NMI budget category, revealing that in a comparative sense, the medium-sized respondents spend the greatest percentage annual average on comparisons, with large NMIs spending the least.

Figure 13b	Percentage average annual spending on comparisons by NMI respondents with an annual budget of less than 3M Euro

Cost of Comparisons (% Budget)	1998	1999	2000	2001
Local RMO				
	1.7% (n=3)	1.4% (n=5)	1.9% (n=7)	3.3% (n=6)
CIPM				
	1.8% (n=3)	1.0% (n=4)	2.1% (n=4)	3.5% (n=4)
Organizations other than local RMO or CIPM				
	1.1% (n=5)	0.9% (n=5)	1.7% (n=6)	1.8% (n=4)
MRA				
	4.0% (n=1)	1.3% (n=3)	2.8% (n=4)	4.2% (n=5)

Figure 13c	Percentage average annual spending on comparisons by NMI respondents with an annual budget between 3M to 8M Euro

Cost of Comparisons (% Budget)	1998	1999	2000	2001
Local RMO				
	8.0% (n=5)	10.6% (n=5)	6.0% (n=6)	6.5% (n=6)
CIPM				
	4.6% (n=6)	24.6% (n=6)	7.6% (n=6)	5.4% (n=6)
Organizations other than local RMO or CIPM				
	4.0% (n=6)	2.3% (n=6)	2.5% (n=6)	1.1% (n=5)
MRA				
	3.4% (n=5)	5.2% (n=6)	12.7% (n=6)	12.1% (n=6)

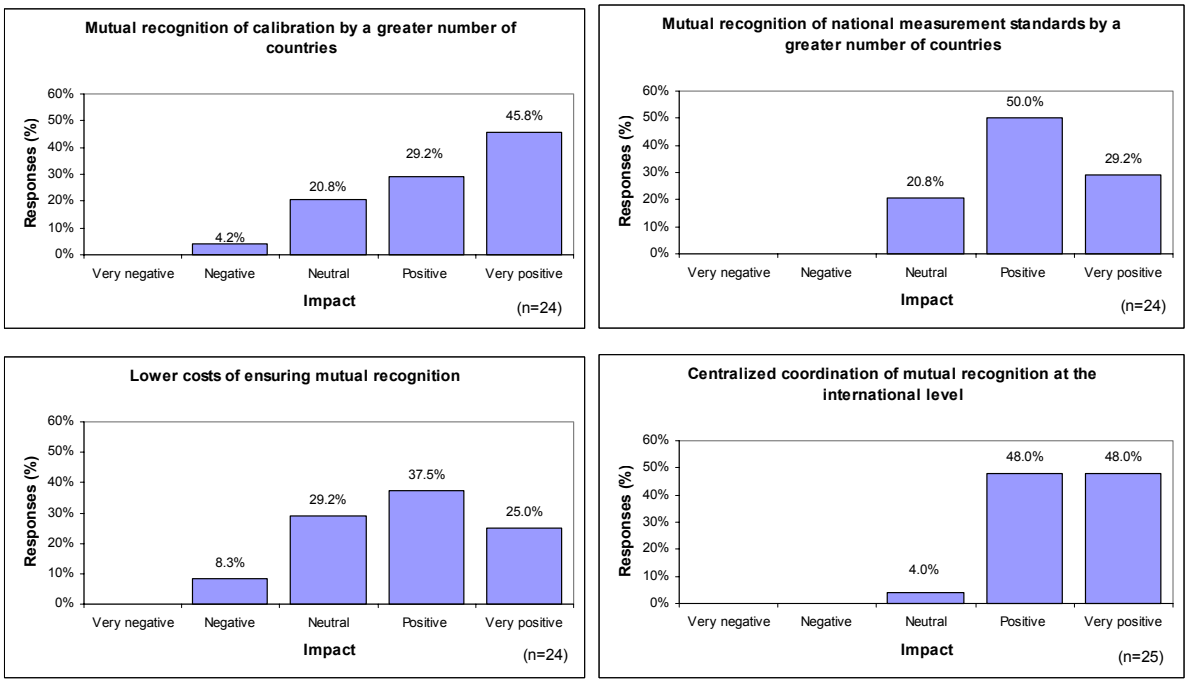
Figure 13d	Percentage average annual spending on comparisons by NMI respondents with an annual budget over 8M Euro

Cost of Comparisons (% Budget)	1998	1999	2000	2001
Local RMO				
	0.6% (n=3)	0.7% (n=5)	1.1% (n=5)	0.9% (n=5)
CIPM				
	1.0% (n=4)	1.0% (n=4)	3.3% (n=5)	1.5% (n=4)
Organizations other than local RMO or CIPM				
	0.1% (n=3)	0.1% (n=3)	0.2% (n=3)	0.2% (n=3)
MRA				
	0.9% (n=3)	0.6% (n=3)	4.4% (n=4)	1.1% (n=3)

Q8. How would you characterize the benefits to your NMI of participating in the MRA?

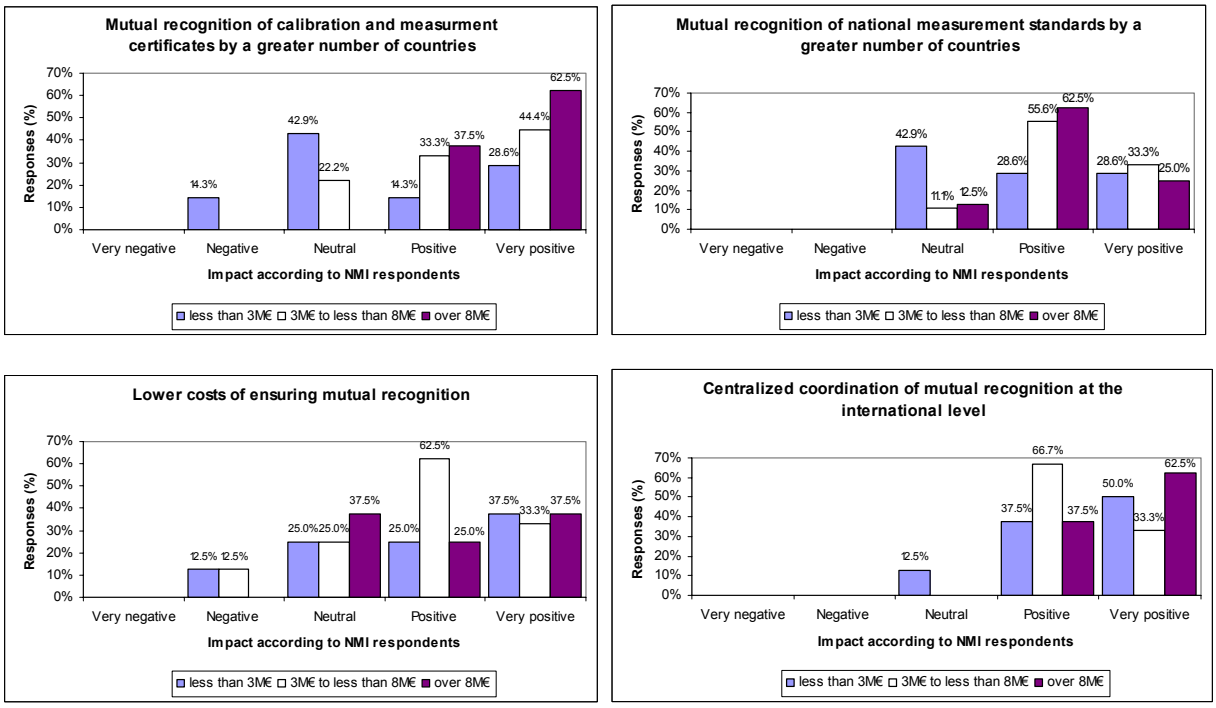
The following figures show the key benefits to respondents from participating in the MRA.

Figure 14a **Key benefits to NMI due to MRA**



The following figures provide responses to the benefits that result from participating in the MRA by size of the responding organization (i.e., annual budget of the responding NMI).

Figure 14b	Key benefits to NMI due to MRA broken down by the annual budget of the responding organization



Q9. For those benefits you identified as being "very positive"/positive" or "very negative" impact, please briefly explain why this is, in your opinion.

a) Mutual Recognition of national measurement standards by a greater number of countries

- *"KCDB allows industry and users access to information on all NMI's."*
- *"We could evaluate the level of our national measurement standards against other NMIs."*
- *"Formalizes recognition between 40+ NMIs in a way that would not be possible based on bilateral arrangements."*
- *"This gives special political added value in making the NMI's activities more visible and directly comparable with other countries. It will also have a positive*

impact metrologically and economically through effective networking and cooperation regionally and globally, especially for smaller NMIs."

- "Because of the tightening increased requirements of global trade."
- "The MRA provides a reputable technical framework through which our measurement standards are recognized by most, if not all, of our trading partners who are signatories to the MRA."
- "Recognizing the equivalent of the national measurement standards by a greater number leads to the elimination of the technical barriers to trade."
- "This works in several ways - making our own measurement standards better known but also ensuring that we have been knowledge of the way in which standards are maintained in the NMIs of those countries with which we trade and collaborate scientifically. The processes also put more pressure on Laboratories that up to now may have had over ambitious claims in areas where the absence of comparisons and thorough assessment of uncertainty budgets has not been possible bilaterally."
- "The fact that all leading NMIs are participating in MRA gives it great status and authority.
- "Reduced number of bilateral comparisons."
- "Export oriented economy, avoiding of trade barriers, support of foreign investors."
- "International acceptance of our national measurement standards impacts the acceptance of our nation's products and services in various ways. One is through the requirements of quality management standards like ISO 9000 and QS 9000. Another is through customer requirements, whose trust in a supplier is often related to the perceived as well as the actual reliability of the national measurement system."
- "The globalization trends, especially concerning WTO TBT arrangements and progress made world-wide with the formation of trading blocs favours the CIPM MRA approach than traditional bi-lateral agreements that ultimately remain an expensive and complicated task."
- "Support to our industry, independence from traceability to national standards of other countries."

b) Mutual Recognition of calibration and measurement certificates by a greater number of countries

- *"Through the availability of the KCDB and CMC database."*
- *"Services provided by us could be recognized by greater number of countries."*

  "Broad based recognition and acceptance of calibration reports by NMIs, accreditation bodies and regulators."
- *"This is the practical end-result of the MRA effort. Acceptance of conformity assessment certificates very much depend on reliable measurement results underpinning the test reports and certificates (accredited or not). There already are some (weak) signals from the manufacturing industry that reference to the BIPM database has effect in lowering of the trade barriers."*
- *"This recognition is important in our trade facilitation."*
- *"When a calibration from one country is accepted across the borders, then recalibration costs is eliminated."*
- *"This is certain to be one of the huge benefits of the MRA, particularly as we engage the commitment of accreditors and regulators. Recognition at the NMI level is technically valuable and gives overall confidence in the efficacy of the world measurement."*
- *"Reduction of trade barriers."*
- *"Important pre-requisition for trade and industry."*
- *"More rational approach of the capabilities of the NMIs."*
- *"Recognition of calibration and measurement certificates is supported by the acceptance of national measurement standards discussed in the previous paragraph. It is important to recognize specifically the equivalence of calibration certificates in accepted ranges and levels of uncertainty in order to reduce technical barriers to trade and promote non-regulated commerce."*
- *"Similar to (a) but added the benefit to commercial accredited laboratories and international acceptance (formally) of measurement results produced by NMIs."*
- *"Support to our industry, independence from traceability to national standards of other countries."*

c) Centralized coordination of mutual recognition at the international level

- *"Gives increased credibility to the process"*
- *"The key benefit is that there is now a single path for mutual recognition that is seen as credible both inside and outside the metrology community. For our situation with trading partners the other factors appear neutral."*
- *"It's simpler and cost-effective compared to many bilateral MRAs."*
- *"Reliable and coherent basis for mutual recognition."*
- *"The role of the BIPM is crucial in building up and sustaining the international database, the key issue for the functioning of the MRA."*
- *"In order to avoid time consuming and costly repetition of bilateral activities"*
- *"Better coordination, increased efficiency reduced operational costs."*
- *"This may be only a mean that leads to the mutual recognition of the equivalence among countries regardless of their location or economics."*
- *"In the absence of BIPM and the MRA, we would need to invent it. Clearly it would be a nonsense for all countries to engage in bilaterals and individual approaches to each other or to international bodies (WTO, WHO etc). The costs of this would be enormous"*
- *"The MRA provides the NMIs with the same procedures for planning and carrying out the key comparisons as well as the same approaches to processing the results and presenting them and the CMC data for the data bases of BIPM. The centralized coordination of mutual recognition at the international level provides a more objective estimation of equivalence."*
- *"No need for local or regional databases."*
- *"Better support and greater influence on reduction of trade barriers."*
- *"The only way to serve a globalized economy."*
- *"Cost effective co-operation, exchange of know how"*
- *"Avoid a lot of bilateral recognition and a better co-ordination for the comparisons"*

- *"Centralized coordination allows for the recognition of a larger number of NMIs without having to repeat the negotiation process and carry out a larger number of comparisons."*
- *"Much improved efficiency much improved administration and much more transparency being brought into the system with added credibility."*
- *"Before the MRA the process was quite random, unclear, and many times policy driven."*

d) Lower costs of ensuring mutual recognition

- *"Cost is a limiting factor for the operation of many NMI's. EUROMET intercomparisons within MRA since they are of low cost, encourage NMI's to participate."*
- *"No evidence yet, may be too early."*
- *"Reduces significantly the number of bilateral comparisons to achieve the same level of mutual recognition."*
- *"This is to be seen. Within the EUROMET region the on-going cooperation including comparisons appears to have been effective for the EU purposes (single market, accreditation MLAs). The CIPM MRA will continue to mean additional efforts in the years ahead and it is now very difficult to estimate the costs."*
- *"One MRA instead of many bilateral arrangements."*
- *"The MRA would eliminate the costs of the multiple peer reviews for bi-lateral MRA."*
- *"Certainly very significant efficiencies exist - bilateral comparisons, approaches to international bodies, etc are just not practical. The added value to an individual NMI of the* attention paid to its own CMC analysis and to the experts drawn from network of partner labs that are involved in comparisons is huge. Equally we have only begun to assess the benefits of quality systems as far as internal improvements are concerned as well as the inevitable improved services to clients."
- "No need for multiple bilateral agreements."
- *"At least for the time being the cost of the KC's are quite high."*
- *"Reduction of third party quality audits"*

- *"This is related to the previous question. As it is, the CIPM MRA is a very expensive proposition. The costs reported in this questionnaire do not include labor."*
- *"NMIs consider comparisons an integral mandated activity and thus the costs associated with that. although we do not expect that costs will decrease, but rather increase, there is great support that much better "value for money" is achieved through this"*
- *"Key comparisons have increased the costs quite substantially, too much driven by a sense for completeness"*

e) Other (please explain)?

- *"Intercomparisons have a great contribution to the growth of new NMI's and offer very valuable experience and know-how."*
- *"In order to support the government and industry in a small country with limited metrological it is necessary to collaborate with bigger NMIs. The CIPM MRA opens an easy access to information suited for various national needs."*
- *"Because certification/accreditation international agreements require also metrological recognitions."*
- *"Without the CIPM MRA, the measurement standards of the developing countries would have only slight chance to be recognized or accepted by a developed country."*

Q10. How would you characterize the benefit, or potential benefit, to other organizations in your country of your NMI signing the MRA?

The following figure identifies the other organizations that stand to benefit from the MRA, as understood by the NMI directors.

