

MEASURING THE IMPACTS OF QUALITY INFRASTRUCTURE

Impact Theory, Empirics and Study Design

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Introduction

Quality infrastructure refers “to all aspects of metrology, standardization, testing, quality management, certification and accreditation that have a bearing on conformity assessment. (...) This includes both public and private institutions and the regulatory framework within which they operate.” (BMZ, 2004)

As it shall be argued, this institutional complex plays a vital role within national innovation systems, especially in a context of rapid growth of global trade and value chains, and higher concerns with consumers and environmental protection. Underpinned by this understanding, a theory of impacts regarding quality services is depicted. Framing quality infrastructure within the concept of innovation systems provides tools to better understand which kind of impacts are to be expected from the existence of quality services, and therefore to select the most appropriate methodologies to assess them.

Accurately assessing the impacts of quality services contributes decisively to improve the understanding at the political, entrepreneurial and academic levels about the relevance of quality infrastructures to the functioning of innovation systems, how they enhance the performance of economic agents and improve the outcomes of social, economic and environmental policies. The key objectives to be achieved through the realization of impact assessment studies on quality infrastructure are:

- the identification of the range of positive and negative effects that they have in societies;
- to advise policy makers on how the accomplishment of their strategic goals may be facilitated through the development of quality services;
- the raise of awareness of consumers, firms and industries about the existence of such an institutional complex, i.e. how it shall be used as a platform where various economic agents are to participate and interact in order to address to a multitude of social, economic and environmental challenges;
- to learn ways of improving the functioning of the existing quality infrastructure.

Estimating the impacts of quality infrastructure services requires the adjustment of the general methodologies applied in impact studies to the particularities of quality systems. For the assessment of the impacts, the researcher has to bear the strong complementarities between services in mind, as they pose an obstacle when trying to isolate the impacts of individual quality services. The researcher has to question whether each impact is a consequence of the functioning of an individual service or from the integration of various services. If the assessment study demonstrates that a quality service is unsuccessful to bring out the expected impacts, an enquiry is to be made to understand whether the complementarities between services were properly considered.

The approach to impact studies on quality services outlined in this article states that they have to pass through three stages: establishment of an impact theory, verification of the theory, interpretation of the results. The impact theory defines the range of possible positive and negative impacts resulting from the functioning of a quality service or of a group of quality services, identifies the stakeholders and the impacts channels. To verify the impacts, a methodology has to be selected from a variety of possible approaches according to the information required, the information available, and the kind of impacts that are at stake. Interpreting the results requires situating the impacts in a context, in a strategy, listing the limitations of the study and proposing ways of optimizing the outcomes.



The purpose of this report is to offer a better understanding about the kind of methodologies that researchers should employ when assessing the impacts of quality services. We start by presenting the concept of quality infrastructure as constitutive of innovation systems, and as having certain characteristics (i.e. strong complementarities between the various services and the need for public intervention) that need to be addressed when developing impact studies. In the second chapter, a theory of impacts concerning quality infrastructure is delineated, the outcomes that its individual elements are expected to produce are summarized. The outlined theory of impacts is confronted with the existing impact assessment studies on quality services in the third chapter. In the fourth chapter, based both on the presented theory of impacts and on the methods employed in existing empirical studies, the methodological approach to impact assessment studies applied to quality services is systematized and a guideline proposed.



The functioning of quality infrastructure

Quality infrastructure is a system of institutions which jointly ensure that products and processes meet predefined specifications. Most notably, it aims at providing technical support to companies so they can improve their production processes and at ensuring compliance with regulations or international requirements.

Quality, the congruence of the actual properties with the required characteristics, is the result of the integration and coordination of a series of activities in several interrelated subjects, which are the main services of quality infrastructure: standardization, metrology, conformity assessment, and accreditation. In the following, the importance of this institutional complex shall be discussed as a consequence to a context that demands a set of new capacities from the innovation system.

Quality infrastructure as part of innovation systems

According to an evolutionary interpretation, innovation is the societal process of problem-solving by introducing something new (e.g. a procedure, a device, an organizational structure). Innovation capability is the competence of social systems to find the adequate solutions for emerging challenges. Innovation system is a concept that describes the network of actors and institutions that interact within this process of adaptation as a reaction to the received signals of misfit. As defined by Lundvall et al (2009):

“[A] national innovation system is an open, evolving and complex system that encompasses relationships within and between organizations, institutions and socio-economic structures which determine the rate and direction of innovation and competence-building emanating from processes of science based and experience based learning.”

The better the functioning of innovation systems: the more effective the performance of societies while creating new processes, products, and organizational mechanisms; the faster the response to social or environmental transformations; the more successful adaptation of productive systems to new strategic economic objectives.

In what concerns to economics, innovation is concretized when, for instance, production systems engage at higher-value activities, develop goods and management practices that respond to rising needs, better realize the benefits associated with the participation in global markets and value chains.

A context of rapid growth of global trade, integration of production systems in global value chains, and of greater social concerns regarding consumers and environmental protection is demanding a set of new competencies from innovation systems. Effectively coping with such pressing concerns requires the development of quality infrastructures.

According to OECD (1999), 80% of the total global trade is already affected by standards and regulation. The costs associated with technical regulations, standards, compliance certification and testing range from 2 to 10% of total production costs (idem, 1996).

- The production system needs constantly to adapt processes, inputs, technologies and the design of products to meet foreign / international standards and regulations in order to have access to external markets. This requires the traceability of measurement units to a common reference so that goods meet the characteristics required by such standards and regulations can be developed.
- Firms need to be confident that their products comply with all the regulations imposed by the targeted markets as the costs and time associated with disputation may be prohibitive. The system has to ensure the adequate calibration of measurement instruments and a structure that evaluates whether the products conform to the norms.

- If the utilization of national quality services is relatively expensive or if they are not internationally recognized, local firms lose international competitiveness when compared with countries with better functioning quality infrastructures.
- Consumers are willing to pay a price premium for products and services addressing their concerns (e.g. fair trade, residues management, social protection of workers) or that offer new utilities. In order to reap the benefits associated with producing innovative goods and services, firms need to be able to make their superior characteristics visible to consumers. Credible certification plays such a role, hence increasing competitiveness of local companies in global markets and creating incentives for more innovations.

Presently, intermediate goods account for 54% of the total manufactured imports (OECD, 2007). This is a consequence of a more profound integration of economies and opens an opportunity for countries to join larger and ever more complex production systems.

- Joining international value chains implies an effort to adapt the productive processes to: new measurement methods and units, characteristics demanded by the buyer in the next stage of the production chain, characteristics of the goods that proceed from the previous production stage. The integration in such a complex network of conversions requires metrological progresses and integration of the national system of measurement units in the global system.
- The more complex the exchanged goods along the value chain, the more needed is the codification of the product characteristics. This makes the formulation of contracts and the compliance to specifications more difficult and costly, hence raising a barrier to entering global chains. Integrating the national quality services in regional bodies facilitates the writing of contracts, the development of metrological tools ensures the compliance with specifications, and therefore promotes the participation of local companies in chains that produce high value added goods, the continuous technological upgrading and higher levels of productivity.
- The increase in the number of partners involved in value chains implies higher coordination costs and higher levels of trust, i.e. the outcomes of one's activities correspond to the expectation of the productive agent in the next stage of the productive chain. The stability of the outcomes of the productive activities, resulting from accurate measurements, improves the trust between the various firms, increasing the likelihood of emerging new partnerships, products and processes.
- R&D is more effective if it takes place at all stages of the value chain - if all the agents are developing better processes and if these efforts are oriented in the same direction (e.g. adapted to consumers' needs, availability of inputs, and so on). Guaranteeing the compatibility of methods, instruments, or properties of products employed in research activities promotes the cooperation and coordination between firms during these processes. It facilitates the inclusion of the national innovation system in the global innovation system.