Figure 15a **Other organizations likely to benefit from MRA**

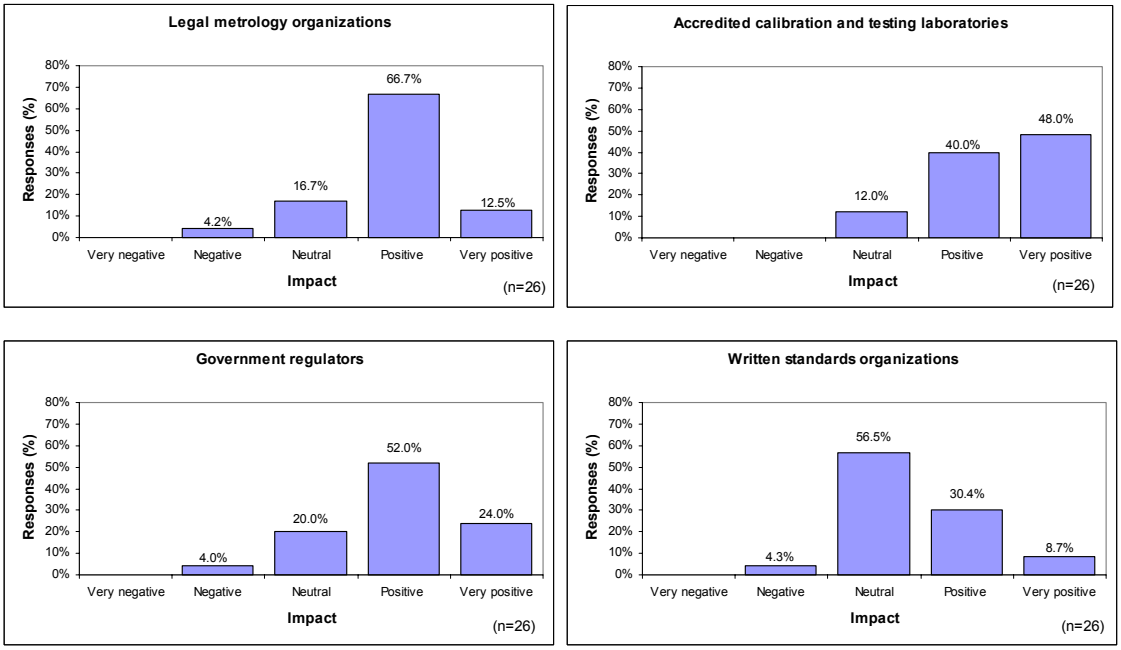
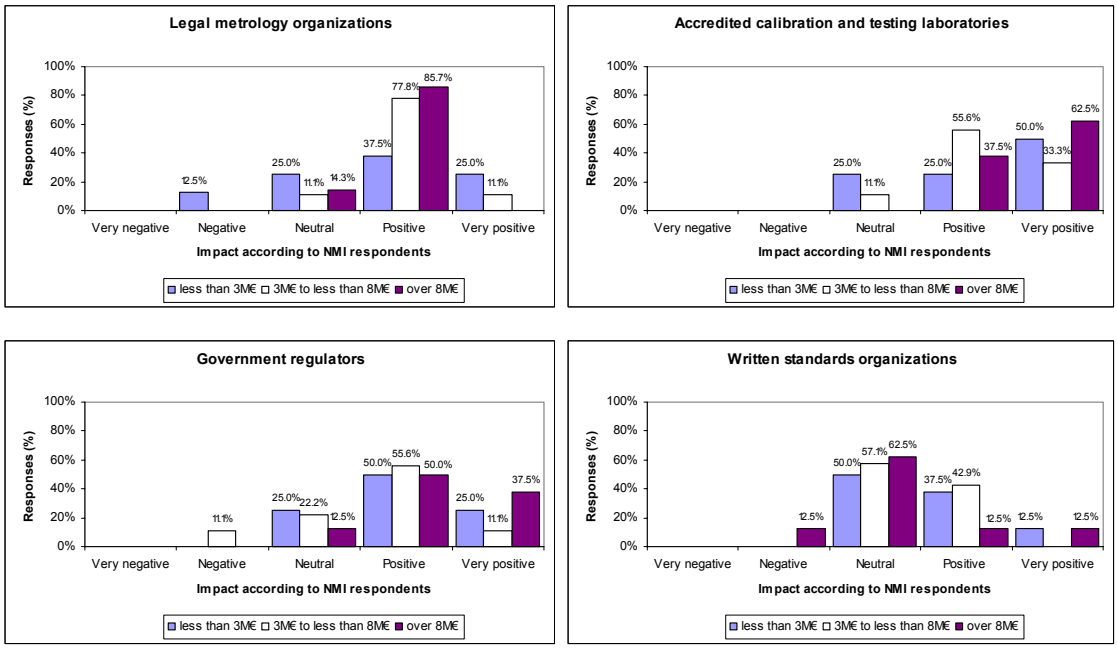


Figure 15b provides responses to the benefits that result from participating in the MRA by size of the responding organization (i.e., annual budget of the responding NMI).

Figure 15b **Other organizations likely to benefit from MRA according to NMI respondents**



Q11. For those organizations that will receive a "very positive/positive" or "very negative" impact due to the MRA, please briefly explain why this is, in your opinion.

a) Accredited calibration and testing laboratories

- *"Traceability of measurements to an internationally recognized NMI has direct contribution to the recognition and acceptance of their own services and certificates, especially when offered abroad."*
- *"The KCDB and CMC's provide concerted, quantitative information for users."*
- *"Supporting the process that underpins the mutual recognition of accredited laboratories is very important."*
- *"Can have the opportunity that their calibration and/or test reports be accepted by other accredited laboratories in other countries."*

- *"Will provide a basis of mutual acceptance of accreditation and measurement traceability."*
- *"See point 6 b). The laboratories serve the end users, industry, trade, government institutions etc, and there the value added must be measured."*
- *"Because it contributes to the acceptance of their certificates"*
- *"They will have the access to the measurement standards of and calibration certificates issued by an internationally recognized metrology institute."*
- *"Could ensure that the results of measurement generated by them are accepted worldwide."*
- *"These are already sensitized to the MRA through the national communication channels. We have had direct contact with several that are concerned with gaining easier access to export markets, particularly the US. We expect more proficiency testing and checks to see that the national traceability systems are consistent with those in other countries, with more attention paid to the ways in which uncertainties propagate down the national chains so that we can understand whether differences at the NMI level are significant as far as accreditation and compliance with written or regulatory standards are concerned."*
- *"The level of confidence of the customers to the works carried out by these laboratories is increased since the measurements they do are traceable to our internationally recognized measurement standards."*
- *"Authoritative support for traceability obtained through other NMIs and evidence to support status of traceability to us."*
- *"Greatly increased acceptability for the traceability to national standards."*
- *"Easier access to the calibration services abroad, support of the MLA (in accreditation)"*
- *"Better traceability links and recognition of the calibration and testing activities related to ILAC activities"*
- *"Calibration and testing laboratories are fundamental for disseminating the accuracy of the national measurement standards. As explained above, it is proposed that ILAC be the signatory"*
- *"A direct benefit in (1) support of the ILAC MRA and (2) an acceptable way forward around the problem often experienced still of specific requirements for "traceability to a specific country's measurement standards" prior to work*

being accepted by foreign users - notably when current problems with regulatory authorities are considered"

- *"Traceability is a necessity for accredited calibration and testing laboratories"*

b) Legal metrology organizations

- *"Measurements in the field of legal metrology traceable to an internationally recognized NMI have a strong validity and are recognized in cases of disputes"*
- *"Can enhance the reliability of their task (e.g., verification) by using the reference standards whose accuracy are accepted internationally."*
- *"The legal metrology service is inherently responsible for reliable measurements in a country. In many cases NMIs themselves are national legal metrology services. It will be interesting to get direct evidence from e.g. OIML on the impact of the MRA."*
- *"Because it contributes to fulfill the requirements of the harmonized regulations"*
- *"Could ensure the enforcement of the weights and measures laws is fair."*
- *"Similar issues - ILAC is thought to be less happy about accredited labs that claim traceabilty to legal metrology labs and their involvement in, and support of the CIPM's MRA will help reduce concerns in this area."*
- *"The activity of legal metrology organizations is more effective when they work in close cooperation with the NMIs having national measurement standards the equivalence of which to the measurement standards of other states of the world has been recognized on an international level."*
- *"In support of common regulatory practices notably concerning legal metrology as a sub-set of regulatory frameworks, it would most definitely be well received should the MRA provide a basis for establishing the degree of equivalence amongst measurement standards as well as international recognition for certificates issued in support of legal metrology standards/regulations."*

c) Written standards organizations (e.g., ISO member bodies)

- *"Collaborate with the standardisers, accreditors and also regulators on metrological questions. The standards organizations need, however more problem oriented support than equivalence of national standards, e.g.,*

participation in development of testing and measurement standards and general QS standards. Yet via standards the knowledge of the existing global structures and equivalence of measurement standards and calibration certificates could be distributed most efficiently."

- *"Could base their requirements on the traceability of measurement to the MRA."*
- *"Little impact so far but increasing signs that if accreditors and regulators take more interest in the measurement aspects of written standards then drafters will be obliged to take this issue more seriously and at an earlier stage in the drafting process."*
- *"Simple international system of traceability to S.I."*
- *"When global harmonization of standards is considered (1 standard, 1 test, etc) for product specification especially, the MRA is an essential component for ultimate success."*
- *"Greater interest for describing traceability and measurement uncertainty requirements in written standards"*

d) Government regulators

- *"Basis for mutual acceptance of measurement traceability and compliance with regulations."*
- *"Could make reference of their requirements and criteria for examination from their own NMI."*
- *"Greatly improved trust in the equivalence of national standards."*
- *"Harmonization, easier conformity assessment"*
- *"Better acceptance of the measurements performed in the regulated areas, no duplication of the calibrations and related audits."*
- *"Government regulators have the greatest role in the global efforts to reduce technical barriers to trade."*
- *"A most vital element for notably intra-regional trade will require harmonization of legislation in support of the acceptance to equivalent measurement standards."*
- *"Hopefully, the traceability requirements to national standards will disappear from governmental regulations"*

e) Industry

- *"Measurements of products traceable to an internationally recognized NMI provide proof of reliability and confidence as well as advantages (direct or indirect) for exports of these products."*
- *"Can promote their international trade by using the internationally accepted test reports and/or calibration certificates."*
- *"Recognition of measurement traceability in compliance testing."*
- *"Because it facilitates export"*
- *"Would be able to ensure the worldwide acceptance of its product quality by the use of the measuring and test equipment that are traceable to its own NMI."*
- *"To be honest we are still at an early stage as far as industry is concerned, although the MRA is giving more world-wide confidence at the NMI level."*
- *"No need for exporters/importers to get multiple traceability."*
- *"Eliminating of trade barriers"*
- *"The MRA ultimately supports the WTO TBT agreement and most definitely play a crucial role to support the diversification of exports and global trade, rule out requirements for re-testing/measurement and support business. More interaction has also been stimulated amongst countries with a better network existing than ever before and more sharing of technologies and expertise. Often to also the benefit of national industries."*
- *"Better acceptance of products world-wide, when the condition described under (d) will be fulfilled"*

Q12. By signing the MRA, you have the opportunity to ensure mutual recognition with all other signatories, in those key comparison areas deemed important to your NMI. Are you yet able to evaluate or characterize the benefits of the MRA, as compared to your experiences prior to the MRA being signed in 1999? If so, please explain.

- *"Too early to be able to undertake a useful evaluation."*
- *"It is still to early to have evidence of benefits, in part because Appendix C is still under construction. Prior problems were largely with regulatory bodies in other countries and*

while it is expected that the MRA will assist with resolving them, we continue to rely on case by case ad hoc solutions."

- *"Awareness of the importance of quality system in every aspect of services we provide to clients.*
- *"More complete coverage of key measurement activities and techniques through a broader and more focused range of comparisons."*
- *"Not really, but you may find some indicators in the earlier answers."*
- *"We are not yet able."*
- *"Not applicable to our Laboratory."*
- *"We are not yet able to evaluate or characterize the benefits of the MRA because our CMCs are still evaluation by the JCRB."*
- *"Evaluation is difficult in these early days, but we have already had the results of several comparisons which have raised doubts about the performance of large NMIs in critical areas. We have also re-examined the results of one in which we have participated and which has shown up an unexpected effect that would have either gone undetected or would have needed a major research programme to address. "*
- *"We receive objective information about the level of metrological assurance around the world."*
- *"Too early for evaluation."*
- *"More reliable national standards, harmonized and mutually reviewed calibration and measurement capabilities".*
- *"MRA is in transition period, benefits are expected, experience is being gathered"*
- *"Not yet any visible benefit, except more exchange with the NMIs and the BIPM"*
- *"Yes, the benefit technological and improvements resulting from the Quality System implementation."*
- *"It is too soon to see the benefits of mutual recognition but we can see benefits already in the areas of method validation and improvements in our measurement processes"*
- *"No evaluation has been performed yet. "*
- *"As yet, the benefits are not visible, although discussions with other organizations such as ILAC, and ISO, indicate that the benefits will grow in the near future. The benefits for*

industry are still hampered very much by national legislation requiring traceability to local national standards."

Q13. In the absence of the MRA, would your NMI have been obliged to engage in mutual recognition arrangements with other NMIs that you had not already engaged by October 1999? If so, with how many?

- *"Because of export oriented economy we would have carried out bilateral comparisons with the most important 8-10 commercial partner countries"*
- *"At that time we clearly required and agreement with the USA and with Europe. It is not clear how many agreements might have been required in Europe and it would probably have been restricted to two or three trading partners."*
- *"We had already been engaged in MRA with ONE NMI before the CIPM MRA was signed. Also, we had had in mind to extend it with more NMIs of the advanced countries who have been the major trade partners of our country."*
- *"The trade negotiations between the EU and USA have raised the question of accepting the traceability of measurement to an EU NMI instead of the NIST. There are some specific cooperation on the EU level to deal with the problem. The exporting industry has chosen to use the NMIs accepted by the US authorities. There are also some cases with Japan. The MRA has been signed to solve these problems."*
- *"At least with 5."*
- *"We have no other arrangements apart from the MRA."*
- *"We had not planned for such engagement until 2004. This is just because we are a newly established NMI, therefore, our first priority is to build up capabilities, as a minimum, equivalent to the neighbouring country NMIs."*
- *"Certainly so. We have had informal arrangements in Euromet for many years and these would have needed to be formalized as far as the EU single market is concerned. We also have had past agreements with about 10 major countries, which have lapsed pending the MRA. My guess is that in today's trading environment we would have wanted to make agreements with 20 countries- especially if accreditors and regulators started asking questions about consistency and as regulations and standards extended away from traditional areas into new ones."*
- *"Yes. All NORAMET members. Leading members of SIM, EUROMET and APMP."*
- *"Yes. We feel the necessity of the MRA in the area of calibration certificates recognition."*
- *"Probably not, as we are well recognized."*

- *"Very probably with the main trade partners, e.g., with at least 10 countries."*
- *"Yes, with NMIS of the RMOs outside EUROMET."*
- *"Most definitely. Prior to the MRA at least 8 bilaterals were in place, at least one was not renewed. Unless the MRA can also provide a sound basis for US regulatory agencies (e.g. FAA, FDA) to accept traceability to foreign NMIs, bilaterals may still be required."*

Q14. Are there actors or organizations that you view to be of fundamental importance to the success of the MRA over time? Please describe which actors/organizations and why/how they are important.

- *"BIPM and RMO's - to ensure the continual implementation of the MRA--Accreditation organisations and Regulatory Authorities must become strong supporters of the MRA, otherwise its value will be diminished."*
- *"NMIs and RMOs carrying out comparisons and providing reliable data--Calibration laboratories using the disseminated capabilities for sake of traceability--Accreditation bodies applying the database at the assessment--Standardising bodies and regulators paying attention the limits of measurement capabilities-- Manufacturers, traders, etc."*
- *"I recognise 3 key organisations:--WTO. It is important that the WTO recognises and supports the role of our MRA in removing non-tariff trade barriers. Explicit reference to this MRA by the WTO would assist governments working to harmonise their measurement, standards and conformance infrastructures.-ILAC. Clearly development of the MRA must continue to be supported by accreditation bodies as they are major beneficiaries.-- OIML. It seems unlikely that non-specialists could ever perceive a clear difference between the roles of the CIPM and the OIML. It is important that both organizations support each other to achieve a common framework for mutual recognition."*
- *"Collaborations of laboratory accreditation organizations such as ILAC and APLAC. The effects of the MRA shall be disseminated by those organizations ultimately."*
- *"It is vital that key user groups have an awareness of the MRA and the confidence and trust to use it. Key groups are the accreditation bodies and regulators."*
- *"From the point of view of a smaller economy, it will be most important to reach a balanced and solid structure where the capabilities are recognised on the level relevant to the economy. The smaller NMIs must have possibilities to participate in metrologically accessible comparisons with major NMIs as pilots. All possibilities of regional key or supplementary comparisons and bilateral comparisons should be clarified and access to them should be guaranteed. The smaller NMIs are in many cases depending on the major NMIs for their own traceability, but to serve their industry they should be included in the database on equal footing to recognise their level of equivalence."*