The raise of awareness about the need to protect consumers (especially in the fields of health and food safety) and environment has been substantiated in an increasing number of regulations that set limits to the characteristics of the products that are traded, demanding from the producers the development of products and processes that respond to such concerns.

- In order to define a norm concerning a certain property that is considered harmful to consumers or to the environment, instruments are required to measure it.

- Guaranteeing the enforcement of the norms at a national level requires a system of institutions that evaluates the conformity of goods to the norms. If there are regional imbalances in the system to evaluate the conformity of goods, the consumers and environment from the region with a less demanding system will probably end up getting the goods that would not be accepted in the stricter areas.
- If the compliance with a norm is expensive or technically difficult, companies may be forced out of the market. The system has to facilitate the compliance with the norm, safeguard competition, and protect small and medium firms that are more likely of having financial constraints for the adaptation to the new rules.

The following table summarizes contributions of quality infrastructure to innovation systems given such pressing demands.

Table 1: Contributions of quality infrastructures to innovation systems

Rising concerns	Importance of innovation system	Contributions of quality infrastructure
Reaching global markets	<ul style="list-style-type: none"> • Capacity to constantly adapt to foreign requirements • Ensure compliance • Guarantee competitiveness • Production of goods with higher value 	<ul style="list-style-type: none"> • Traceability of measurement units and procedures, resulting in the comparability of the results. • Development and calibration of measurement instruments • Cost-effective adaptation processes • Making innovations visible to consumers
Integrating global value chains	<ul style="list-style-type: none"> • Integration in more complex production systems • New forms of integrating different productive sectors • Increase number of partnerships • Integration in global innovation systems 	<ul style="list-style-type: none"> • Harmonization of processes, materials, measurement units and instruments • Comparability allows writing of contracts • Decrease of uncertainty and leverage trust between worldwide productive agents • Harmonizing tools and methods used in R&D
Protection of consumers and environment	<ul style="list-style-type: none"> • Ability to measure certain properties • Guarantee quality of product • Discovering cost-effective procedures • Protect small and mediums enterprises 	<ul style="list-style-type: none"> • Development of tools to measure such properties • Setting technical regulations and guaranteeing conformity • Avoidance of regional imbalances • Minimization of market power creation



Innovation systems consist of a network of formal and informal entities where procedures and relations depend on a variety of factors, e.g. cultural values, historical practices, trust between economic agents, etc. which differ from society to society. Analogously, the architecture of a quality infrastructure depends on such cultural phenomena and on the strategic goals they serve for, thus varying across countries.

There are, nevertheless, some general conditions that quality systems are to assure in order to optimize their contributions to national innovation systems:

- Confidence. Products and services that are traded conform to the characteristics settled in contracts.
- Reliability. In a value chain where different companies are producing at different stages, each enterprise has to trust on its counterparts regarding, for instance, the measurements units and procedures that are used, the materials or methods that are employed.
- Comparability. The possibility to compare different products and services in terms of their properties across countries or regions.
- Traceability. "An uninterrupted chain of comparison measurements with increasingly higher accuracy instruments (smaller measurement uncertainty), starting at the instrument used in industry up to the national measurement standard." (Sanetra and Marbán, 2007, p. 63)
- Competence. The different institutions within the quality system are technically able to perform the tasks that are assigned to them.
- Conformity. Products and processes meet the requirements that were established through a standard.
- Transparency. Practices and procedures of the involved institutions are accessible and auditable by the civil society.
- Impartiality. Institutions need to be protected from political influence and regulatory capture in the fulfillment of their technical contribution.

The impacts of quality systems go beyond the functions above described. The direction of innovation depends on the context because innovation is not an end in itself but a means of reaching a variety of goals. Thus, when new processes are found or new products are developed they are contributing to various spheres within the social, economical and environmental realms, solving concrete problems, helping to achieve specific objectives. Consequently, looking for the impacts of a quality system implies finding a broad range of effects that are situated at various levels.

Particularities of quality infrastructure

In order to assess the impacts of quality infrastructure services one has to take the particularities of a quality system into consideration and adapt the general methodologies employed in impact assessment studies to these specificities. There are two key characteristics of quality infrastructures that need to be addressed when designing an impact study in this field. On the one side, the effective performance of an individual quality service depends on the functioning of the quality system as a whole. This poses a challenge when establishing the causal relation between intervention and impact: which service is responsible for each impact?



On the other side, quality services, according to their nature and the idiosyncrasies of each society, are performed not only by private institutions, but also by public bodies. For this reason, the impacts have to be assessed taking in consideration the reasoning of public intervention, recognizing the various perspectives associated with the quality service and the medium-long run objectives associated with services as such, hereby creating an additional challenge: how to analyze the public interest of a service?

Complementarities

The effectiveness of a quality service depends on the ways that the different services are interrelated, how they mutually support each other. To serve as an illustration, it is only possible to formulate a standard regarding the properties of a product, if the measurement units associated to those properties are defined and measurement instruments exist and are calibrated. This standard is made effective when producers comply with it and this is more likely if there are incentives to do so, for instance, when compliance is signalized to consumers through certification. The impacts of certification are more significant the greater the trust that consumers have about the certification institute, which is higher if the competences of the institute are evaluated by an accreditation institute.

The high interdependence between quality services advice us to look at these activities as integrative of a system, not as independent activities that can be tackled individually irrespectively from the functioning of the whole. This is an important consideration both when defining a strategy for a quality system and to measure the impacts of quality services (i.e. often impacts have to be attributed to various services and not to only one intervention). It requires the framing of each service within the functioning of the whole infrastructure (how does it support and is supported by other elements?) and the embedding of this infrastructure as a pillar of the national innovation system (which strategic role is it performing?).

Public Intervention

The design of the strategy for quality systems and coordination of the various quality services require the direct execution of certain activities by public bodies:

- necessary for the development of regulatory frameworks which typically can only be enforced by institutions with legislative power;
- as providers of services because certain activities (namely metrology) within this infrastructure are often perceived as public goods, meaning that private agents when left alone will not provide the most desirable design of the quality service from a welfare perspective;
- required in order to integrate the national quality infrastructure in the international quality system - a vital step for the reduction of technical barriers to trade, and hereby to improve the access of local companies to global markets and value chains. National metrology institutes may integrate regional metrology organizations which “ensure the accuracy of measurements within the region and promote the regional use of national measurement and calibration capabilities” (Sanetra and Marbán, 2007, p. 43). Analogously, accreditation institutes may join regional accreditation organizations or agreements.