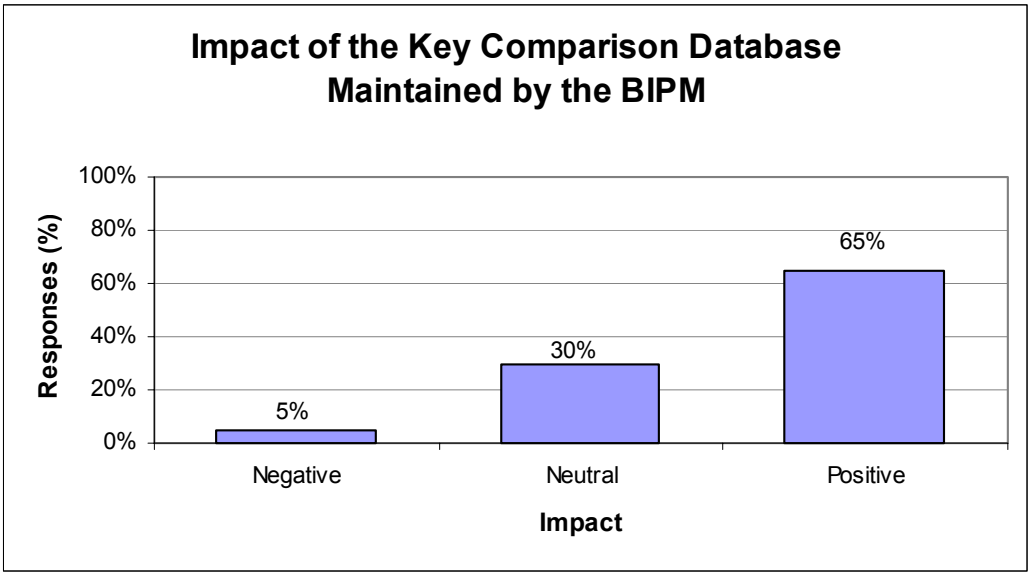
- *"ILAC, OIML, ISO because of the relationship of metrology the fields covered by those organizations"*
- *"BIPM, ISO and ILAC including their respective regional organizations play the most important role for the MRA. ISO defines the requirements for the quality management and competence of testing and calibration laboratories and ILAC aims for the conformity assessments while BIPM is responsible for the equivalent of the measurement standards."*
- *"European Union.-This is a typical and already existing example for mutual recognition."*
- *"WTO, Regulators, ILAC and accreditation bodies. Increasingly the attractiveness of the MRA to new areas of technical interest will be enhanced because of our ability to offer a proven and working system of displaying and creating international consistency of measurement. There are also the new Associate Members of the Metre Convention to be considered. Most, we believe, join because of the perceived trade benefits. In time I would hope that all would gravitate towards full Metre Convention membership with enhanced credibility and benefit for them and well as the Convention. In addition, Associate Membership has helped bring some new and developing or newly independent countries into the network"*
- *"CIPM, BIPM, JCRB, Inter-state Council on Metrology and Standardization of the member states of the CIS, the Gosstandart of Russia. All these organizations provide a single metrological space."*
- *"The principal actors are the NMIs who bear the brunt of effort."*
- *"BIPM, RMOs, EA, ILAC, NMIs"*
- *"Regional Metrology Organizations with important MRA tasks- Accreditation Organizations promoting traceability to the SI. Government regulators should recognize CMCs provided by MRA signatories world-wide."*
- *"ILAC, BIPM, WTO, TBT"*
- *"CIPM/BIPM as a central coordinating"*
- *"BIPM as the co-ordinator of the MRA through the JCRB, the CIPM as the manager of the MRA, the CCs taking care of the comparisons, the RMOs as in charge of the CMCs and the main contributor and link between the NMIs and the BIPM"*
- *"The MRA will be successful if it can reduce technical barriers to trade and promote in the private sector confidence for suppliers from signatory countries. Therefore, acceptance by Government regulators and large trans-national companies or coordinated sectors like the automotive or oil industries will be fundamental for the continued success of the MRA. Of course, this assumes the strength of the JCRB and a continued commitment from all its participants."*

- *"ILAC, ISO, legal bodies, and professional scientific organizations."*

Q15. How would you describe the impact, so far, of the key comparison database maintained by the BIPM? Please explain your answer.

Approximately two-thirds (65%) of respondents view the key comparison database maintained by BIPM as having a 'positive' impact.

Figure 16 **Impact of the Key Comparison Database Maintained by the BIPM**



- *"The role of ISO 17025 accreditation in the MRA remains unclear. There is merit in creating an application document for NMIs. This could help in clarifying understanding of recognition through the MRA in addition to recognition through accreditation."*
- *"The additional cost of maintaining accreditation to satisfy the quality system requirements of the MRA is estimated to be ~150K per annum, in addition to the key and supplementary comparison programs."*
- *"The information above includes the metrological activities of the NMI but not the accreditation activities. The accreditation division has 18 + staff. There are also some operational national standards laboratories in other organizations outside the NMI, but their financial or staff data is not included, except for data on comparisons."*

- *"However, even though the BIMP MRA was signed and has been taken as the systematical tools to be followed for the mutual recognition of the equivalence of the NMIs capabilities, I think there are still some problems in practices. I wish those should be solved taking into account the interests of both industrialized and developing economics."*

- *"One of the main results of the key comparisons is the determination of a reference value (KCRV). Frequently this KCRV contradicts the physical sense of the definition of a physical quantity unit. We believe that it is necessary to consider some other estimates for evaluating the equivalence without application of KCRV."*

4.0 Implications for BIPM

There are three classes of implication for BIPM that result from the theoretical and empirical examination of the Mutual Recognition Arrangement.

1. Efficiency gains from the MRA – The MRA creates a formalized structure for mutual recognition between NMIs in a manner that is more efficient than an equivalent system of bilateral relationships. For BIPM, this implies that the central coordination of mutual recognition should be viewed as a positive economic outcome of the MRA. The organizational role played by BIPM in helping to facilitate relationships, based partly on its neutral international standing, and partly on its administrative function, is viewed as a positive impetus for creating the benefits of the MRA.

2. Institutional and organizational arrangement of the MRA: Reducing TBT – The MRA provides the institutional framework for governing relationships between NMIs in their production of mutual recognition. It also represents an institution upon which *other* related organizations can base their actions; this potential is discussed below, primarily in the context of the MRA's potential in facilitating the reduction of TBT. The role that is required of BIPM in this regard has several potential implications for its strategic and managerial focus moving forward, including the possibility of assuming a more direct role in promoting the importance of the MRA to other international organizations.

3. Longer term development of the MRA: Key Issues – The longer term development of the MRA is also important to consider, as it points to a set of key issues that will frame the implementation and impact of the MRA over time, including an appropriate role for BIPM.

As mentioned above, the implications are based on the theoretical presentation, the survey results, and the information and judgments gathered in the interviews. The following discussion is thus a reflection of the economic role of the MRA and of BIPM, informed by the views of the NMI Directors who responded to the survey, the NMI Directors interviewed directly, and the other key individuals involved in metrology, and the governance of international trade.

4.1 Efficiency gains from the MRA

With regards to its direct effect on NMIs, the MRA creates efficiencies through the centrally coordinated system of mutual recognition, in comparison to an alternative system that might be characterized by a multiple set of bilateral arrangements. This is an important impact given that NMIs are charged with the responsibility, both scientifically and in terms of costs, for ensuring international mutual recognition for national standards and measurement capabilities. And even though the largest positive effect of mutual recognition is likely to be the result of trade facilitation for which NMIs have no immediate responsibility, it is reasonable to conclude that the MRA does confer direct benefits in terms of an avoided cost to the NMIs.

A monetary measure of these benefits can be estimated as follows:

- It is reasonable to assert that signing the voluntary MRA is evidence of NMIs' desire to establish mutual recognition with each other. By signing, NMIs reveal their willingness to invest in the process(es) whereby mutual comparability and acceptance of national standards and measurement capabilities is ensured.

- The assertion that signatories are willing to invest in mutual recognition is borne out by the results of Question 8 of the NMI Survey:

  - 75% of respondents have a 'positive' or 'very positive' impression of benefits due to *mutual recognition of calibration by a greater number of countries*

  - 79% of respondents have a 'positive' or 'very positive' impression of benefits due to *mutual recognition of national measurement standards by a greater number of countries*

  - 63% of respondents have a 'positive' or 'very positive' impression of benefits due to *lower costs of ensuring mutual recognition*

  - 96% of respondents have a 'positive' or 'very positive' impression of benefits due to *centralized coordination of mutual recognition at the international level*

- It is reasonable to suggest that a majority of signatories to the MRA would have engaged in some degree of bilateral comparison or mutual recognition, beyond their RMO, in the absence of the MRA. This assertion is supported by respondents' comments to Question 13 of the NMI Survey provided above, and by the revealed preferences of the NMIs to establish mutual recognition through the MRA.

- The efficiency of the MRA can be calculated by looking at the costs of comparison activity and the number of NMIs with which mutual recognition is established, in both the pre- and post-MRA settings. The extent to which mutual recognition has been established post-MRA is clear: there are currently 48 signatories, implying that each signatory NMI enjoys mutual recognition with 47 other NMIs. In the pre-MRA environment, however, the number of formal (bi-lateral) mutual recognition arrangements between NMIs was relatively small (e.g., Canada had only 3 pre-existing mutual recognition arrangements, with Australia, the United States, and the United Kingdom). In the absence of a 'data-base' of these arrangements, we estimate the upper limit of these relationships by considering membership in the RMOs.

- Based on NMI membership in RMOs, the average number of pre-existing relationships with MRA signatories can be measured by comparing RMO membership to MRA membership. This comparison indicates that, on average, direct contact with MRA members through RMO membership in the pre-MRA setting numbered approximately 12; post-MRA this number is 47, suggesting an increase of 4 times (for survey respondents as a subset, this number is

approximately 14 pre-MRA, to 47 post-MRA or roughly 3.4 times).[8] It must be emphasized, however, that RMO relationships are not the equivalent of mutual recognition arrangements, and thus the number of pre-MRA arrangements must be treated as an upper-limit estimate.

- The corollary to using RMO membership as an upper-limit estimate of pre-MRA mutual recognition is that the calculated increase in mutual recognition arrangements post-MRA is therefore a lower-limit estimate.

- As revealed by the NMI Survey (Question 7), respondents indicated that there has been an approximate increase in average annual spending on key comparisons of 4.5% (or approximately 720k €), post-MRA (2000 & 2001).

- The results of the Survey therefore suggest that based on a reasonable, conservative, interpretation of the costs of establishing mutual recognition, **the centrally coordinated MRA provides for approximately a 3-times increase in the number of NMIs with which mutual recognition is established, at an approximate increased cost of 4.5% of annual NMI budget**.

- Another way to interpret this result is to compare the 'average cost per mutual recognition' pre-MRA, versus post-MRA. Pre-MRA, survey respondents had arrangements through their RMOs with an upper-limit average of approximately 14 MRA NMIs, at an average annual cost of 11.2% of their budget, or roughly 130k € for the establishment of mutual recognition with one other NMI. Post-MRA, these same NMIs had established mutual recognition with 47 countries, at an average annual cost of 15.7% of their budget, or roughly 55k € for the establishment of mutual recognition with one other NMI. In other words, on a per-country basis, **the MRA results in an approximate 75k € reduction per year in the (opportunity) cost for the establishment of mutual recognition with one other NMI.** This figure should be treated as a lower-limit estimate.

- The results also indicate that for each of the *n* signatories of the MRA, the cost of establishing and maintaining mutual recognition with each partner NMI is 75k € lower than it would be without the MRA. The total saving to the community of *n* NMIs is thus (*n*/2)(n-1) multiplied by 75k €. For 48 NMIs this amounts to approximately 85M € per annum, at present levels of cost and comparison activity. Taking account of mutual recognitions that were already in place before the MRA would reduce this figure somewhat, but pre-MRA mutual recognitions are thought rarely to have included the many checks and reviews that the MRA procedure now requires and were, therefore, likely less robust. The conclusion is that **the cost of establishing mutual recognition on the scale currently achieved would have been prohibitively expensive in the absence of the centrally coordinated MRA.**

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[8] *This number is calculated by looking at RMO membership, and discounting RMO members that are common with the MRA (e.g., Chile is a member of SIM, where SIM has 6 other MRA members – Chile's membership in the MRA increases its mutual recognition by 41, excluding itself; Germany, by contrast, is a member of EUROMET and COOMET, and had relationships with 25 other MRA members, indicating an increase of 22, excluding itself).*

The efficiency gain to NMIs associated with the MRA is a function of the centrally coordinated process of comparing and recognizing key references and CMCs on a multilateral basis, as opposed to a multiple bilateral basis. The results of the survey and subsequent interpretation indicate that this efficiency gain is suggested to be in the order of 75k €, as a lower-limit estimate per country newly recognized as a result of the MRA. For BIPM, this implies that the MRA, even though it raises costs to NMIs in gross terms, establishes mutual recognition amongst its member NMIs at a rate that is, arguably, lower than a comparative system of bilateral arrangements. This argument rests on the assertion that the pre- and post-MRA costs of comparisons, as revealed by the NMI Survey, are a reasonable estimate of the annual costs of establishing mutual recognition between MRA NMIs, and an associated assertion that MRA members have revealed their preference for establishing mutual recognition with other members, simply by signing the voluntary MRA. In both cases, there is no reason to suggest that either assertion is fundamentally flawed, and thus it is reasonable to conclude that based on the results of the NMI Survey, the MRA confers a net benefit to its members.

That this benefit is directly linked to the role that BIPM plays in organizing, coordinating and administering the MRA is inarguable. Respondents to the Survey also appear to view BIPM's role as favourable in this regard (see Question 9 and 14 above). Still, the creation of benefits in the MRA is not the singular role of BIPM, and therefore it is not prudent to conclude that BIPM could be ascribed a 100% "share" of the efficiency gains. The corollary to this statement, however, is that the MRA itself would not exist in the absence of a central coordinator/administrator, and that de facto, this role is and *should* be played by BIPM as the obvious neutral international body with the historical experience of facilitating international metrological relationships. This is not the same thing as suggesting that 'BIPM creates a 75k € efficiency, per country, in the costs necessary to establish mutual recognition amongst signatory nations', but rather that 'BIPM is one of a number of organizations responsible for this efficiency'.

The magnitude and endurance of the efficiency gain of the MRA is, however, subject to two concerns that have been highlighted in the NMI Survey, and should also be viewed as implications for BIPM. The first of these is that the MRA is in the early stages of its development. As such, several NMIs feel it is difficult to assess the direct impact it has on their own activity (see Question 12), and this is also extended to the impact on other organizations. Secondly, a majority of Survey respondents feel that the number (and hence cost) of key comparisons is likely to increase over the next five years (see Question 6b). By extension, this implies that the cost of mutual recognition is, perhaps, also variable over time. Moreover, the voluntary nature of the MRA implies that if the costs of mutual recognition outweigh their long-term benefits, the MRA might be viewed unfavourably by some nations. Indeed, we return to both of these points below, in a discussion of future term implications.

4.2 Institutional arrangement of the MRA: Reducing TBT

The MRA establishes an institutional arrangement upon which relationships between signatory NMIs are organized. It is also the case that this institutional setting is important for other actors

involved in the world of metrology and measurement, including calibration and testing laboratories, legal metrology organizations, written standards organizations, and government regulators. The main reason for this, quite clearly, is the importance of traceability to the NMIs. For organizations whose activity rests on traceability to national standards, mutual recognition between the NMIs charged with the responsibility for maintaining those national standards, offers a sound, formalized, international basis for the activities and relationships between all members of the broadly defined metrology community. The results of the NMI Survey and the interview discussions support this conclusion, and highlight the following issues as being important:

- The 'measurement pyramid' as a whole benefits from the CIPM MRA, in that it becomes much easier, at both a pragmatic and philosophical level, to encourage cooperation and conformance at various levels of the pyramid, when the NMIs have done so themselves. Indeed, NMI Directors appreciate the impact that the MRA can have on other actors as revealed in the NMI Survey:
  - 88% of respondents have a 'positive' or 'very positive' impression that the MRA will benefit *accredited calibration and testing laboratories*
  - 79% of respondents have a 'positive' or 'very positive' impression that the MRA will benefit *legal metrology organizations*
  - 39% of respondents have a 'positive' or 'very positive' impression that the MRA will benefit *written standards organizations*
  - 76% of respondents have a 'positive' or 'very positive' impression that the MRA will benefit *government regulators*
- The importance of the MRA to government regulators is an interesting point, as it is evidence of a widely held belief that the MRA has the potential to offer "quality of life" benefits, as mediated through regulators. In particular, the emerging emphasis internationally on policy areas such as health and genetic research, biotechnology, and environmental protection (among many), implies two immediate roles for metrology. First, scientific research and development in these fields require, at the laboratory bench level, the realization and maintenance of national standards and/or certified reference materials in a wide-ranging number of areas, most notably those of chemical and biological metrology. In many of these areas, however, techniques and standards have yet to be established. The MRA stands to facilitate, in part, the international cooperation necessary to promote the development and application of metrology in this regard. Second, the increasing attention to regulations in these emerging fields also stands to benefit from the mutual recognition between NMIs, as the metrological standards, once developed, can form the basis of more scientifically and technically mature regulations (however defined). Indeed, one possible role for the MRA, is to help create an international system where "technical truth", speaks more reasonably to, and is better appreciated by, "regulatory power".
- The potential value of the CIPM MRA is starting to be appreciated by some of the other actors mentioned above. In particular, two recent developments provide important evidence:

- The Memorandum of Understanding between CIPM and ILAC indicates the two organizations recognize the need to "strengthen the links between accreditation and metrology and to cooperate and to coordinate their actions in respect of their tasks related to national and international measurement infrastructure".

- The International Organization of Legal Metrology (OIML) in its revised Long-Term Policy Action Plan (OIML 2001) recognizes the importance of promoting acceptance of measurement results in international trade. Part of this strategy involves the promotion of intercomparisons concerning testing standards and equipment, and the testing of measuring instruments. In situations where discrepancies exist, one recommended response is the "development of specific supplementary comparisons by the BIPM"; the MRA stands to aid in this regard.