However, depending on the capacities and limitations of the national production system and the strategic approach to capacity building, the pace of the implementation of new norms and of the international integration is to be defined and will affect differently each stakeholder.

For example, if the productive fabric is not prepared yet to create or assimilate certain advanced technologies required to conform to an international agreement and if it is, nevertheless, enforced in a short period of time, small firms may be driven out of the markets, while larger firms are more capable to finance their adaptation to these new demands. Therefore, assessing the impacts requires the analysis of the how different stakeholders are affected by quality services.

Apart from trying to analyze how different players win or lose from certain interventions and how it matters for the design of the services in order to optimize the public interest (minimize the social losses, maximize the social benefits), this has to be framed given the medium-long run political and economic strategy associated with the quality service at stake. One has to enquire about the meaning of the analyzed intervention in terms of the future welfare or interests of the overall population or certain economic sectors, which imply a further forward-looking analysis.

Finding the appropriate methods to estimate the impacts of quality services requires the understanding of the systemic role of each quality service, the public interest associated to the various services, and also of the kinds of social, economical and environmental impacts that are expected as a consequence of the functioning of quality infrastructures.

In the following chapter, a theory of impacts concerning quality infrastructures is outlined. It aims at providing a summary of the possible goals that can be reached through the means of a quality system.



A theory of impacts concerning quality infrastructure

Quality infrastructures may enhance the performance of economic systems in various ways. Depending on their design, their impacts range from the stimulation of network effects and knowledge transfer, to the increase in economic efficiency and markets competition. But quality infrastructure may also have counteracting effects. In this chapter, we start by summarizing a spectrum of possible positive and negative social, economic and environmental impacts from the functioning of a quality system as a whole.

Positive impacts

Network effects through enhancing interoperability

- Quality infrastructures increase the value of goods with network externalities and promote the development of networks as long as they allow products to work as a part of a larger number of productive systems. By ensuring compatibility between products, their integration in a broader number of value chains is facilitated, hence increasing the number of economic agents that derive benefits from using them. The linkages between firms and industries are multiplied, more information is exchanged and the cooperation in research increased.

Better management procedures

- Quality infrastructures aim at improving not only production related procedures, but also management practices which “may generate improvements in all aspects of a company: better quality, new schemes of internal organization and of service delivery, and also facilitate the creation of new products and services.” (European Commission, 2007, p. 7)

Knowledge transfer

- Through metrology, standardization or accreditation, a quality system is providing information about the state of the art of a certain technology. As this information is freely available to everyone (both to market agents and non-market agents such as research institutes), they are able to internalize it and use to generate new products or processes.

Competition

- Opening markets. The development of a quality infrastructure may reduce the dependency of businesses to a small number of suppliers, hence opening the markets. By guaranteeing comparability, traceability, conformity, a quality system broadens the buying possibilities of companies, increases the competition among suppliers and the confidence of buyers on the quality and reliability of those suppliers that conform to the norms (DIN, 2000).
- Reducing entry barriers. Quality infrastructures enhance transparency and help firms reaching new markets. According to European Commission (2007), companies are able, through the information contained in standards, to appropriate the preferences of consumers in foreign markets and the required technical specifications. Furthermore, through certification and accreditation, local firms obtain more easily the trust from the foreign consumers as it guarantees that their products are in conformity to the specified norms.

Economic efficiency

- Economies of scale (the cost reduction associated with a larger scale of production). A quality infrastructure,



namely through standardization processes, reduces variety in the sense that it sets limits to a certain number of characteristics of products. This enables lower per-unit costs for suppliers since they do not need to produce a specific good for each buyer. Instead, they produce a homogenous good that serves all their clients.

- Economies of learning. The mentioned variety reduction also allows economies of learning, which is the increase of efficiency associated with the skills and experience gained by being focused on products with fewer technical variations.
- Reduction of transaction costs. As long as the supplier complies with the standard, the product is certified, and there is trust regarding the certification, the consumer does not have to incur in costs associated, for instance, with double testing to check whether the product conforms to the requirements.
- Reduction of search costs. The effort of finding a product that has some specific characteristics is substantially reduced given that there are standards that specify those properties and compliance is assured through certification.
- Reduction of adverse selection. A well functioning quality infrastructure enables producers to differentiate their products in terms of quality (the producers that comply and those that do not comply with certain norms). Through the conformity assessment framework, innovators are allowed “to differentiate their product/ service offer or to improve their internal processes” (European Commission, 2007). That is a major incentive as through this differentiation innovators are able to charge a price premium (a higher price than their competitors) for their innovative products, hence compensating the investment made with higher revenues.
- Reducing information asymmetry. The effective existence of a quality infrastructure may reduce the differences in the information that the various economic agents (consumers, producers, governments) possess regarding the product that is traded. By doing so, allocation of resources is more accurate and market efficiency increased.

Box 1: Asymmetric information

“In Akerlof’s (1970) famous paper about failure in the market for second hand cars (“lemons”), the cause of the market failure is in asymmetric information, and as Barzel (1982) argues, the problem in the “lemon” case is that measurement is really rather expensive. If it were not, then buyers could cheaply measure any of the product characteristics they want to, and they would have perfect (or perfectly adequate) knowledge about the quality of the product. It is the fact that measurement is not cheap that means the buyer bears this risk from asymmetric information. The growth of trade requires the reduction of transaction costs, and an essential part of that is the emergence of common standards and measurements. The comparability and traceability of measurements reduces some of the risks in trading, reduces transaction costs and hence facilitates trade. Markets for innovative new products require a high degree of information and trust, and improvements in the quality and comparability of measurement are important for such products. The accurate measurement of product characteristics makes it easier to demonstrate quality and safety, and hence to sustain a price premium for superior products” (Swann, 2009, p. 65).



Consumers and environmental protection

- Concerns of consumers and environmental protection are increasing and quality infrastructure is a means to safeguard such interests. For example, if a certain chemical is regarded as harmful for the health of consumers or for the environment, metrology instruments can be developed to measure the levels that products contain of that chemical; a technical regulation (a mandatory standard) can be established forbidding the existence of this chemical beyond a certain level; conformity assessment guarantees that products effectively follow the norm.

Negative impacts

Constraints on technological innovation

- Variety reduction. This may be perceived as a contradiction as it was mentioned as a positive impact of a quality infrastructure. However, namely in the process of standardization the positive effects “on technical change are counterbalanced by their negative effects on product variety. By specifying product characteristics, such as form, performance, or interface, standards limit innovation. Obsolete, inappropriate standards may hamper technical change by preventing the adoption of superior technology through the lock-in effect.” (Guash et al., 2007, p.24).

Box 2: Lock-in effects

“The QWERTY computer keyboard is a well-known case of technological lock-in. Although many alternative keyboard layouts have been designed to increase typing speed and comfort, the nineteenth-century QWERTY layout is still used because the costs of retraining workers to use a different keyboard would be prohibitively high. Furthermore, new users will still prefer to learn to type on a QWERTY keyboard as long as this layout dominates the market.” (Guash et al., 2007, p.25)

Constraints on Competition

- Potential barriers to trade. A quality infrastructure may create impediments to trade:
 - if measurement procedures require complex practices and technologies which foreign companies have difficulties to internalize;
 - if compliance with different national standards requires high adaptation costs or if testing is expensive;
 - if the existing certification agencies are difficult to reach or corrupt;
 - if the created standards are not well documented, difficult to find, poorly understood, or protected by intellectual property rights.
- Creation of market power. Quality infrastructures may have anticompetitive impacts when only one or a few producers are able to internalize the benefits or control the content of a product or a measurement procedure, namely in technological fields where only a few players “have property rights, exclusive knowledge, or the exclusive resources needed to use a technology” (Guash et al., 2007, p. 25).