- As mentioned several times in this Report, the greatest potential impact of the MRA is its role in helping to reduce TBT. This role has similarities to the importance of the MRA within the 'measurement pyramid' as outlined immediately above, but it must be appreciated that the realization of reduced TBT is in large part a function of the acceptance of results from the measurement pyramid by trade regulators, more than it is of changes within the pyramid itself. This is a fairly simple argument, in that the MRA offers an opportunity for trade regulators to base their efforts, particularly with regards to conformity assessment procedures, on the CIPM MRA. Traceability to *any* of the signatory NMIs, would replace traceability to a *particular* NMI, effectively reducing the costs of measurement in line with the theoretical arguments presented above. Having said this though, the application of the MRA is at such an early stage of development, that the reduction of TBT as a result of the MRA is still an *expected outcome*, as opposed to a real outcome. Still, it is possible to offer some suggestions about what this expected impact might be, at least in terms of its order-of-magnitude. Some high-level trade statistics, in conjunction with a review of the very limited literature on the value of TBT, are thus presented below.

4.2.1 Order-of-magnitude expectations for the MRA in reducing TBT among member nations

In the absence of any direct measure, investigating trade export patterns between (a set of) MRA nations offers a clue as to the order-of-magnitude potential impact of the MRA. Analysis of these patterns indicates that for nations within the MRA, trade inter-dependence is remarkably high. The following discussion provides a synopsis.

4.2.1.1 The export data

The data source is the OECD's International Trade by Commodities Statistics released in 2000. For the year 1998, total exports and exports to each individual country within the MRA are provided for 28 representative MRA countries (26 OECD countries plus China and Hong Kong).

The values are originally measured in thousands of 1998 US$. The totals have been inflated into 2000 US$ using a conversion factor of $1 1998 = $1.085 2000.

Total commodity exports (no services) for each country are measured as the sum of exports over 6873 products to 260 countries. Total exports to MRA countries are measured as the sum of exports over the same commodities to the 43 MRA members for which data was reported.

The average percentage of exports to MRA countries for the group is 89%. Australia, Japan, and Korea lag behind the other countries primarily because of the importance of exports to Indonesia, the Philippines and Chinese Taipei (in the order of 7.5 to 10% of total exports for these countries).

4.2.1.2 Trade within MRA/OECD group

Figure 17 presents export trade data for a set of 28 MRA signatory nations (See Appendix 1 for Country Code).

Figure 17 **Export trade data for 28 MRA signatories**

Country	World (b$US 2000)	In Group (b$US 2000)	% of Total Trade in Group
aus	60.57	50.05	83
aut	66.03	61.12	93
bel	190.91	175.92	92
can	232.85	227.74	98
che	85.63	78.07	91
chn	199.43	177.17	89
cze	33.12	31.20	94
deu	590.06	532.33	90
dnk	51.99	44.82	86
esp	120.84	107.65	89
fin	46.88	41.22	88
fra	326.04	286.37	88
gbr	296.66	264.35	89
grc	11.68	9.13	78
hkg	189.73	169.07	89
hun	24.96	23.24	93
ire	69.70	65.78	94
ita	262.68	229.37	87
jpn	421.13	347.59	83
kor	143.55	113.69	79
mex	127.32	122.16	96
nld	181.89	153.75	85
nor	43.84	41.92	96
nzl	12.96	11.16	86
pol	30.59	26.55	87
prt	26.28	24.69	94
swe	89.51	83.60	93
usa	738.27	636.97	86
average/total	4675.09	4136.67	89

Figure 18 and Figure 19 present summaries of this data by % of trade in-group, and value of trade.

Figure 18	% of trade to MRA countries

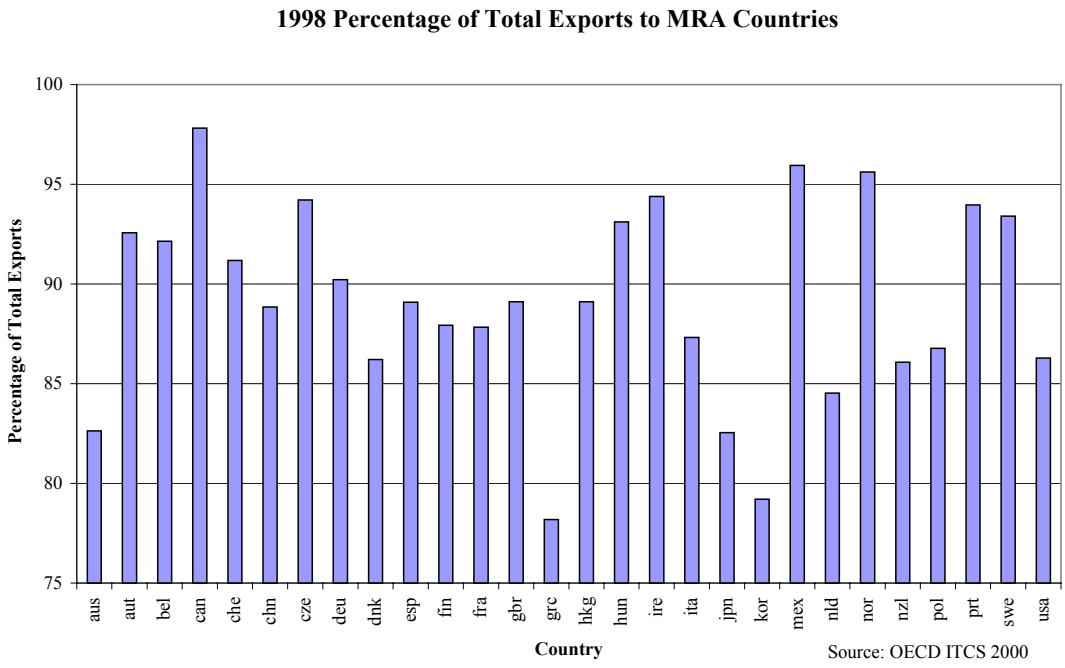
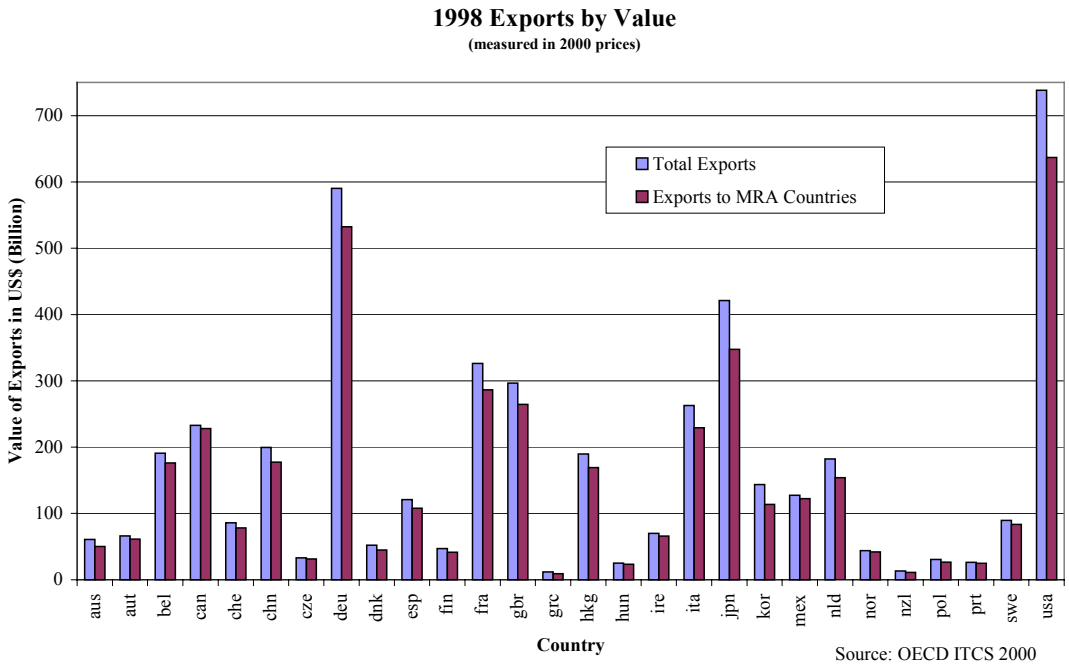


Figure 19	Value of trade exports



The export trade data indicate the dramatic inter-dependence of MRA nations. Perhaps most striking here, is that the average amount of trade-dependency within the reported MRA group is 89% of total trade, representing a range between a low of approximately 78% for Greece, and a high of approximately 98% for Canada. Moreover, the implication of this dependency is even clearer, when one considers that approximately 89% of total world trade in merchandise exports occurs between MRA signatory nations.[9]

Unfortunately, a measure of the extent to which TBT might be limiting or raising the costs of trade between these (and other) nations, has yet to be estimated here, or in other similar analyses. Indeed, while the World Trade Organization, the OECD, and the World Bank have acknowledged the importance of pursuing a comprehensive investigation of the value of TBT worldwide, empirical evidence has yet to be presented.[10]

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[9] *Source: World Trade Organization 2001 International Trade Statistics.*

[10] *For a review of this important issue please see for example: Maskus, K. E., J. S. Wilson and T. Otsuki (2001), Quantifying the Impact of Technical Barriers to Trade: A Framework for Analysis, Policy Research Working Paper No. WPS 2512, (World Bank); Deardorff, A. B. and R. M. Stern*

Similar studies, however, have been presented in relation to the reduction of trade-limiting non-tariff barriers to trade, including those associated with customs procedures, administrative procedures, and trade facilitation measures. These studies acknowledge that TBT are a particular form of barrier to trade, but no study has isolated their impact directly. As part of the broader form of non-tariff barriers though, four studies have been successful in estimating the costs to trade. Figure 20 presents an overview of the results of this research.

For current purposes, the results of these studies indicate that the reduction of non-tariff barriers to trade can be expected to result in as much as a 10% net benefit, depending on the measures taken and the economies involved. Clearly, these studies cannot be applied directly to the case of the CIPM MRA. However, they do indicate that reducing non-tariff barriers to trade can have significant economic impacts, and it is reasonable to assume that the same holds true for TBT (as is predicted by Maskus et. al. (2001), Deardorff and Stern (1997), and Stephenson (1997)). Given the extent to which trade exists between MRA signatory nations, it seems reasonable to suggest that if the MRA can act play a strong role in helping to facilitate the reduction of TBT, the direct impact will be large in monetary terms. For example, a one-tenth of a percent increase in trade values would translate into an increase in value of over $4 billion US, amongst the 28 nations presented here. Given the results of the comparative studies presented in Figure 20, this is viewed as a conservative estimate.

(1997), Measurement of Non-Tariff Barriers, Economics Department Working Papers No. 179, (Paris: OECD); Stephenson, S.M. (1997), Standards and Conformity Assessment as Nontariff Barriers to Trade, Policy Research Working Paper 1826, (Washington D.C.: World Bank).

Figure 20	Reference summary of percentage savings to trade from reduction of non-tariff barriers

Source	Scope	Estimated Impact
Commission of the European Communities "Cecchini Report" and other related studies (1988)	Intra-EC Trade Customs Procedures	1.6-1.7% of total intra-EC trade value for administrative costs to firms (approx. 5% if lost business opportunities are included)
Removing barriers affecting overall production (e.g., divergent technical standards and other restrictions)		2.0-2.4% of GDP in the area
UNCTAD "Columbus Ministerial Declaration on Trade Efficiency" (1994)	Trade Efficiency Measures: banking & insurance; customs; business information; transport; telecommunication	Costs of trade transactions are 7-10% of the total trade value
Australia Industry Commission "The Impact of APEC's Free Trade Commitment (1995)	Facilitation measures in the Osaka Action Agenda (APEC):	
	– Direct cost savings from administration and delays associated with customs controls	
	– 5% of total trade value	
	– Direct cost savings from above plus a more extensive set of facilitation measures	
	– 10% of total trade value	
Economic Committee APEC "Impact of Trade Liberalization in APEC" (1997)	Non-tariff facilitation measures incorporated in the Manila Action Plan for APEC	1.9% of total trade value

Source: APEC 1997

Arguably the most striking implication for BIPM has to do with its role in helping to facilitate the reduction of TBT, particularly in those instances where traceability requirements "alone" are the cause of the TBT (e.g., traceability requirements to the *importing* country's NMI), or when the source of the TBT is directly related to differences in measurement/testing methods and standards. This is a role that is likely necessary if the MRA is to have its intended impact. To a person, interviewees suggested that it is suitable for BIPM to represent the MRA at the international level, particularly as this relates to the promotion of positive impacts for other organizations (most notably those associated with the reduction of TBT). Two specific strategies or responses appear directly relevant to this role for BIPM:

- Promotion of the MRA at the international level—There is an obvious role for BIPM in promoting the MRA at the international level. This would involve a more proactive dissemination of information about the importance of the MRA, and its potential role as a basis for other international agreements on trade facilitation. It is inarguable that metrological infrastructure is important in this regard, and increasing the overall awareness of the MRA stands to benefit its application. In the short-term, the strategy here could be to 'market' the MRA to all actors – including industry trade associations – that have a direct interest in measurement-related trade or regulatory practice (e.g., WTO, EU, APEC, ISO, ILAC, NCSL, World Bank, G8, G20, numerous trade bodies, etc.). Over the longer-term, it is reasonable to pursue a more formalized alignment of the MRA with other international organizations in the measurement pyramid, with an emphasis on mutual recognition of conformity assessment procedures (e.g., calibration, certification, measuring instruments). In essence, this could be viewed as a strategy to promote a fully developed and integrated pyramid of mutual recognition for all pertinent measurement-related systems.

- Promotion of the MRA at the national level—The promotion of the MRA at the national level is also important, in that ultimately it is domestic legislators and officials within each signatory nation who are charged with the responsibility for governing regulatory affairs and trade relationships. As such, each NMI must itself be responsible for the promotion of the MRA – and its potential benefits – within its own nation. For instance, in order for issues of metrological infrastructure to be properly appreciated, national trade representatives must be made aware of the MRA, and its potential for helping to reduce TBT. Within a given nation, this is clearly something that must be done by the NMIs. Collectively, however, BIPM might play a supportive role here, in terms of being a credible international authority on the importance of metrology, by supporting the communication of the MRA across nations, and by helping NMIs to develop arguments and strategies for promoting the MRA.

It should be noted that there is a widely held view that BIPM's 'promotional' role, internationally and in support of domestic NMIs, can only be based on its credible, neutral, international voice. It is also well accepted that BIPM's credibility is a function of its ability to speak from a position of scientific expertise. And while it is beyond the scope of the current study to discuss how this scientific expertise is created or organized, it is useful to point out that there is an almost unanimous feeling amongst those organizations interviewed, that BIPM must maintain its

scientific credibility in order for it to establish and promote the MRA specifically, and metrological issues more generally, worldwide.

4.3 Key Issues for the MRA and BIPM

Both the theoretical and empirical examinations presented in this Report point to a number of key issues that face the future development of the MRA and BIPM's associated role. Essentially, these issues can be regarded as the conclusions of this study, as they point to two specific considerations that will frame the longer-term success and impact of mutual recognition between NMIs.

- Voluntary nature of the MRA—A key consideration for the future impact of the MRA is its voluntary nature. NMIs/nations are not obligated to participate, and there is thus an implied balance between the benefits of the MRA and its costs, and this balance must be appreciated and managed over time. In part, the balance rests on the MRA's application as a basis for reducing TBT, thereby creating economic benefits that are likely to accrue at a significant rate. As discussed above, there is an implied responsibility for both the BIPM and the NMIs in this regard. Failure to appreciate the importance of promoting the MRA to its broader audience may seriously impede the creation of expected second-order benefits for nations and their industries. This balance also rests on the direct impact of the MRA on NMI costs, as measured by the requirement to participate in key comparisons, and the requirement to maintain quality systems that are accepted by other signatory nations. The argument here is straightforward: if the costs of participating in comparisons and/or the costs of maintaining quality systems are viewed as being too high relative to the benefits of membership for a given NMI, then it is conceivable that the NMI would withdraw from the arrangement. At the moment, this would appear not to be the case. However, there is sufficient evidence for some of the larger NMIs that careful monitoring of the balance between the costs and benefits of MRA membership is prudent over the longer term.

- MRA and Trade—The intended role of the MRA is to establish the metrological infrastructure upon which other organizations' efforts at reducing the costs of trade will rest. Stated another way, the MRA has a core objective to avoid the opportunistic use of measurement-based standards or technical regulations as a means of imposing technical barriers to trade. A challenge exists, however, in that the MRA does not have a direct role in governing trade relations. As such, the BIPM and the NMIs will be forced to work, over time, for the inclusion of the MRA in discussions held by other actors over the reduction of technical barriers to trade. And while this may seem like a fairly simple conclusion, it is not immediately clear the specific strategies that might be employed in the promotion of the MRA as a means to reduce TBT. What is clear is that this issue must be taken seriously, if the intended benefits of the MRA are to be realized.