The contributions of individual quality services

In this subsection, we look in detail into the expected impacts of the different quality services to innovation systems, how their specificities have implications on the functioning and impacts of the system as a whole.

Standardization

Standardization may work as an instrument that: fosters international trade because it normalizes the characteristics of products and processes across countries; promotes technological transfers by facilitating the integration of value chains; creates incentives for the investment on R&D by reducing the risks associated with it as long as companies are able to influence the content of standards (DIN, 2000, p. 16).

As summarized by Araby (no date), it also increases the economic surplus of both consumers and producers:

- For consumers:
 - transmits information about the products,
 - allows a more effective comparison between goods,
 - increases competition among producers leading to lower prices,
 - creates the possibility for the consumer to mix and match components within the same system.
- For producers:
 - reduces production costs (economies of scale and learning);
 - through the information contained in the standards knowledge and technologies are diffused, hence productivity and efficiency increased;
 - permit repetitive production,
 - reduction of inventories
 - the combination of parts and components.

However, the misuse of such an instrument can also bring adverse effects. Standardization can, for instance, work towards the protection of certain companies or national industries. This discussion is particularly complex given the multitude of impacts that standardization may have considering the perspectives of each individual firm, the society or an industry as a whole.

Box 3: Controversy about innovation effects of standards

“Meeting standards and regulations can also be perceived by business as a constraint on their ability to undertake certain forms of innovation. There is though scope for debate about whether such constraints on individual businesses reduce competition and innovation at the level of the market or the economy as a whole. The argument is essentially that by setting some limits on novelty, the trajectory of product development is moved closer to the preferred path for customers, who value backward compatibility and some stability in market offerings. Many firms report finding meeting standards and regulations to be factors hampering individual innovation projects. (...) There are two reasons why this is an apparent and not a real paradox. One is that what the individual firms perceives as a problem may be of benefit to the national innovation system and thereby to overall economic performance. Standards enable larger markets and promote competition, so individual firms see a smaller market share and more competitors than they would like. But this diversity faces customers with more compatible choices and lower prices, promoting their welfare.” (NSSF, no date, p. 3)

While some positive effects of standardization on economic efficiency are widely undisputed, the above argumentation (Box 3) shows that the impacts of standards on competition and innovation are somehow ambivalent and subject to debate.

Furthermore, “once the technology is available, an additional problem frequently arises of reaching agreement among buyers and sellers on the content, form, and timing of the standard. Although common to most standards-setting processes, this latter problem is particularly severe in markets based on advanced technologies because of the typically intense levels of competition and the dynamics of the technological change process” (Tassey, 1982, p.311).

In standardization many conflicting interests are at stake. Through the establishment of standards some players win and some lose as firms try to control their content. When analyzing the impacts, it is important to frame the service within the strategic objectives to be reached through the means of quality infrastructure and the specific roles that standardization is to undertake. This is a way of evaluating whether the interests of societies are safeguarded or if the creation of a standard is serving vested interests. It promotes the transparency and accountability of standardization institutes to civil society.

Metrology

Quality infrastructure services such as testing, inspection, certification, and accreditation rely on accurate measurements. The metrological and calibration activities are typically performed by the National Metrology Institute (NMI). According to Sanetra and Marbán (2007, p. 66) the role of a NMI is to:

“(...) obtain, conserve, develop and disseminate the basic measurement units and the highest level of calibration standards. It provides traceability to the national system and it ensures that international technical guidelines are followed for the metrological performance and testing procedures of measuring instruments subject to legal controls, and from the point of view of manufacturers it ensures that their products meet international specifications for metrological performance and testing”.

Once a well functioning NMI is established, it is easier for companies, research institutes, testing labs, universities, to interact and collaborate, find more efficient production processes and new products for the markets. The quality of the goods produced will be more consistent, hence facilitating commercial transactions and allowing their regulation – the creation of new standards. The integration of the NMI in regional metrology institutes strengthens trust in the national production system, facilitates the access of local companies to new markets for their exports and fosters the integration of firms in global value chains.

As asserted by Swann (1999), metrological and calibration activities are often regarded as having a public good character. There are reasons that sustain the idea that this sector should be supported by public policy, that justify public intervention and funding:

- High fixed costs associated with the research and small marginal costs for the spreading of the developed knowledge;
- High externalities, since the investment of one metrology agency in this field will create benefits for other players;
- Strong network effects derived from metrological activities;



- Need to ensure that knowledge is not monopolized;
- Need for impartiality and integrity of measurements.

For these reasons, Swann defends that the production of metrology is more efficient when centralized, coordinated at one place, and when the findings are provided to all the players. The contributions of metrological activities to economic systems are also relevant for enabling technology-based growth as “they affect all stages of the technological change process from research and development (R&D) to market transactions involving the final user” (Tassey, 1982, p. 311).

The effective establishment of NMIs enhances the following impacts:

- On market efficiency:
 - Reduction of information asymmetry. More accurate measurements reduce the information gap between what buyers and sellers know about a product, hereby reducing information asymmetries, which will in turn reduce fraud.
 - Reduction of transaction costs. Once it ensures smaller measurements errors, the disputation within the market will be reduced, namely the costs associated with double testing, the time spend with discussions for the formulation of contracts regarding the properties of the traded good, converting units.
 - Improve allocation of resources. If transaction costs and information asymmetry are reduced, economic efficiency is increased in the sense that decisions are better made by economic players according to their needs and budget constraints.
- On governance:
 - Government revenue. A significant part of the fiscal revenues comes through taxing transactions, namely exports. The more accurate the commodities are evaluated, less arbitrariness will underlie the tax system and the better the estimations that government makes about its own revenues. This is relevant for political stability and also for the better intervention of governments in the markets, namely by using fiscal tools (taxes and subsidies) in response to structural and conjectural changes.
 - Allowing regulation. Legal metrology allows the credible enforce of regulations associated with, for example, issues as public health, public safety, or environmental issues (e.g. the CFCs and ozone depletion). This is only possible once there is a measurement framework that allows evaluating whether a product is in conformity with the regulation itself.
- On effectiveness of R&D
 - Provision of information. “To measure is to know” and “if you cannot measure it, you cannot improve it”, are words attributed to Lord Kelvin, 19th-century mathematical physicist: The provision of accurate information about physical product characteristics is an important input to R&D and part of the knowledge production and innovation process, supporting the improvement of process technologies.

Conformity assessment

The conformity assessment has the role within a quality system of differentiating those goods and services that conform to a standard and those that do not. As argued by Guash et al. (2007), without such differentiation, standards are of limited use and the economic benefits associated are not reaped. Therefore, the importance of the conformity assessment is directly related with the impacts that metrology and standardization are supposed to bring by increasing their magnitude.

The conformity assessment ensures that product conform to specified characteristics, increases the information that consumers have regarding the products, creates incentives for producers to upgrade their production processes - it establishes a “visible link between standards and the market” (DTI, 2007, p.2). As elements of the conformity assessment framework testing, inspection and certification services can be distinguished.

- Testing and inspection activities directly benefit some of the stakeholders:
 - Decrease the gap between expectations for the outcome of a certain production process and actual results. If returns become more predictable, the risks of investment are reduced and investment levels are increased.
 - Improve the accuracy of measuring equipment means that the research for new products or processes uses better tools and therefore the results of such research are likely to be better.
- The benefits of certification are to be directly felt by producers and consumers:
 - For producers who aim at providing goods that comply with certain standard, they profit from certification because they are able to differentiate their products from those that do not comply with standards. The possibility of having the certification of a product or process creates incentives for producers to invest in their quality, as it will be compensated with a differentiated demand curve for their products and the possibility of charging a higher price for their products. This brings more dynamics to the innovation system as it publicly recognizes that innovations add value to commodities.
 - For consumers, it is beneficial because it increases the information available about the different products in the markets. They are able to compare products regarding a certain number of characteristics, therefore being able of making better judgments about the quality of the product that they are buying. Their decisions are more rational in the sense that they can find product that are more suitable given their needs and budget constraints.

Accreditation

The main function of accreditation is to assess the competence of the remaining quality institutions, i.e. to create trust of the economic agents in the quality infrastructure. For this reason, accreditations’ most salient role is to amplify the impacts of each individual quality service and of the system as a whole. For instance, as accreditation ensures the correctness and independence of the certification process, it guarantees the quality of the certified commodities to the consumer. As the credibility of certificates increases, producers reap more easily the benefits of their innovations, which create incentives for investment in R&D.

Accreditation may indirectly also contribute to increase the quality of quality services. For instance, the evaluation of laboratories contains, implicitly or explicitly, suggestions to improve the performance of these laboratories. This represents a transfer of knowledge from the accreditation institutions to the assessed laboratories (Gilmour et al., 2003).



This element of quality infrastructure is especially important in the context of international trade and globalization of value chains. On one side, as long as the buyer trusts in the certified good, he does not need to do new tests in order to assess the quality of the good (avoid double testing), and on the other side, contracts are more easily settled, the penetration in foreign markets fostered.

Optimally, accreditation bodies are independent, impartial and recognized internationally. When that is so, they ensure competence, confidence, reliability, transparency and political independence. This is particularly more difficult in small countries, where accreditation institutions have insufficient income to face the costs and, therefore are more dependent on subsidies from the state (jeopardizing the objective of impartiality). In addition, the lack of practice of the staff keeps low their expertise when compared to their counterparts in bigger countries (Sanetra and Marbán, 2007),

Table 2: Impact expected from quality infrastructure services

QI	Activity	Main functions	Main beneficiaries	Main Impacts
Standardization	Formulation of standards (optional compliance) and technical regulations (compulsory compliance)	<ul style="list-style-type: none"> • Knowledge exchange • Coordination • Harmonization of products and procedures 	<ul style="list-style-type: none"> • Firms • Consumers 	<ul style="list-style-type: none"> • Economies of scale • Economies of learning • Innovation • Diffusion of technology • Competition • Lower market prices • Consumers and environment protection
Metrology	Establish measurement procedures and ensure calibration of measurement instruments	<ul style="list-style-type: none"> • Traceability • Comparability • Uncertainty reduction 	<ul style="list-style-type: none"> • Firms • Industry • Government • Consumers 	<ul style="list-style-type: none"> • Efficiency of R&D • Access to foreign markets • Integration in global value chains • Stability of government revenues • Consumer protection against fraud
Conformity Assessment	Check whether management procedures, products or services conform with established standard	<ul style="list-style-type: none"> • Conformity • Confidence • Reliability 	<ul style="list-style-type: none"> • Firms • Consumers 	<ul style="list-style-type: none"> • Reduction of information asymmetry • Innovation premium
Accreditation	Formal recognition that an organization or person is competent to carry out specific tasks	<ul style="list-style-type: none"> • Competence • Traceability • Transparency • Political independence 	<ul style="list-style-type: none"> • Quality infrastructure as a whole 	<ul style="list-style-type: none"> • Economic integration in international markets and value chains • Provide information to quality services about better practices

Empirics on the impacts of different quality infrastructure elements

Standardization

Most of the current empirical studies concerning the role of standardization are at a macroeconomic level and are focused on its impacts on economic growth, trade, innovation, and development. In this subsection some of the outcomes of these studies shall be summarized.

Impacts on growth

Standardization has differential impacts across sectors and countries: For instance, a more significant impact on productivity has been observed in mature industries than in R&D-intensive industries. An overview of the empirical literature is given by AFNOR (2009).

Table 3: Impacts of standardization on growth

Organization	DIN	DTI	Canadian Council of Standards	Standards Australia	AFNOR
Country Analysed	Germany	UK	Canada	Australia	France
Impact in % points of standards on GDP growth	0,9	0,3	0,2	0,8	0,8
Contribution of standards to growth of GDP (%)	27,3	11,0	9,0	21,8	23,8
Contribution to the productivity of work (%)	30,1	13,0	17,0	Not estimated	27,1

(Source: AFNOR, 2009)

- Blind, Grupp and Jungmittag (1999). In this study the German economy was analyzed during the period of 1960 – 1996. It identified a statistically significant positive impact of standards on productivity and in terms of the contribution of standards to growth. It was estimated that the impact of standards accounted for about 1% point of the average growth rate.
- AFNOR (2009). This study observes the impact of standardization in two dimensions. From a macroeconomic standpoint, standardization directly contributes to the growth in the French economy by an average of 0.89% per year, or almost 25% of GDP growth. The study also confirms the microeconomic benefits of standardization acknowledged by companies of all sizes and from all sectors of activity: product interoperability, increased productivity, market share gains, and ease of cooperation with public R&D institutions.
- DTI (2005). This study analyzed the impacts of standardization in the UK's GDP growth in the period 1948 – 2002. It concluded that standards contributed with 0.25 percentage points of the total GDP growth in UK during this period.

Impacts on trade

Empirical studies generally hint at a trade enhancing role of harmonized standards, but there is no consensus concerning the role of country-specific standards. A review of the empirical literature on standards and trade is given by the Guash et al. (2007) and Swann (2009).