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Appendix 1: List of NMI Signatories to the MRA

Original signatories (October 14, 1999)

Argentina		(arg)
Australia		(aus)
Austria		(aut)
Belgium		(bel)
Brazil		(bra)
Bulgaria		(bul)
Canada		(can)
China		(chn)
Czech	Republic	(cze)
Denmark		(dnk)
Finland		(fin)
France		(fra)
Germany		(deu)
Hungary		(hun)
India		(ind)
Ireland		(ire)
Italy		(ita)
Japan		(jpn)
Korea	(Republic)	(kor)
Mexico		(mex)
Netherlands		(nld)
New	Zealand	(nzl)
Norway		(nor)
Poland		(pol)
Portugal		(prt)
Romania		(rom)
Russian	Federation	(rus)
Singapore		(sng)
Slovakia		(slo)
South	Africa	(rsa)
Spain		(esp)
Sweden		(swe)
Switzerland		(che)
Thailand		(thd)
Turkey		(tur)
United	Kingdom	(gbr)
United	States	(usa)
Uruguay (uru)		

Subsequent signatories

Chile			(chi)
China,	Hong	Kong	(hkg)
Cuba			(cub)
Ecuador			(ecu)
Egypt			(egt)
Greece			(grc)
Latvia			(lat)
Lithuania			(ltn)
Malaysia			(mly)
Malta			(mlt)

Appendix 2: A "Technical" Discussion of the MRA

Transaction Cost Economics

Modern economic theory rests fundamentally on the assumption that economic actors seek always to satisfy, to the extent feasible, their wants and desires.[11] On balance, this leads to behaviour that is described as utility optimizing. This basic assumption frames the majority of economic research, including the models designed to describe the manner in which economic actors interact with one another, i.e., the way they *transact*.

An economic transaction is a transfer of goods or services from one actor to another. To ensure that transactions result in efficient outcomes – defined as an outcome that satisfies all actors – governance mechanisms are instituted. This is especially true in cases where transactions are subject to costs (for which prices are not charged), as indeed all transactions are. So-called transaction costs are those incurred in arranging, managing, and monitoring transactions across markets, and can be viewed as the economic equivalent of friction in physical systems. The cost of transacting differs depending on both the nature of the transaction and on the way that it is organized. Some transactions are simple and can therefore be managed through markets by the price system. Others are more complex and must be governed by explicit contracts between formal organizations and made under centralized decision making or hierarchies. The ultimate choice of organizational structure and contract design, however, is made in an effort to minimize transaction costs (Williamson 1985).

This fairly simple premise has direct implications for the current study, as it is useful to think of the MRA as an institution, whose creation has been a necessary response to the costs of transacting between NMIs. The MRA is designed to govern the process(es) by which mutual recognition of national measurement standards and calibration and measurement certificates is assured. In doing so, the MRA effectively creates a benefit to its members by helping to reduce the costs of transacting, which might otherwise prohibit comprehensive multi-lateral mutual recognition.

To see this, consider the following generic problem facing any given NMI trying to establish measurement standards in an international context.

Two countries are engaged in trade over two goods, where the economic value of each good depends only on the other country's ability to measure, ex ante, the quantity of the good being

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[11] Economic theory threats the *individual* as the basic economic actor. However, it is also possible to view organizations – from the smallest firm to the largest nation state – as economic actors (i.e., organizations are viewed as aggregations of individuals). Clearly, it is well beyond the scope of the current study to examine this issue; still, we accept the assertion that organizations, of which NMIs are an example, can be viewed usefully as economic actors.

exchanged.[12] Such might be the case between two countries engaged in trade of oil for wheat. If information is costless, both sides to the bargain will know, *ceteris paribus*, the quantity of each good being exchanged. Holding everything else constant, the (Pareto) efficient equilibrium result will be trade in oil and wheat until such time that benefit cannot accrue to one country without the other losing benefit.

Now consider a similar starting point, but in a transaction where information is costly. In this situation, neither country will know with certainty, the quantity of oil or wheat being promised by the other agent. In order for exchange to be successful, the cost of determining the quantity of goods must be less than the expected benefit resulting from gains-from-trade. Put another way, if measurement costs are sufficiently high, they will prevent what could otherwise be mutually beneficial exchange.

In the general case, the presence of high measurement costs amongst a large number of potential trading partners implies inefficiency, either because measurement costs prohibit mutually beneficial exchange, or because there is a socially inefficient investment in measurement, the result being that resources are not allocated to their highest economic value (e.g., through problems related to asymmetric information). As a result, there is an incentive for agents to establish a mechanism whereby measurement costs are reduced collectively, as may be the case when a well-known, ubiquitous, measurement *standard* is instituted. Indeed, this is the economic function of the International System of Units (and associated standards such as certified reference materials or CRMs).

At the core of the SI/CRM system, is a set of primary scientific standards against which national measurement standards are compared to establish known ranges of measurement realization and uncertainty. In scientific terms, a nation's ability to demonstrate technical capability through its NMI determines, in part, its comparability against the SI, and *de facto*, to other NMIs. In economic terms, the investment required to demonstrate technical/scientific capacity is equivalent to investment in a specific asset. More importantly, under-investment in this specific asset – i.e., metrological standards – is likely to result in inefficient exchange for all circumstances where measurement capability matters.

The organizational consequence of this can be seen in two regards. First, countries invest in their ability to demonstrate scientific credibility against SI units on a one-by-one basis. The very existence of NMIs, whose role is to maintain national measurement standards and traceability to the SI as governed by BIPM, is evidence of this investment. However, scientific credibility has economic value only if potential trading partners know about it, and are willing to accept it as a basis for exchange (and vice-versa). This stimulates a desire for nations (through their NMIs) to establish a way to ensure the mutual recognition of metrological capabilities, revealing the second organizational response: the MRA. The MRA is thus properly viewed as an institution whose

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[12] *For simplicity, we hold quality constant in the current discussion. In the broader context, both quantity and quality can be expected to attribute to economic value, and both dimensions are subject to transaction costs in exchange.*

function is to govern the investments made by signatories in a specific asset, namely mutual recognition of measurement standards and CMCs. BIPM's role, in turn, can be viewed as that of an arbiter governing NMIs' investments in mutual recognition.

Overall then, the MRA can be seen as the organizational response necessary to govern NMIs' investment in a specific asset. In economic terms, this effectively lowers the cost of transacting, and reduces the probability that any one NMI will behave opportunistically (i.e., dishonestly) in demonstrating metrological traceability, and the mutual recognition thereof between nations.

Public Goods and Club Goods

In this section we discuss the circumstances under which public provision of commodities is required in the face of market failure. Special attention is given to understanding goods that are excludable but non-rival.

Characterization of public goods

Pure public goods have two key characteristics that differ from the more standard private goods: non-rivalry of consumption, and non-excludability of benefits. A good is non-rival if consumption of the good does not diminish the opportunities for enjoyment of the same unit of the good by others. A good is non-excludable if it is not possible, or prohibitively costly, to limit the number of agents who benefit from consuming the same unit of a good once produced. To illuminate, consider the example of a lighthouse. If one ship's path through a dangerous sea-lane is made safe by the light, this does not diminish from the lighthouse's benefit to other ships. Thus the lighthouse's benefits are non-rival in consumption. At the same time, it would be extremely difficult, and certainly quite costly in economic terms, to reserve usage of the light to only one ship. Thus the lighthouse's benefits are non-excludable.

Most public goods only partially meet either or both of the above conditions. So called impure public goods fall into two categories. Goods that are rival in consumption but mostly excludable are known as common pool resources. Goods that are non-rival in consumption but excludable are known as club goods. Measurement standards exhibit non-rivalry in that adherence by one agent in no way precluded adherence by another. However, measurement standards are excludable in that agents reap the benefits of the standard only to the extent that they can demonstrate adherence to them. Internationally, the Convention of the Metre, the International System of Units, and the MRA, all govern demonstration of adherence. Essentially, a country must be a member of the 'club', in order to gain economic benefit from measurement standards.

Public goods can also be characterized by their scope. That is to say, they can be local, regional, national or international in nature. For example, consider the lighthouse that is useful only in a localized place as compared to depletion of the ozone layer that affects people throughout the world.

Finally, a distinction can be made within the category of global public goods with respect to their place in the production process. Final global public goods are tangible or intangible outcomes. Examples include the state of the environment, world peace and global financial stability. Intermediate global public goods are those that contribute towards the provision of final goods and include international regimes such as the Metre Convention and the BIPM.

Provision of public goods

For the case of private goods, the market outcome is one that allocates resources in such a way as to equate the total amount of goods supplied to the total amount that consumers demand. The price that equates supply with demand, or clears the market, also ensures that the market outcome is optimal. Optimality, or Pareto efficiency, is a situation in which any reallocation of resources will make at least one economic agent worse off. Efficiency is achieved in competitive markets because the price system ensures that the all consumers value the goods equally, producers do not waste resources, and the economy produces what each consumer wants.

Private goods are rival and thus as more of the good is demanded more needs to be produced. Therefore aggregate, or market, demand for a good is simply the horizontal summation of individuals' demand. The overall marginal benefit of an additional unit of output is simply equal to the additional marginal benefit the person who consumes it receives. Individuals will consume the good as long as the marginal benefit of doing so exceeds the price they pay for it. Producers will sell a unit of the good as long as the price they receive exceeds the marginal cost of production.

In contrast to the private good case, public goods are non-rival and so everybody in the economy can consume the same units. This has important implications for the efficient provision of public goods because the overall marginal benefit of an additional unit of output is the sum of the marginal benefits each consumer receives from it. In other words, aggregate demand is the vertical summation of individuals' demand. The condition for efficiency for public good provision is that the marginal cost must equal the sum of marginal benefit for all economic agents. A problem arises, however, because at the optimal quantity of public good provision, no single consumer places enough value on the public good to provide it on his or her own. Efficient public good provision will therefore not be carried out in the market and cooperation between consumers or government provision is required.

Another source of market failure in the provision of pure public goods results from their characteristic of non-excludability. Without the ability to exclude people from consuming the good once it is provided, the opportunity arises for individuals to free ride by consuming the good without having to pay for it. As long as any single individual's contribution to the total amount of public good is insignificant, the choice to free ride will have little impact on the final outcome. However, if all individuals face the same incentive to free ride, none will contribute and no public good will be provided. Again, some form of intervention in the market place is required to overcome this problem.

Club goods and the MRA

Club goods, those that are to a large extent non-rival but excludable, may be optimally provided in the market through consumption-sharing arrangements. Examples of club goods include many sports groups like gyms, swimming pools and golf courses. Because club goods are excludable to non-members, it is possible to charge a positive price (the total cost of provision can simply be divided between the members) and at the same time overcome the free rider problem. As the number of members to a club increases, the average cost per member falls and therefore at one margin there are benefits to increased membership. However, there are often costs of congestion associated with increased membership that must be weighed against the benefit of lower per member fees. While it might be possible to overcome these congestion problems by providing a larger amount of the club good, this in turn increases the cost of membership. The optimal provision of club goods, from the point of view of club members, is one that simultaneously solves for the optimal number of members and the optimal quantity of club good. In other words, one must determine at the same time the optimal membership size for a given quantity of club good, and the optimal quantity for a given membership size. The optimal membership fee is straightforward to calculate as a per member share of total cost of provision.

In the case of the MRA, the problem is not to establish the optimal membership size or membership fee, but rather to value membership itself. This issue is complicated because the value of the club increases as the total number of members increases due positive network externalities. In other words, mutual recognition of standards amongst a greater number of countries establishes an opportunity for second-order benefits associated with things like reduced technical barriers to trade (a point we return to below). The benefit of membership is thus a function of the benefits of collective action, which, in this case, are usefully thought of as the avoided costs of engaging in a series of bilateral arrangements to establish mutual recognition, including lower transaction costs as outlined above. Indeed, the MRA confers a club good to its members, who benefit from their mutual and centrally coordinated cooperation.

Cooperative Strategy

Cooperative strategy is the attempt by individuals or organizations to realize their objectives through cooperation with others, rather than in competition with them. It focuses on the benefits that can be gained through cooperation and how to manage the cooperation so as to realize these benefits. Many strategic situations involve simultaneous interaction between numerous players and concern problems of collective action.

In collective action problems the aims of the society as a whole can be best served only if its members take some particular action or actions that are not in the best private interest of those individuals. Thus, in order achieve socially desirable outcomes, the institutional environment in which these interactions take place must be carefully designed.

Two-player games and collective action

Imagine a situation in which two neighbours wish to erect a fence between their properties. The neighbours can build the fence together, sharing the cost of materials and labour, or it can be built by either of them individually. Acting alone, the builder must pay the full construction cost while the non-builder gets to free ride. Depending on the actual values of the cost and benefit of the project, a number of different outcomes, or equilibira, might result.

Figure A shows one possible payoff matrix for the fence game described above[13]. In this case, if the neighbours act together they will find it in their best to interest to proceed with construction because the values in the cells corresponding to the strategy combination {build, build} are positive. However, neither neighbour would wish to undertake the project on his or her own (strategy combinations {build, not} and {not, build} both have negative payoffs for the builder). In fact, it is better not to participate regardless of what the other does. The neighbours face what is called a prisoners' dilemma in that the dominant strategy for both neighbours is to free ride off the actions of the other, but both would be better off if they could work together. The prisoners' dilemma illustrates the problem of fostering collective action when individually optimal choices are not in line with the group's optimal choices.

13 The first number in each cell of the payoff matrix, or normal form of the game, is the payoff for the Row player and the second number in each cell is the payoff for the Column player. An (Nash) equilibrium results when neither player has an incentive to change their strategy. Cells that are shaded indicate equilibrium outcomes.

Figure A	Collective Action as a Prisoners' Dilemma Game

		Your Neighbour: Build	Your Neighbour: Not
You	Build	(5,5)	(-1,10)
	Not	(10,-1)	(0,0)

A second possible equilibrium outcome for a collective action game is illustrated in Figure B. Here the cost of building the fence is low enough relative to the benefits it generates so that either neighbour would be willing to build the fence on his or her own. Importantly, however, the best response to your neighbour's decision to build is to free ride. In this game of chicken, the problem facing the neighbour is one of coordinating on one of the three socially optimal outcomes that result in fence construction. Coordination requires both communication and enforcement of any agreement, though, so the likely outcome may not be different than that of the prisoners' dilemma example.

Figure B	Collective Action as a Game of Chicken

		Your Neighbour: Build	Your Neighbour: Not
You	Build	(5,5)	(3,10)
	Not	(10,3)	(0,0)

A different form of the coordination problem in a simple two-person game can be demonstrated in the game of assurance. In this example, shown in Figure C, disagreement over the style or location of the fence means that failure to have input into the production process results in an outcome for a free rider that is less satisfactory than participating in the construction process. The socially optimal outcome is {build, build} and is one of the two equilibria. Moreover, it is the preferred outcome for both players potentially making coordination easier.

Figure C	Collective Action as a Game of Assurance

		Your Neighbour: Build	Your Neighbour: Not
You	Build	(10,10)	(-1,5)
	Not	(5,-1)	(0,0)

The three examples above can easily be extended to allow for any number of players. As the total number of players increases, the value of both cooperating and free riding will generally increase though perhaps at different rates. This means that there might be a critical number of participants for which the choice of strategy switches. In prisoner dilemma games shirking will always result in a higher payoff than cooperating regardless of the number of players. In a game of chicken, on the other hand, it might be the case that the payoff to cooperating exceeds that of shirking when only a small number of players are participating. The opposite is likely for games of assurance.

Solving collective action problems: The MRA

For collective-action problems of the form found in the assurance game (and to a lesser extent the chicken game), all that is needed for success is to make the socially optimal outcome a focal point. Simply creating and relying on customs or conventions can often do this, in other cases sanctions or punishments may be required. Groups can also create norms of behaviour, and their associated costs of shame and guilt for not adhering to them, to influence outcomes. Norms have an advantage over explicit sanctions in that the costs of punishment are internalised in each player's payoff and thus become automatic. Norms are also reinforced as members of the group adhere to them. An international organization, or regime, is broadly defined as a set of explicit or implicit principles, norms, rules, and decision-making procedures around which actors coordinate their behaviour in various areas of international relations.

The MRA represents one such organization, as membership requires participation/cooperation in a well-established set of procedures for the mutual recognition of measurement standards and certificates. The exact form of these procedures need not be discussed, but their impact is clear: by establishing a formal set of decision-making rules, the MRA sets forth a means by which to coordinate the actions of member NMIs. Included in the 'rules of the game' is a primary role for BIPM – both scientific and administrative – that is instructive in guaranteeing the cooperation of MRA members, and thereby leading to an optimal outcome i.e., mutual recognition.