- Blind and Jungmittag (2001). In this paper, two models are estimated. One takes in consideration the trade relations of Germany with the rest of the world and the other one, the bilateral trade relations between Germany with UK. It was found that: regarding the adoption of international standards, standardization has a positive and weak but significant effect on trade (increase of imports and exports); when Germany adopted national standards, that the effect was negative and weak but significant.
- Moenius (1999, 2004). These studies refer to a trade-off associated with the implementation of standards at a national level. From one side it demands adaptation costs for exporters, therefore hindering trade; on the other side, they provide relevant information for new entrants in the market regarding the preferences of consumers which otherwise would be very difficult and costly to collect. Furthermore, it is argued that the latter effect prevails; meaning that the reduction of transaction costs compensates the increase of adaptation costs, and therefore trade is promoted. In these studies 12 OECD countries are analysed.
- Swann, Temple, and Shurmer (1996). In this study, an econometric analysis is made in order to evaluate the impacts of standards on UK's trade performance between 1985 and 1991 regarding the manufacturing sector. The authors argue that, according to the results, it improved the trade balance performance of UK but that it also helped making the market more open. It is further asserted that national standards are by and large irrelevant for the trade performance of UK.
- Raballand and Aldaz-Carroll (2005). In this paper, it is assessed the impacts of existing multiple standards on trade costs applied to the case of pallets. The main finding is that most of the burden of such an excess of variety is on low income countries. The increase of costs is associated with necessity of manually load and unload the goods that are in the pallets at borders given the specific standards of the destination country, increasing delivery time and costs. As argued, this will be particularly more difficult to bear for low income countries given the unavailability of outsourcing, renting or exchanging pallets. Taking the case of the exports of bananas from Ecuador to Europe, the lack of standardized pallets will increase by 21% the transportation costs. "How Do Differing Standards Increase Trade Costs? The Case of Pallets."
- Chen et al. (2006). This study tries to quantify the impact of standards and technical regulations on the export performance namely in low income countries. Their results indicate that when standards are not harmonized, it create diseconomies of scale, prevents the entry of exporters in new markets. As argued, testing and inspection procedures reduce trade by 9% and 3% respectively. Multiple standards reduce the probability of an exporting company to penetrate in more than 3 markets by 7%.

Impacts on technological innovation

The empirical relationship between innovation and standardization shows an inverted U nonlinear pattern. For example, standards promote the adoption of new technologies as sources of information on innovation, but also introduce economic constraints that impede the innovation process.

- DIN summary report (2000). This study takes in consideration four main stakeholders in the standardization process: businesses, private households, the state and the standards body. In order to collect information, it was conducted a survey to companies in different industrial sectors, interviews to different partners, regressions were estimated in order to establish a relation between innovation and standards. According to this study, which also refers to the difficulties of separating the effects of standards on innovation from other factors, there are positive effects of standardization on innovation. As argued in this paper, standards lead to innovation by a reduction of the risk associated with R&D and by directly reducing its costs. Among other things, harmonization of technical rules (implied in standards) helps businesses and institutions to communicate, cooperate and establish alliances, and therefore reduces costs. However, as argued, these alliances can also lead to a higher concentration of market power, and therefore to less competition.
- Temple, Spencer & Witt (2005). These authors estimated the elasticity of labor productivity with respect to standards to be around 0.05. "This means that a 10% increase in the standards catalogue is associated with a 0.5% increase in labour productivity" and, given that this study takes into consideration only UK during the period 1948 to 2002, it means that during this period standards contributed for 13% of labor productivity growth. They further add that standardization processes are very connected with other factors such as innovation and that it would be difficult to separate the specific effects of trade separated from other factors.

Impacts on low and middle income countries

Empirical findings on the impact of standardization on low and middle income countries draw a very mixed picture. On the one hand, some case studies reveal the potential of standards as a technical barrier to trade, which excludes developing countries from international markets. On the other hand, there are positive cases illustrating standardization induced technological upgrading and transition to higher-value-added activities of firms in developing countries. Buyer-driven value chains seem to be of particular relevance to the integration of small low and middle income countries' exporters to the global economy.

- Wilson and Otsuki (2004). This study was based on a survey that enquired 689 companies, in various industries, spread in 17 low and middle income countries. The majority of the firms surveyed acknowledged standards as a barrier to their exports. Nevertheless, a significant percentage of Eastern European and Latin American companies stated that the existence of standards were important for the success of their exports (namely, quality standards and testing/certification requirements). By some companies it was also recognized that standards reduce production costs. Trade barriers posed by mandatory standards: technical regulations, additional compliance costs for each export market.
- Czubala, Shepherd, and Wilson (2007). In this paper which examines the impacts of standards in 47 Sub-Saharan countries regarding the textiles and clothing industries, it was found that EU standards that differ from ISO standards restrict the level of exports from those countries to EU, but harmonized with ISO standards have no significant negative impact on exports.
- Maertens and Swinnen (2006). This study analyses the impacts of EU standards on Senegal's exports of food and vegetables. The main conclusions were that, in spite of the stricter demands of EU in terms of standards, the exports from this country increased significantly; and that the existence of such standards led to structural changes in the supply chain, namely from production structure mostly based in small farms to large-scale farms, yet, as argued, with positive effects in terms of the welfare of rural households. The households benefited from the development of labor markets that substituted the product markets.

- Naik (2006). This study analyzes the impacts of EurepGAP certification requirements on the grape sector in India. The major findings were that such requirements increase production costs by 40%; imply the employment of techniques harmful for the soil and the usage of residues that may be toxic; have redistributive consequences, namely by impeding small farmers to enter in the market. On the other side, India's market share is growing, domestic markets are developing, and an innovation system has been developed made of partnerships between public and private entities.

Metrology

- King et al. (2006) tested whether good measurements would support innovation because the incentives to innovate depend on the capacity of the firm and consumer to measure and verify whether the product has certain special characteristics. He collected data from the Community Innovation survey and regarding the use of the National Measurement System (NMS) by different industrial sectors. The findings were different for product innovations and process innovations. While the impacts of good measurements were significant and positive for the former, the effects on the latter were not significant. It was also shown that the direction and magnitude of the impacts also depend on other factors that range from good testing systems to the level competition on goods and services markets.
- NIST (2006). The American institute for standards and technology conducted a survey which enquired for measurements requirements on different sectors asking how innovation was refrained by the lack of good measurements. Two of the most notable outcomes of this study were: lacking accuracy of measurement tool is the most common problem to innovation, namely in those sectors whose dynamics lead to more technological changes (e. g. IT, telecommunications, health care, nanotechnology); the inexistence of standards, metrics and so on, that enable the assessment of new technologies hinders significantly innovation.
- Birch (2003). The Canadian institution for legal metrology assessed the impacts of their measurement activities on trade. In this study it was argued that for each dollar spent by this organization with periodic inspection in order to evaluate the quality of measurement tools would save in average \$11.40 in measurement errors. This value would vary from sector to sector. In those where the measurement accuracy was more relevant, this value would go up to \$28.7.
- National Measurement System of UK (1999). In this paper several case studies made by the Department of Trade and Industry of UK (DTI) are analysed. Among others, the case of Warm Petrol is a good illustration of the importance of legal metrology. This case refers to the losses associated with the temperature of oil, higher than the ambient, incurred by retailers because suppliers were ignoring that petrol contracts when it cools to the ambient temperature and that there are vapour losses associated with the temperature at which it is delivered. The dispute between retailers and suppliers went on for more than a decade and the losses allied with the high competition on the retail market started putting many firms out of the business. This issue caught the attention of DTI who made an assessment of the benefits if legislation would be made by the National Measurement System in order to force oil suppliers to keep the temperature of the oil below the ambient temperature. In order to do so, the costs that producers would have to incur to comply with the new legislation were calculated, and amounted to £ 15 millions, and the costs associated with to implement this legislation was of £ 75 millions. On the other side, externalities are expected from this legislation: retailers would face lower losses and less retailers would go out of business hence increasing competition. For retailers, losses would be reduced by £ 80 million. Regarding the retailers that would not go out of business, the reduction of employment that is avoided amounts to a benefit of £ 13 million. As mentioned in the paper, most of the benefits would be reaped every year while the costs would mostly be only incurred once.



Conformity assessment

- Lima et al. (2008). The Brazilian Agricultural and Forest Management and Certification Institute made an impact assessment study to measure the consequences of socioenvironmental certification on community forest management in the State of Acre for wood production. This study shows that the impacts of this certification were relatively small, because there are already several public institutions involved with Community Forest Management. Still, some changes were noted, namely regarding the disposal of residues, awareness about the use of fire, measures to protect wildlife and degree of involvement in environmental complaints. In order to sanction the impacts of this certification, it was selected a group of community producers with similar economic and geographic characteristics to those of the certified community producers and against whom a group of certified producers were compared regarding: environmental preservation, quality of the administration of the association, use of Personal Protection Equipment (PPI), and income from wood sales.
- Imhof and Lee (2007). This study aimed at assessing the impacts of certified fair-trade plantations in Bolivia. Some of the major findings were that: fair trade has impacts on poverty reduction and therefore contribute for the reduction of political related conflicts; it increased the competition among intermediaries as a result of the emergence of fair trade cooperatives which led to an increase of the price paid to the producers; it enabled capacity building because certified fair-trade implies constant training on organic production, management issues and so on. In order to conduct this study, 160 interviews were made using a semi-directly administered questionnaire, which permitted the gathering of data regarding prices, yields, processing stages, and average costs.
- Martin et al. (2000). This is an impact assessment study on NIST's certified reference material for the sulfur content in fossil fuels on a range of economic and environmental issues, namely, on the increase of production efficiency, changes of transaction costs, reduction of sulfur entering the environment, reduction of penalties imposed by regulatory agencies. In order to do so, it was evaluated how the reference material led to a change in the accuracy of the measurement of sulfur in fossil fuels and in the cost of these tests, how these changes affected the behavior of stakeholders, and the quantification of the economic benefits or losses associated with these changes. In order to compare the situation before and after the creation of standard reference materials, it was assumed that the level of uncertainty associated with the measurement of sulfur in fossil fuels would be today similar to what it was prior to the introduction of the reference material in the middle 1980s. The estimated present value of benefits was US\$409 million against costs of US\$3 million.

Accreditation

One of the main functions of the accreditation element of the quality infrastructure is to strengthen the international recognition of the national quality system. However, it was not possible to find impact studies specifically related with this quality infrastructure service. A probable reason for that concerns to the difficulty to isolate the impacts resulting from a given accreditation from other quality infrastructure activities.

Designing impact assessment studies on quality infrastructure

The two main tasks of impact studies are to establish causal relations between an intervention or group of interventions and changes in the social, economical and/or environmental domains and to estimate the magnitude of such relations.

Box 4: Case studies (CEPAL, 2011)

In order to systematize the methods employed in impact assessment studies on quality infrastructure, literature on the topic was reviewed and lessons were derived from the following impact assessment studies, which had our methodological support:

- A case study conducted by CENAMEP (Panama) about the effects of large scale calibration,
- A case study conducted by GRADE (Peru) about the effects of the introduction of Pisco certification on the Pisco industry,
- A case study conducted by INDECOPI (Peru) about the effects of installing water meters on private households in the city of Lima,
- A case study conducted by INMETRO (Brazil) about the effects of the development of certified reference materials for bioethanol on producers and laboratories,
- A case study conducted by INTI (Argentina) about the effects of legal metrology,
- A case study conducted by LATU (Uruguay) about the effects of various quality infrastructure services on the milk industry.

In order to effectively do so, the design of an impact study needs to be adapted to the specificities of the interventions that are analyzed. In the case of quality infrastructure services, on the one side, impact studies have to be aware of the existence of complementarities between services, meaning that certain impacts can only be understood as a consequence of the activities of various quality services. LATU's study is illustrative of an impact analysis that takes the effects of various quality services into consideration. On the other side, impact studies have to take also into account that quality services often receive public intervention and therefore they shall be able to answer the question of whether the overall public interests are safeguard, i.e. stating how the various stakeholders benefit or lose from a certain quality service while bearing in mind the middle- and long-term effects of these services (situating them in the strategic goals of policy makers). INTI's study in Argentina offers a detailed picture of how the different stakeholders were affected by the intervention, i.e. economic agents in the private sector, the State, and with an emerging economic sector that follows INTI's intervention.

On the strictly technical side, the most prominent challenge associated with doing an assessment study on quality services has to do with the kind of impacts that one is looking for. These services perform systemic functions within innovation systems and for this reason many of their effects on social, economical and environmental realms are indirect. This does not mean that it is not possible to estimate these impacts. Instead, that it is more delicate to establish a causal relation (i.e. to isolate impacts of the quality service) as this requires the kind of data that usually is not collected through common means.

To overcome this obstacle one has to establish a system of data collection since the beginning of the implementation of the quality service. A list of indicators required for the future's assessment study is to be defined. Those indicators that are not already collected by any institution or whose quality is questionable have to be identified and a mechanism to collect them established. These systems support insightful analyses, which are not only important for the estimation of the impacts but also to provide suggestions for the improvement of the services. INDECOPI's assessment of the impacts of installing water micro-meters in Lima is exemplificative of the need to establish a data collection system before the intervention. This case concerns to the water consumption levels of the households and how it changed after installing the water meters. This baseline data would not be



collected and therefore it would be impossible to estimate the change in the consumption patterns if a data collection system as such would not be put in place before the actual intervention.

The basic structure of an impact assessment study consists of three stages: construction of a theory on the impacts of a specific project; formulation of the appropriate methodologies to test each impact; establishment of conclusions that can be derived from the results (whether and how the theory of impacts was verified) along with the provision of policy recommendations.

1st Stage: constructing an impact theory

In this stage, the researcher has to stipulate the links between a quality service and its expected main social, economic and environmental consequences, as well as to identify the stakeholders most probably affected by such impacts. The selection shall be broad enough to capture all the important impacts; but not too broad because it would be too costly to evaluate all the imaginable impacts.

The effectiveness of an impact study relies on its capacity to convince the reader that the claimed changes are due to the existence of certain quality service and not to other factors. Studies in this field have to address the idea that some impacts are the consequence of the activities of more than one quality service and that some players may lose from such activities. Therefore, the mapping of impacts has to state those that the service is producing alone, the ones that are resultant from the combination of various quality services, and stipulate a number of possible agents that may be benefited or hindered by the existence of certain activities. By doing so, the systemic nature of quality services is addressed and the assessment study becomes better prepared to contribute for the amelioration of the service itself.

In addition, a theory of impacts shall question the existence of factors that may condition the performance of indicators and which are external to the intervention.

At last, an inquiry shall be made concerning the location, sector of activity or other socio-economic characteristics of the stakeholders and that may affect the magnitude of the impacts of the quality service. This contributes for the understanding of how the impacts shall be maximized given specific socio-economic features of the stakeholders and may offer important policy recommendations.

Structuring a detailed theory of impacts supports an investigation able to capture: a wide variety of impacts, issues influencing the effectiveness of the quality service, external factors that need to be isolated in order to avoid biased estimations.