Overall then, the MRA has an effect on economic behaviour in three regards:

- It reduces the costs of transacting between NMIs. This particularly important given that establishing mutual recognition is akin to investing in specific assets, which require organizational governance to maintain efficiency.
- It provides a club good to its members, the value of which can be represented by lower transaction costs, and the conference of positive second-order impacts as a result (i.e., reduced technical barriers to trade).
- It forces cooperation and coordination between its members by establishing 'rules of the game' for mutual recognition. These rules, in turn, represent a response to collective action problems that might otherwise prevent multilateral cooperation.

Theory of technical barriers to trade

Perhaps the greatest impact of the MRA will be its role in the reduction of technical barriers to trade. As such, it is important to review what these are, and how they affect the economic condition of nations in a global economy. Indeed, the post-war era has seen significant reductions in barriers to trade. The efforts to liberalize trade were first concentrated on tariffs partly because they were easy to identify and therefore to remove. However, the reduction in tariffs has lead to an increase in non-tariff barriers to enable the countries to continue protecting the domestic industries from foreign competition. For example, the General Agreement on Tariffs and Trade

(GATT) Tokyo Round, which was completed in 1979, emphasized the need to eliminate these non-tariff barriers. The World Trade Organization (WTO), an organization established in 1993 as a permanent umbrella organization to govern GATT agreements and further trade liberalization, has continued the work. While average tariffs rates have been reduced substantially in industrialized countries, there continues to be room for removing non-tariff barriers to trade.

Non-tariff barriers to trade consist of all instruments but tariffs that are used to discourage or encourage international flows of goods and services. These instruments include quantity restrictions such as quotas and voluntary export restraints; export subsidies; antidumping and countervailing duties; and technical barriers to trade.

Perhaps most difficult of all of the non-tariff barriers to observe and measure are technical barriers to trade. Technical barriers to trade refer to any regulations and standards that restrict the behaviour of domestic firms and international firms asymmetrically. These standards include varying product standards, health standards, measurement standards, product packaging, marking and labelling requirements, fire ratings, etc. Notice that regulation and standardization per se are not considered barriers to trade – they become barriers to trade if they make exporting more costly than producing for the domestic market.

The US National Research Council (1995) found that technical barriers to trade were significant and expected their complexity to continue to grow. At least the following types of technical barriers to trade were found in use:

- Standards that differ from international norms are employed as means to protect domestic producers
- Restrictive standards are written to match the design features of the domestic products rather than essential performance criteria
- Unequal access to testing and certification systems between domestic producers and exporters
- Failure to accept certifications performed by competent foreign organizations
- Significant lack of transparency in the systems for developing technical regulations and assessing conformity

The above are barriers to trade because they make it costly for firms to export and because they break the level playing field between imports and domestic production.

When no international standards exist or when countries use standards that differ from the international norm, firms currently operating in domestic markets and looking to enter into export markets have to often incur following costs

- Costs of monitoring the varying regulatory requirements in target countries. There is often considerable uncertainty regarding the costs of complying with foreign standards, and this uncertainty contributes to deterring firms from entering export markets.
- Cost of changing product design to meet the standards that are stricter or different from the domestic country's standards.
- Cost of reorganising the production system to facilitate multiple product designs.
- Costs of testing and certification. The test may have to be carried out in the target country, which implies that redundant multiple tests have to be carried out.
- Time delay costs in getting the product into the market due to the time that goes into product re-design and certification. These are particularly important in high-tech industries where the product life span is often as short as 12-18 months.

In aggregate, these compliance costs can be defined as the additional costs necessarily incurred by businesses in meeting the requirements laid upon them in complying with a given standard or regulation (Henson 1997).

The WTO Technical Barriers to Trade Agreement (TBT Agreement) is designed to address the trade-restrictive properties of technical barriers to trade, and covers technical regulations, standards and conformity assessment procedures and applies to all products, including industrial and agricultural products. Sanitary and phytosanitary measures and government procurement procedures are excluded as they are addressed in Agreement of Sanitary and Phytosanitary Measures and Agreement on Government Procurement, respectively. Under the 'umbrella' provisions of the WTO, all Parties to the GATT are obligated to adhere to the agreement.

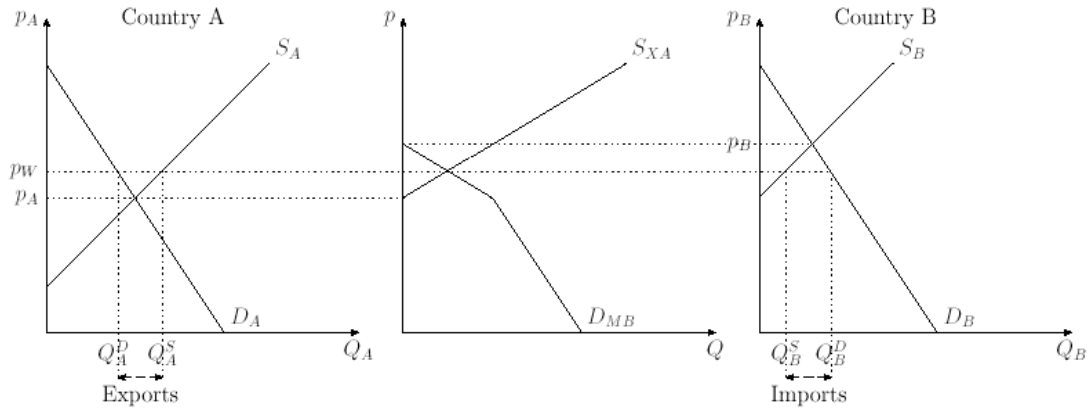
The WTO's TBT Agreement encourages the development of international standards and conformity assessment systems and it encourages the members to enter into Mutual Recognition Arrangements (MRAs) as means to reduce TBTs. Accreditation bodies throughout the world have established international and regional groupings for cooperation, information exchange, harmonization of procedures and the establishment of MRAs.

The welfare effects of removing technical barriers to trade can be assessed theoretically using cost-benefit analysis, a standard method in assessing the welfare effects of tariffs, quotas and other barriers to trade. The method uses a two-country static partial-equilibrium analysis of trade to assess the total change in economic welfare caused by eliminating the TBT. This total welfare consists of changes in consumer surplus, producer surplus and government expenditure. In what follows, we will first use the analysis to illustrate that there are gains from trade for both exporting and importing countries. Next, we will see how technical barriers to trade will form a wedge between the market-clearing prices in the two countries. Last, we will assess the welfare effects of these price changes in the two countries.

No trade vs. free trade

Consider a partial equilibrium model with two countries and one sector that is perfectly competitive. Assume that the goods produced in the two countries are perfect substitutes. Also, assume that there are no transportation costs. Without international trade, each country must consume what is produced domestically, and the market equilibrium is found where domestic demand (D_A in A, D_B in B) equals domestic supply (S_A in A, S_B in B). Due to differences in technology or factor endowments, the supply in country A is greater than that of country B (for simplicity, assume that demand conditions are identical in each country), and therefore the no-trade equilibrium price is lower in country A (p_A) than in country B (p_B) as illustrated in Figure D.

Figure D **Free trade market equilibrium**



Trade liberalization induces a flow of goods from country A, where the goods are cheaper, to country B. Thus, country A becomes the exporter and country B the importer. The price starts rising in A and falling in B reflecting the increased demand for the goods in A and reduced demand for the goods in B, respectively. In A, for any price above p_A, the domestic supply exceeds the domestic demand by an amount that is increasing in the price. This excess supply can be referred to as A's *export supply* (S_{XA}). In B, for any price below p_B, the domestic demand exceeds the domestic supply by an amount that increases as the price falls. This excess demand can be referred to as B's *import demand* (D_{MB}). The price that clears the global market, i.e. the price at which A's export supply equals B's import demand is the new equilibrium world price p_W and the price at which both countries' consumers and producers trade when there are no restrictions on trade.

The effects of a TBT

The costs associated with technical barriers to trade can be put in two broad categories which have different implications on their welfare effects: fixed and variable costs.[14]

When the firm's total compliance cost is independent of the volume of sales, the costs of the TBT are fixed. Costs of monitoring, conformity assessment and time delay costs are largely fixed, as are many of the product design costs. When firms face fixed compliance costs, their behaviour is unaffected as long as the costs are not prohibitive, i.e. as long as the costs are sufficiently small for the firm to continue to export. If the costs are not prohibitive, there should be no changes in prices (domestic or export market) or in volume of exports. Fixed compliance costs can be particularly detrimental to small exporting firms that have small product runs and large product range each of which has to go through a separate conformity assessment process.

When the firm's total compliance cost increases with the volume of sales, the costs of the TBT are said to be variable. If conforming to a standard requires using more inputs or more expensive inputs, then this cost increases with exports and therefore is classified as variable. When the compliance costs are variable in nature, each firm has an incentive to export less. Exports decrease with the cost and become prohibitive when the firms no longer find it profitable to export. The cost will create a wedge between the price levels in the domestic and export markets reflecting the changes in supply conditions caused by the increased cost structure.

A distinction can also be made between *non-recurring* or temporary compliance costs and *recurring* or continuous compliance costs. Non-recurring costs refer to one-off items of expenditure, which are required for initial compliance. Recurring costs of compliance refer to increases in costs of production. Whereas the non-recurring compliance costs are by definition fixed (because they do not affect production costs), the recurring costs can be either fixed or variable.

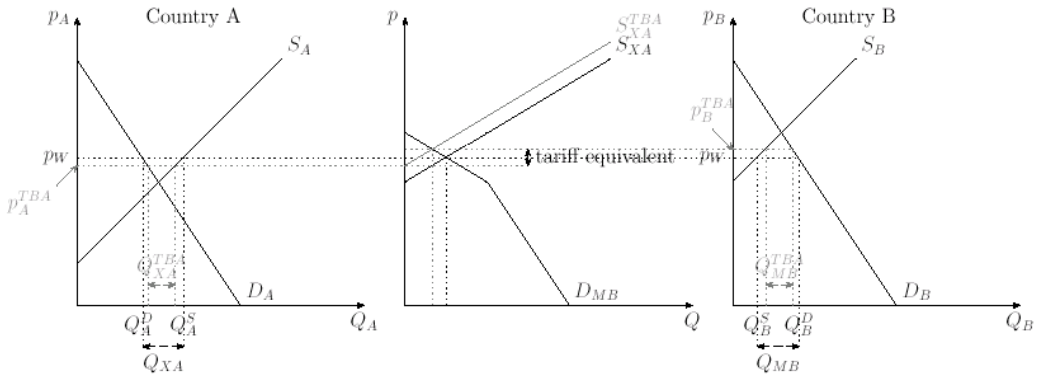
Consider the effects of a TBT set by country B. Assume that the TBT creates an additional variable cost to A's producers not incurred by the domestic producers in B. For any given price of the good, A's producers' revenue from the export market equals price minus the additional variable cost, but their revenue from the domestic market equals the price, which makes country A producers unwilling to supply to the export market at the current prices. This creates an excess supply in country A and excess demand in country B, which leads to a decrease in the price in country A and an increase in the price in country B. Once the differential between the prices in the two countries reaches the level of the variable cost, exports resume and new equilibrium is reached.

The effects of the TBT can be illustrated as an upward shift of A's export supply curve by an amount equal to the additional cost as is shown in Figure E where S_{XA} refers to the free trade

[14] *According to the definition used in this paper, costs are variable (fixed) if changes in output have (do not have) an impact on the total cost of the TBT. Notice that this definition is not the same used by Polinsky and Shavell (1989) or Henson (1997), according to whom costs are variable (fixed) if the stringency of regulation affects (does not affect) the total cost.*

export supply and S_{XA}^{TBT} refers to the export supply under the TBT. The new equilibrium in country B (the importer) involves consumers paying a higher price and domestic producers receiving a higher price than with free trade ($p_B^{TBT} > p_W$). The new equilibrium in country A involves consumers paying less and producers receiving less than before ($p_A^{TBT} < p_W$).

Figure E	The effects of a TBT



The extent to which the additional cost is born by the consumers in B (increase the price in B) and the extent to which it is born by the producers in A (decrease in the price in A) - what is usually called the *tariff incidence* but perhaps more appropriately called the *TBT incidence* in our context - depends on the price elasticities import demand and export supply. Everything else constant, the more elastic (flatter) the export supply, the higher share of the cost is born by the consumers in A as opposed to producers in B and vice versa. In the extreme case where country B is a small country, the export supply is horizontal at p_W.[15] The TBT shifts the export supply by the amount of the additional cost. Since the export supply is horizontal, all of the cost is born by the consumers in B and the price remains unchanged in the "large" country A.

The difference between the prices in the two countries, or $p_B^{TBT} - p_A^{TBT}$, caused by the TBT is referred to as the price wedge.

[15] *The smallness of country B implies that the changes in demand and supply conditions in country B have no impact on the world price or the price in country A as these changes are small relative to the magnitude of supply and demand in country A. Therefore, country A is always willing and able to supply any amount of imports demanded by country B at the world price, which implies that the export supply of A is infinitely elastic.*

The welfare effects of a TBT

The TBT affects the welfare of consumers if it changes the price the consumers pay for the good (imported or domestically produced). Producers' welfare is also affected by a price change. Profits are affected not only by the price change but also by any fixed costs the exporting firms incur due to the TBT. The following looks at the welfare effects of a TBT first if it affects the exporting firms' variable costs only and second if it affects the exporting firms' fixed costs only. Normally, one might expect both fixed and variable costs to be affected, in which case the total effect is the sum of the two effects.

TBT results in an increase in the variable cost

Figure F shows the total welfare effects of the variable TBT in country A, or the country where exporters are subject to the TBT. With free trade, consumer surplus equals *a* and producer surplus equals *b* + *c* + *d*. The TBT and the subsequent price decrease to p_A^{TBT} in A make consumers better off by increasing their surplus by *b*. However, producers in A become worse off by *b* + *c* making the overall welfare loss equal to *c*.

Figure F	A's welfare effects of a TBT

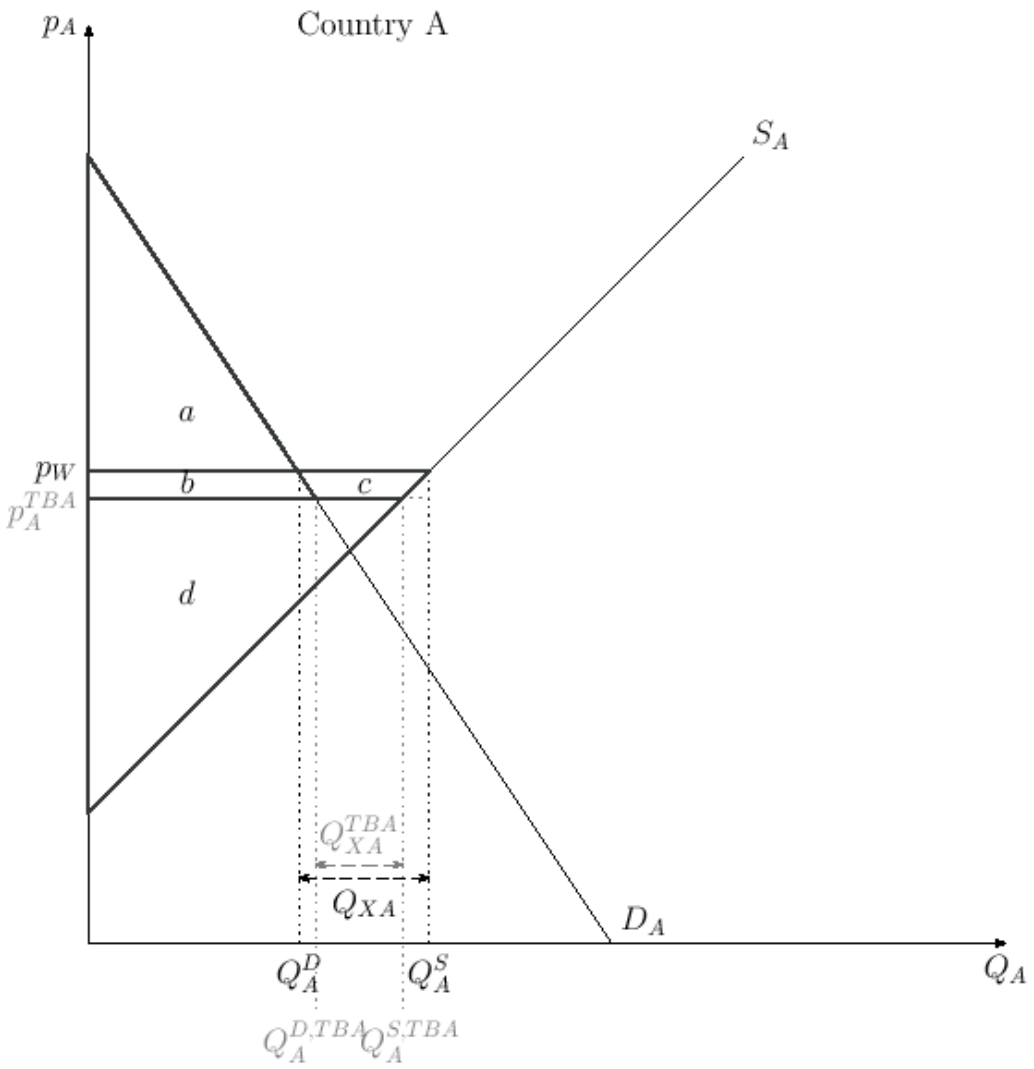
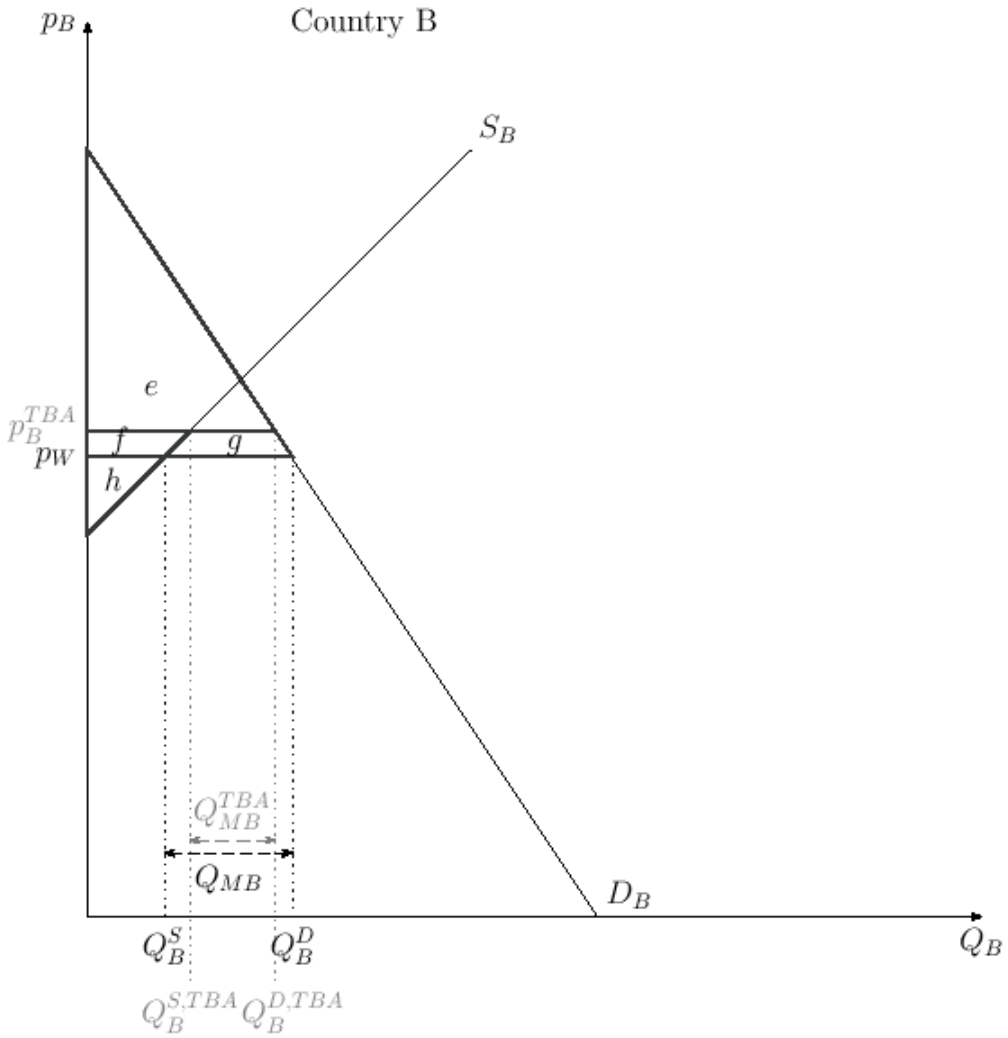


Figure G shows the total welfare effects of the variable TBT in country B, or the importing country that restricts its imports by using a TBT. With free trade, consumer surplus equals $e + f + g$ and producer surplus equals h. The price increase to p_B^{TBT} makes consumers worse off by $f + g$ and producers better off by f. Overall, the welfare is reduced by g.

Figure G	B's welfare effects of a TBT



This analysis suggests, then, that removing the TBT would improve welfare in the two countries by *c* and *g*, respectively. These areas are the larger the larger is the additional variable cost created by the TBT, and approaches to triangle defined by the demand, supply and p_W in each country when the TBT becomes prohibitive. When the TBT becomes prohibitive, the sector in the two countries reverts to autarky and therefore all gains from trade are lost for both countries

TBT results in an increase in the fixed cost

If the TBT involves an increase in the fixed cost, there are no changes in the price levels in the two countries as long as the increase in fixed cost is not prohibitive, i.e. as long as the exporters continue finding it profitable to engage in exporting. However, if some exporters cease exporting and others don't, the outcome is the same as with variable cost – the export supply shifts in[16] and there is a welfare loss equal to area *c* or *g*. This area is the larger the more firms find the TBT prohibitive.

The total welfare cost to country A, or the exporter, equals area *c* plus any fixed costs unaccounted in the calculation of *c* (the fixed costs that do not change the behaviour of firms do not show up in the estimate for *c*). The total welfare cost to country B, or the importer, is area *g*.

16 The export supply curve, just as domestic supply curve, is a horizontal summation of individual firms' supply curves. When some firms cease exporting, the export supply shifts in.

Appendix 3: Issues in Empirical Methodology

The preceding discussion outlined several key considerations for an economic theory of the MRA, its effect on NMIs, and the potential for reduced TBT as a result. Presenting this theory, however, is only part of the challenge. Indeed, the key objective of the current study is to measure the real impact of the MRA – an objective that is confounded by the challenges associated with measuring the types of impact and benefits established by the MRA. The following review presents a discussion of these challenges.

Measuring Economic Value for Non-Market Goods

The value of the MRA, particularly when its impact on NMIs is considered, is difficult to measure due to the non-market character of the benefits it creates. Indeed, there is no price to measure, and no market in which to measure it (by definition for club goods). As a result, one must rely on the estimation of benefits as revealed by using techniques developed for measuring non-market goods.

Various techniques are available for estimating the monetary value of goods and services that are traditionally not traded in markets. It is possible to use these techniques to estimate the economic surplus, or benefit, of changes in quality and quantity of these goods. For market commodities, this information is readily available from observed information about the supply and demand for the good or service itself. Many goods and services, however, are not traded in markets and therefore this information is not directly observable. As a result, a number of other techniques for gathering this information have been developed.

There are three broad categories for non-market valuation methods. The first category consists of methods that use market data for goods that are either traded in markets or are used in the production of traded goods. Unfortunately, relatively few non-marketed goods fall into this category. The second category consists of methods that use revealed preference information about marketed goods that are used in tandem with the non-marketed good to infer its economic value. Revealed preference, or surrogate market techniques rely on market data for the valuation of the non-marketed benefit, but this data is gathered for some good or service for which the non-marketed benefit of concern is a complement or attribute. The third category consists of methods that use expressed or stated preference information to infer economic value. These methods elicit values for non-marketed goods or services by directly getting people to state their tastes. These techniques are also called contingent valuation methods because the good or service is not necessarily going to be provided and the situation the respondents are asked to value is hypothetical (or the benefit has yet to accrue).

Revealed preference approaches are most useful when estimating the use value of non-marketed goods and services. They have the advantage that they are based on real, rather than hypothetical choices. However, the revealed preference technique can only be used when people are aware of the non-marketed effects that are components of the market good. As such, these revealed

preference techniques are best suited to valuing particular sites or location services and for urban pollution problems. Expressed preference techniques, on the other hand, are often used to measure values of goods and services for which no conventional market exists. Moreover, it is the only way to estimate non-use or existence values.

Below, valuation techniques in the first and third of these categories are summarized. Factor income or productivity method is an example of market methods. Contingent valuation method is an example of expressed preference methods. Travel cost method and hedonic pricing method are examples of revealed preference methods but are most often used to value environmental goods and as such are not relevant to this study. The last method discussed, the benefits transfer method, can fall into any of the three categories.

Factor income / Productivity method

The factor income/productivity method is used to value non-marketed goods which are not directly sold in markets but which are used as inputs in production of market goods. For example, fast flowing water is used as a factor of production for electricity. Fast flowing water itself is not sold in a market, but electricity certainly is. The value of water and other non-marketed amenities can be estimated by measuring their contribution to the profits of the final goods.

This method is especially useful in two situations. The first situation is when improvements to the non-marketed good in question increase the output of some marketed good but do not affect other factors such as market price. In this case, the benefits can be measured in terms of increased profits for producers. The second situation is when the non-marketed input is a perfect substitute for some other input. In this case, an increase in the quality or quantity of the non-marketed good or service potentially reduces the total costs of producing a fixed amount of the final good and the associated benefits can be measured in terms of decreased costs.

The first step in the use of the factor income/productivity method is to specify the production function for the final good. The production function is simply a relationship between the inputs, for example labour and capital, and the output. The non-marketed good may enter into this production function as an exogenous, or external variable. Econometric or statistical estimation of this production function yields parameter estimates that can be used to derive the marginal product of each factor input. The marginal product of a factor input is the additional amount of the final good that can be produced by increasing the amount of the input by one unit while keeping all other factors constant. This value, multiplied by the price of the final good, is the marginal value product and corresponds to the value of the last unit of the factor employed in the production process. The marginal value product is an estimation of the benefit of a small change in the non-marketed good or service used as an input.

Alternatively, the value of an increase in the non-marketed amenity can be estimated by measuring the decrease in reliance on other inputs. For example, an increase in the use of one input may allow for the same level of production to be attained with less reliance on some other

type of physical capital. The cost saving, in terms of decreased costs of physical capital, can then be used as an estimate of the value of the change in the non-marketed factor.

In order to use this method, one must have data on the final good's costs of production, the final good's supply and demand, the supply and demand for the inputs (including the non-marketed good), and the final good's production function. This information is then used to link the effects of changes in quality or quantity of the non-marketed good or service to changes in surplus measures for the final good. This method is the easiest to apply when the non-marketed good is a perfect substitute for some other input, or when only producers of the final good benefit from the changes in the non-marketed resource. The primary resource requirement is to obtain the data for the non-marketed variable. However, this data requirement is limited and often readily available.

The main strength of the method is that it is a straightforward and a relatively inexpensive way to estimate the benefits associated with non-marketed goods and service. Because it focuses only on the supply side of the marketed good, the data requirements are limited. Unfortunately, this main strength can also be a weakness in many cases.

The method does not require the use of demand data, but it does require information on prices. Therefore, it is applicable only if the price does not change as a result of changing the amount of the non-marketed good or service. This is because we can only estimate the price with information on both the supply and demand conditions. The requirement that the price is fixed also implies that the supply must not change because any changes in supply would change the price in a way that would not be predictable without information on the demand condition. Because the supply function shifts around with changes in the marginal cost structure, it is necessary that changes in the non-marketed variable do not affect the marginal cost structure. When it is unrealistic to assume that the change in the non-marketed factor will not affect the price of the marketed good, information regarding both supply and demand conditions are needed and analysis beyond the factor input/productivity method is necessary.

Contingent valuation method

The contingent valuation (CV) method is used to estimate values for all types of non-marketed goods and services including non-use values. In a contingent valuation study, people are directly asked about their willingness to pay for improvements in the quality or their willingness to accept decreases in the quality of some non-marketed good. The contingent valuation method is a stated preference, rather than a revealed preference, technique and as such is open to manipulation by both practitioners and those who are taking part in the survey. Contingent valuation studies can therefore be extremely controversial.

Similar to the contingent valuation technique, conjoint analysis (e.g., contingent ranking, contingent choice) involves asking people to compare possible alternative states of the world. Each state has a different price or cost, and thus this method can be used to estimate dollar values for changes in non-marketed goods. In choice modeling applications, both monetary and non-monetary factors can be included as attributes of the options in a choice set. This way, it is

possible to determine simultaneously the importance of economic, social and non-marketed factors in a single valuation exercise. In CV studies, it is usually only possible to value one type of outcome at a time.

The key assumption behind the contingent valuation method is that people have well defined preferences for different goods. If this is true, peoples' preferences can be elicited by simply asking them to reveal their willingness to pay in surveys. These surveys can be designed to gather data on specific valuations for various individuals, or to gather information on discrete (take it or leave it) choices of individuals. In the latter case, the information could be used to estimate indirect utility functions from which willingness to pay values can be calculated.

To apply the contingent valuation method, one must first choose what type of survey questions to ask. There are a wide variety of formats that could be used, including open-ended WTP questions, iterative bidding games, and discrete choice formats. Discrete choice contingent valuation surveys are often preferred over other methods due to their advantages in performance and incentive properties. Discrete choice questions require respondents to make simple choices that are in-line with their actual preferences, and are less likely to be plagued by bias problems than other types of questions. Once the survey format is selected and questions are designed, the process simply involves administrating the survey and compiling the benefit estimations.

A contingent valuation survey must include three important elements. First, the choice scenario, along with a description of the good or service and how it is to be provided and paid for, must be clearly explained. To obtain meaningful estimates of value, respondents must understand the issue at hand. Moreover, the payment vehicle must be both realistic and neutral. In other words, the use of a tax increase to fund a project may be realistic, but because most people dislike tax increases the vehicle may not be neutral. However, survey designers must be aware of the trade-off between providing respondents with sufficient information to make informed choices and overloading respondents so that they become confused or bored. Second, there must be a set of preference elicitation questions that ask respondents whether they would or would not buy the described good at the stated price. Finally, there should be a set of validation questions designed to verify that respondents understand the scenario and valuation questions they have been presented with. These questions also help to identify the motivations for survey responses and allow one to identify possible protest bids. Included in this part of the survey can be a series of questions about the socio-economic and demographic characteristics of the respondent.

There is a wide variation in the resource requirements for contingent valuation studies depending on the degree of sophistication of the form of survey used. State-of-the-art contingent valuation studies that employ methods to test for, and control potential sources of error in the survey responses can be substantially more expensive than basic open-ended contingent valuation question formats. Moreover, the type of survey used, whether it is mail, telephone, or in-person interviews can drastically affect the total cost of the program. Finally, technical expertise in survey design and statistical and econometric procedures is required. However, the degree of expertise that is needed varies with the type of contingent valuation study that is preformed.

Contingent valuation is extremely flexible and can be used to value almost anything. It is one of the only ways to estimate non-use values and as such, it is widely used in total economic value measurements where revealed preference techniques are unsuitable. Contingent valuation studies are also reasonably easy to administer and the results are often easy to interpret.

There are three major weaknesses of contingent valuation studies. First, while people have experience making valuation decisions in market setting, they may not be able to place accurate values on non-market goods such as the environment in contingent valuation studies. Second, even with the most stringent controls, there may be bias in the valuations gathered in contingent valuation studies. Bias can come in the form of untruthful responses, confused responses, or through problems in aggregating individual responses to the group level. Finally, the choice of whom in the general population to survey can be problematic. Unlike in market situations where the relevant population is self-determined, the contingent valuation approach has no natural indicators as to whose valuations should be considered.

Benefit transfer method

The benefit transfer method involves estimating the benefits for one context by adapting estimates from other studies for similar contexts. If it is possible to use, perhaps after some adjustment, the estimate of economic value from some other study, a great deal of time and money can be saved. Information from other studies is often readily available and inexpensive to acquire and adapt. Moreover, in many cases the similarities between projects are substantial.

There are two main types of benefit transfer studies. The first is a unit value transfer that involves using average values for some unit of non-marketed good or service. The second is a valuation model transfer in which entire willingness to pay functions are adapted from one project to another. Problems arise in either technique when site-specific variables change drastically. Therefore the technique may find limited applicability.

The idea that valuations from one site can be applied elsewhere is based on a high degree of similarity between areas. However, demand functions and unit value estimates are site and user specific and therefore the similarities must lie in specific non-marketed and project characteristics. In addition, the valuation of a new good using existing studies can only be as accurate as the original study. It is important to remember that any errors or biases in the original study will be transferred as well.

The first step in a benefit transfer study is to identify existing studies that can be used for the transfer. This decision should be made on the basis of the comparability, or similarity, of the important characteristics outlined above. Some consideration should be given to the quality of these studies as well. Once a suitable source for the transfer has been found, the method simply involves fine-tuning the valuation on the basis of site-specific characteristics. In order to make these adjustments, some additional data might need to be gathered. Not surprisingly, the benefit transfer method is a low cost alternative that requires less time and expertise than other methods.

New valuation studies require primary data and can take months or years to complete. When only rough or ballpark estimates of value are needed, the benefit transfer method may be ideal.

Choosing among valuation techniques

All of the valuation techniques that have been described in this report have strengths and weaknesses. Therefore, the choice of method requires experience and judgment on the part of the analyst. Following some basic guidelines can help this selection process.

First, it is often possible, and desirable, to use more than one valuation technique and then compare the results simply because multiple estimates give greater confidence in the results. Second, different techniques complement each other because they measure different things. Use values can be estimated using a number of different techniques but contingent valuation is the only method that can measure non-use values. Revealed preference methods measure the perceived benefits to individuals but do not value effects which people are unaware of. Third, it is important to consider the needs of the users of the valuation studies, as they may simply prefer one method to another. For example, contingent valuation studies may be considered too subjective. Finally, it is important to consider the cost of carrying out the study. In many cases the concern is that the study is too expensive. However, in cases where non-marketed impacts are likely to be felt long into the future it is important not to spend too little.

Measuring the size and impact of TBTs

Conforming to standards that differ between the domestic and the export market increase the costs of the exporter because of the measures they have to take to comply with the standards. Many studies that attempt to measure the size of TBTs express the findings in frequency measures. The frequency measures usually take one of two forms; *Frequency Ratio* expresses the percentage of those product categories that are subject to a TBT, and *Import Coverage Ratio* expresses the value of imports of those product categories subject to the TBT as a percentage of all applicable product categories (Deardorff and Stern 1997). The problem with frequency measures is that all TBTs enter the measurement symmetrically regardless of how much extra costs they involve. The frequency measures are useful first steps in detecting problem industries and are sometimes accompanied by subjective or objective measures of the severity of a TBT in a given industry. Frequency type measures of TBTs and other non-tariff barriers can be found in National Research Council (1995) and Brenton et.al. (2001).

Other studies try to estimate the additional costs that the firms must incur due to the existence of the TBT. Analysis of this type can relatively easily be extended to estimate the welfare effects of the TBT.

The approaches that try to estimate the additional cost created by the TBT fall into one of two main approaches – the micro approach and the macro approach (OECD 1999).

The micro approach

The micro approach involves using survey methods or industry studies to identify the specific changes in the product design or the production system and any procedures the firms have to undertake to satisfy the standards and demonstrate conformity in their target markets. The cost of these changes and procedures is estimated on a case-by-case basis using actual or reported cost data. The costs are then aggregated appropriately to arrive at a total cost of the TBT in a target sector.

The micro approach is quite demanding in its data requirements and quite costly to perform but has several benefits. The results are generally more accurate and reliable than the results of a macro approach because the micro approach allows for isolation of the cost of a particular TBT whereas the cost arrived at using a macro approach may include the effect of other barriers to trade and other factors that influence market prices (see below). Furthermore, the micro approach can discriminate between fixed and variable costs, whereas the macro approach cannot identify all fixed costs. However, care must be taken when asking firms directly about their costs because those adversely affected may have an incentive to overestimate the cost. Henson (1997) uses the micro approach to indicate the specific areas where food producers would find compliance costs in meeting food safety regulations, although he does not quantify the costs. U.S. International Trade Commission (1998) conducted interviews of corporate executives, officers of trade associations and government officials in the US, the EU, and some countries in Asia and Latin America for their views on how TBTs affect trade in the IT sector. Most computer hardware, software and telecommunications equipment manufacturers indicated that having to undergo multiple conformity assessment procedures to meet duplicative government technical regulations in international markets was the most significant TBT faced by them. The study found that MRAs may help to reduce the costs especially in heavily regulated industries. The study did not try to quantify the effects of TBTs but did present some estimates made by others. Among them, the Information Technology Industry Council estimated that mandatory US and EU testing for the information technology products was costing the US firms and consumers $1.3 billion annually. OECD (1999) conducted a micro survey to assess the effects of non-tariff barriers in three sectors (telecommunications equipment, automotive components and dairy products) and four study countries (The US, the UK, Germany and Japan). Interviews of 55 firms revealed that firms' own estimates of their cost of complying with foreign standards ranged from no cost to 10% of the value of exports. Furthermore, the interviews showed that companies generally find harmonization of standards helpful in reducing costs of product redesign and testing, and that the companies have noticed a distinct and beneficial effect of MRAs on conformity assessment procedures on their cost of compliance. Standards New Zealand (2001) conducted a micro survey of 381 New Zealand exporting firms. The findings include that one in seven exporters thought that non-tariff barriers impact in export performance to a great extent, one in ten thought that compliance costs presented more than 10% of their export revenue, and one in four thought that non-tariff barriers make it prohibitive to engage in trade with some countries.

Maskus et. al. (2001) provide a framework for future efforts to quantify TBTs. The three steps recommended by them for getting a better grasp of the role of standards in exports include 1) using firm-level surveys; 2) devising methods for assessing the trade restrictiveness of standards;

and 3) establishing econometric approaches that can be applied for analyzing survey and micro data.

The macro approach

The macro approach estimates the additional costs created by TBTs indirectly through inter-country variations in prices given the differences in product standards or conformity assessment procedures (OECD, 1999). If the assumptions of perfect competition, homogenous goods, no transportation costs and no other trade barriers are satisfied, the TBT creates a price wedge equalling the per-unit variable cost of the TBT. This wedge is increased by any fixed costs of the TBT that have lead to firms exiting the export market, but fixed costs that are not prohibitive are not reflected in it. In the absence of any complications caused by the above assumptions not holding and in the absence of significant fixed costs of the TBT, the size of the TBT can be directly inferred from the price wedge.

The macro approach often expresses the cost as a *tariff equivalent,* or the ad valorem tariff rate that would have the same impact on the prices in the two countries as the TBT. The tariff equivalent is the price wedge divided by the price in the exporting country under the TBT. Expressing the effect of the TBT as a tariff equivalent makes comparing the impact of the TBT to tariffs or other trade barriers easier.

In practice, finding the tariff equivalent may be difficult. Market power, product differentiation, transportation costs, co-existence of other barriers to trade and fixed costs bring about complications to the estimation procedure. Market power breaks down the one-to-one relationship between price and cost; the more market power firms in the market have, the smaller is the upward shift in the export supply and therefore the smaller proportion of an additional cost will be reflected in the price. This implies that the price wedge underestimates the per-unit cost of the TBT. Product differentiation leads to the same conclusion: A trade barrier increases the price for the import good, which leads to an increase in the demand for the domestic good (the demand shifts out) when the goods are imperfect substitutes. This causes an inward shift in the import demand leaving the price wedge below the per-unit cost of the TBT. Transportation costs create a wedge between prices in A and B even in the absence of trade barriers and therefore the price wedge overestimates the per-unit cost of the TBT unless transportation costs are accounted for. The co-existence of other trade barriers imply that the effect of a particular TBT is difficult to isolate, and if these other barriers are not accounted for, the price wedge overestimates the per-unit cost of the TBT. This is partially why this method is most widely used in assessing the total impact of all TBTs as opposed to the effect of a single TBT. Finally, because tariff is a variable cost, this method does not identify any fixed costs that did not lead to a change in behaviour of the firms. As a result, it tends to underestimate the per-unit cost of the TBT.

Baldwin (1970,1991); Thilmany and Barrett (1997), Deardorff and Stern (1997), and Calvin and Krissoff (1998) are examples of studies that use the macro approach for estimating the size of non-tariff barriers.

Appendix 4: NMI Survey

NMI Preamble

KPMG Consulting has been hired by BIPM to conduct a study of the potential economic impact of the Mutual Recognition Arrangement (MRA), covering national measurement standards and calibration and measurement certificates issued by national metrology institutes (NMI).

The objectives of the MRA are:

- To establish the degree of equivalence of national measurement standards maintained by NMIs.
- To provide for the mutual recognition of calibration and measurement certificates issued by NMIs.
- Thereby to provide governments and other parties with a secure technical foundation for wider agreements related to international trade, commerce and regulatory affairs.

In each of these areas, the MRA has the potential to generate significant economic impacts, evidence of which has emerged since the Arrangement was signed in October 1999. As experience with the MRA grows, opportunities will be created periodically to measure its economic impact. As such, KPMG consulting is conducting the first study of the potential economic impact of the MRA on the activities of individual NMIs, on the calibration activities of member states, and on the potential impact of the MRA in terms of its effect on international trade.

This survey is designed to measure the impact of the MRA on the activities of signatory NMIs, with specific attention on the equivalence of measurement standards, and the mutual recognition of calibration and measurement certificates.

As an NMI director, your response to this survey will be extremely valuable, and will be used in conjunction with the responses of each of the other NMI directors who are signatories to the MRA. It is important to emphasize that your response, and those of your colleagues, will be strictly confidential, and no individual attribution will be made or implied in the study. *Results will be reported in summary form only.* As they are available, the results of the study will be communicated directly to you.

Your participation is warmly appreciated, and we would like to thank you in advance for submitting your completed survey by **February 15, 2002**. The survey should take approximately 20 minutes for you to complete.

If you have any questions about the study, please contact Dr. Mark MacDonald at the coordinates below:

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Demographics

To contextualize your responses to the survey below, it is helpful to begin with an understanding of a few key characteristics of your organization. As such, we have four brief questions that will give us a sense of your NMI's demographics.

Which country's NMI do you direct? Please specify: _____ _____

1. In local currency, what is the annual budget of your NMI? (Note: We will convert your answer to Euros) _____ Please specify your local currency: _____
2. Expressed as a percentage of your NMI's total budget, how much is spent annually on research and development? _____ %
3. How many employees work at your organization? _____

   What percentage of your employees would be classified as:

a. Research scientific staff _____ %

b. Technical scientific staff _____%

c. Managerial staff _____%

d. Administrative support staff _____%

e. Business development staff _____%

f. Other (please specify) (_____) _____%

100 %

Impact of the MRA on your NMI

Reliability of the international measurement system is enhanced through continual effort by NMIs to base measurements and measurement uncertainties on universally accepted units, normally those of the International System of units (SI). It is important for individual NMIs to compare national measurements and establish their mutual equivalence, not only in an effort to enhance measurement capabilities, but also as a means to reduce technical barriers to international trade. The extent to which an NMI can secure the mutual equivalence of national measurement standards and calibration capabilities, within known uncertainties, is thus a contributing factor to its Nation's ability to engage in global trade.

Historically, mutual equivalence has been determined through an NMI's participation in international comparisons of its measurement standards organized by the Consultative Committees of the Comité International des Poids et Mesures (CIPM), by local regional metrology organizations (RMO) and through bilateral comparisons. In October 1999, however, the whole system was put on a much more formal and structured basis with the signing of the CIPM MRA.

Accepting that a more formal structure for mutual recognition of national measurement standards had become necessary, the value of the MRA to a given NMI can be identified as (a) the benefits of more broadly accepted measurement equivalence obtained through the MRA, together with (b) the costs that would otherwise have been incurred in operating a formal but decentralized system based on a comprehensive series of bilateral relationships directly with other NMIs, or with other non-local RMOs. It is this value that the current survey measures, as uncovered in the set of questions below.

4. Which RMO(s) is your NMI a member of?

   a. APMP 1

   b. COOMET 2

   c. EUROMET 3

   d. MENAMET 4

   e. SADCMET 5

   f. SIM 6

5. Which CIPM Consultative Committee(s) is your NMI a member of?

   a. Electricity & Magnetism 1
   b. Photometry & Radiometry 2
   c. Thermometry 3
   d. Length 4
   e. Time & Frequency 5
   f. Ionizing Radiation 6
   g. Units 7
   h. Mass & Related Quantities 8
   i. Amount of Substance 9
   j. Acoustics, Ultrasound & Vibration 10

6a) On average, how many international (i.e., key) comparisons has your NMI participated in for the past four years? (Note: calendar years are used for ease of international comparison)

Number of Key Comparisons	1998	1999	2000	2001
Local RMO				
CIPM				
Organizations other than local RMO or CIPM				
Of these, how many in direct response to MRA				

6b) Do you expect this number to change, on average, over the next five years?

No 1
Yes 2
Why/How? _____
_____

7. In sum, how much does it cost your NMI to participate in key comparisons on an average annual basis for the time period considered above? Please express your answer as percentage of your total budget. Costs include factors such as travel and communication time, dedication of staff's time, direct scientific/technical costs, costs of materials, costs of quality assurance, and so on.

Cost of Key Comparisons (% Budget)	1998	1999	2000	2001
Local RMO				
CIPM				
Organizations other than local RMO or CIPM				
MRA				

8. How would you characterize the **benefits to your NMI of participating in the MRA?**

	Impact: Very Negative				Very Positive	Don't Know
a) Mutual Recognition of national measurement standards by a greater number of countries	1	2	3	4	5	9
b) Mutual Recognition of calibration and measurement certificates by a greater number of countries	1	2	3	4	5	9
c) Centralized coordination of mutual recognition at the international level	1	2	3	4	5	9
d) Lower costs of ensuring mutual recognition	1	2	3	4	5	9
e) Other (please explain) _____	1	2	3	4	5	9

9. For those benefits you identified as being "very positive"/positive" or "very negative" impact, please briefly explain why this is, in your opinion.

   a) Mutual Recognition of national measurement standards by a greater number of countries

   _____

   _____

   b) Mutual Recognition of calibration and measurement certificates by a greater number of countries _____

   _____

   c) Centralized coordination of mutual recognition at the international level

   _____

   _____

   d) Lower costs of ensuring mutual recognition _____

   _____

   e) Other (please explain)? _____

   _____

10. How would you characterize the **benefit, or potential benefit, to other organizations in your country of your NMI signing the MRA?**

	Impact: Very Negative				Very Positive	Don't Know
a) Accredited calibration and testing laboratories	1	2	3	4	5	9
b) Legal metrology organizations	1	2	3	4	5	9
c) Written standards organizations (e.g., ISO member bodies)	1	2	3	4	5	9
d) Government regulators	1	2	3	4	5	9
e) Other (please explain)	1	2	3	4	5	9

_____

11. For those organizations that will receive a "very positive/positive" or "very negative" impact due to the MRA, please briefly explain why this is, in your opinion.

    a) Accredited calibration and testing laboratories_____

    _____

    b) Legal metrology organizations _____

    _____

    c) Written standards organizations (e.g., ISO member bodies) _____

    _____

    d) Government regulators _____

    _____

    e) Industry _____

    _____

    f) Other (please explain) _____

    _____

12. By signing the MRA, you have the opportunity to ensure mutual recognition with all other signatories, in those key comparison areas deemed important to your NMI. Are you yet able to evaluate or characterize the benefits of the MRA, as compared to your experiences prior to the MRA being signed in 1999? If so, please explain.

    _____

_____

    _____

13. In the absence of the MRA, would your NMI have been obliged to engage in mutual recognition arrangements with other NMIs that you had not already engaged by October 1999? If so, with how many?

    _____

    _____

    _____

14. Are there actors or organizations that you view to be of fundamental importance to the success of the MRA over time? Please describe which actors/organizations and why/how they are important.

_____

_____

_____

_____

15. How would you describe the impact, so far, of the key comparison database maintained by the BIPM? Please explain your answer.

Impact

Very Negative				**Very Positive**	**Don't Know**
1	**2**	**3**	**4**	**5**	**9**

_____

_____

_____

_____

Thank you again for participating in this survey; your efforts are greatly appreciated. If you have any other comments, please feel free to provide them below.

_____

_____

_____

_____

Appendix 5: List of Interviewees[17]

AdvaMed – Advanced Medical Technology Association, USA

Neil Greenberg, Manager, Regulatory Affairs, Ortho-Clinical Diagnostics
Chandra P. Jain, Senior Staff Technical Operations Scientist, Beckman Coulter Inc.
Carolyn D. Jones, Associate Vice President, Advamed
Fred D. Lasky, Director, Diagnostics Compliance, Ortho-Clinical Diagnostics
Dennis R. Mertz, Senior Manager, Regulatory Affairs, BD Diagnostic Systems

Czech Republic Metrology Institute

Frantisek Jelinek, Deputy Director

Eurolab/Bundesanstalt für Materialforschung und prüfung, Germany

Horst Czichos, President
Manfred Golze, Secretary
Adolf Zschunke, Head, Analytical Chemsitry & Reference Materials

European Commission, Trade Directorate

Andreas Julin, Investment, Standards and Certification Unit

Institute for National Measurement Standards, Canada

Janusz Lusztyk, Director General

International Laboratory Accreditation Cooperation

Alan Squirrell, ILAC Secretary

NCSL International

Edward Nemeroff, Vice President International Affairs

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17 KPMG Consulting would like to acknowledge the contribution made to this Report by the interviewees, and to thank them sincerely for it. Their individual and collective knowledge informed, in an instrumental way, the arguments and conclusions presented herein; clearly, the burden of errors or omissions remains with KPMG Consulting.

National Institute of Standards and Technology, USA

Karen H. Brown, Deputy Directory, NIST
William E. Anderson, Director, Electronics & Electrical Engineering
Hratch Semerjian, Director, Chemical Science and Technology

National Physical Laboratory, UK

Bob McGuiness, Director
Andrew Wallard, Deputy Director and Chief Metrologist
Paula Knee

Physikalisch-Technische Bundesanstalt

Ernst O. Göbel, President
Michael Kühne, Head of Presidential Sector

Productivity and Standards Board, Singapore

Lam Kong Hong, Director

World Trade Organization

Vivien Liu, Counsellor, Trade and Environment Division