Apart from contributing for the development of a consistent impact assessment study, such an approach improves the cost-effectiveness of the study, especially as through a single survey all the required information can be gathered.

To sum up, an impact theory states: what affects whom in which ways and through which channels. For each one of the formulated impacts, the researcher must be clear about such a narrative and may sum it up entire theory using the Summary Matrix (Annex 1). For each stated impact, an appropriate method and indicators are to be selected and this is the second stage of an impact assessment study.



2nd Stage: formulating a method

There are no methods that can be said perfect for all the situations. The selection of a method always depends on what is tried to be proven (which impact?), the information that is required in order to assess it (which indicators?), the information that is possible to collect with quality. Accordingly, a study may utilize different methods to estimate each impact. There are four main approaches that are often used to estimate the impacts of interventions in the field of quality infrastructure. In the following, a brief description of the reasoning underlying these methods is presented.

Experimental method

This method requires the selection of the social group that receives the intervention of a quality infrastructure service (i.e. treatment group) and a comparison group that does not (i.e. control group) prior to the beginning of the intervention. Such selection process has to guarantee that both the treatment and the control group are randomly selected and share the same relevant characteristics. Both groups have to be comparable: the differences realized after the intervention should be attributed to the intervention itself, and not to other socio-economic features, nor to the influence of other interventions. In order to estimate the impacts, the difference between the two groups sanctioned by the indicators before and after the intervention would be considered the impacts of the service. INDECOPi's study uses this method. The capacity of establishing a causal relation between the intervention and the impacts and of estimating their magnitude is very high. However, the process of implementing a study as such requires more time, and more costs with human and technical resources. Therefore, this method is especially suitable for pilot projects, i.e. when the implementation of a certain quality service would require very high investment levels, thus being important to know in advance whether the intervention leads to results that compensate the investment.

Quasi-experimental method

The quasi-experimental method is very similar to the experimental method. The key difference in this empirical approach is the lack of random assignment. This may be the case when a priori selection of the treatment and control groups is not possible, for instance within an impact assessment study of a services that is already underway. The INDECOPi case illustrates the difficulty in realizing random assignment, as there are technical as well as moral restrictions to the purely random implementation of water meters. Since a deficiency in randomization makes it harder to rule out confounding variables and introduces new threats to internal validity, INDECOPi has still made substantial efforts to make the household selection as random as possible.

In quasi-experimental designs, where random assignment cannot be assured, the membership assignment to the treatment or control group may be subject to a selection bias. One way to overcome this problem is to match the participants of the two groups afterwards by propensity scores according to their socio-economic characteristics, for instance, age, education, income, sectors of activity, religious beliefs, etc.

GRADE's study gives a good example for a quasi-experimental design. In this case, there exists a data selection problem, as those companies that comply with the pisco certification have very different characteristics when compared with those that do not, since the certification is de facto obligatory to producers that sell in Lima and export, but unnecessary for those producers that serve other markets in Peru. The study describes how these biases may be corrected for by propensity score matching procedures. In many cases this posterior matching may be easier applicable than the rigorous experimental method, but its power to establish a causal relation between an intervention and the impacts is, naturally, not so strong.



Both the experimental and the quasi-experimental methods are effective when the expected impacts of an intervention can be directly sanctioned by socio-economic indicators. However, quality services often have impacts not so easily sanctioned through such indicators. Both the contingency valuation and the hypothetical deductive methods may be solutions to overcome this drawback.

Contingent valuation method

INMETRO's study on the impacts of the development of a certified reference material for bioethanol uses the contingent valuation method. This method was initially created to estimate the value of public goods or services for which no market exists since users cannot be excluded from its utilization, as for instance environmental quality or public security.

INMETRO argues that there was no market established for the kind of certified reference material when the study was put in place, as it was not yet widely used by laboratories and producers. Therefore the contingency valuation method was applied to estimate whether the benefits from the introduction of the certified reference material would at least cover the costs associated with its development and production. A notable advantage of this method is that it is less costly than the implementation of an experimental approach (as was used by INDECOPI), however the quality of the results may be questioned.

Similar to the two previous approaches, the contingent valuation method is survey based. This technique consists of inquiring stakeholders regarding their willingness to pay for a certain public good or service for which no market exists. The most salient challenge associated with this kind of approach is the need to avoid strategic responses by the participants. This precondition may be seriously violated if respondents expect to influence the price of the good or service by their answers. For example, if a good provided by public authorities for a certain fee brings benefits to a company, this firm may prefer to understate the true value of the good, fearing that if it states the real value the fee will be higher in the future. In other situations, respondents may be induced to exaggerate the value.

Since INMETRO can be expected to sell their certified reference materials in the future, the occurrence of strategic responses cannot be ruled out. Since potential buyers are asked to value the product by a future potential seller, the situation comes very close to a negotiation. Consequently, the respondents are most likely to understate their true valuation of the product. In this case, the method thus leads most likely to an underestimation of the true benefits of the product. However, since the objective of the INMETRO study was to show that benefits at least offset the costs of development, a conservative estimation of the benefits supports the positive result.

Hypothetico-deductive method

The hypothetico-deductive approach is among the mentioned approaches the one that requires the most abstract construction. It relies on reasoning when empirical measurement is not possible. Optimally, "deduction begins with theory (laws or law-like premises), it moves through the use of logical rules and reasoning to hypothesis derived from the theory, and then tests hypotheses via prediction and observation" (Ezemer et al., 1999, p. 30).

This method is useful whenever it is difficult to find socio-economic indicators representative of the impacts that a quality service is having. For example, if an intervention increases the accuracy of an instrument to measure the content of sulphur in oil by x%, one hypothesized impact could be: How much lower is the probability of a company to fail on complying with the regulation that states the maximum level of sulphur allowed in a given quantity of oil? In this case, the changes of accuracy are estimated and using this number as a premise, the consequences of such a change are hypothesized and its magnitude predicted.

With this method the impacts are not empirically verified - it would be difficult to isolate effects of a better measurement instrument with the actual augment on the probability of complying with a norm because there are many other variables influencing it. The lacking of empirical verification particularly facilitates the overestimation of the impacts of a quality service and that may seriously damage the credibility of the study. Though it is a very important methodological approach given the kind of impacts resulting from quality services, it needs to be carefully handled, particularly when it comes to the design of the counterfactual.

The experimental and quasi-experimental methods are suitable when the indicators can be sanctioned by the stakeholders. For example, if the hypothesized impact concerns to the reduction of the health problems after the creation of a certain technical regulation, the stakeholders may be asked to state the number of days per month that they have to miss work due to health problems.

On the other side, if the creation of a certified reference material or of a standard, as hypothesized in the impacts theory, leads to a reduction of production costs which are difficult to isolate given the existence of many other factors contributing to changes in the production costs, the hypothetico-deductive approaches may be the most appropriate methods.

Among the case studies reviewed, both INTI and CENAMEP developed their impact assessment studies using a hypothetico-deductive approach. Both of them deal with the impacts of a better calibration of scales. They started by empirically measuring the change in the precision of the scales after the intervention, and developed a reasoning concerning the impacts on costs and government revenues that follows such a hypothetico-deductive approach.

The counterfactual

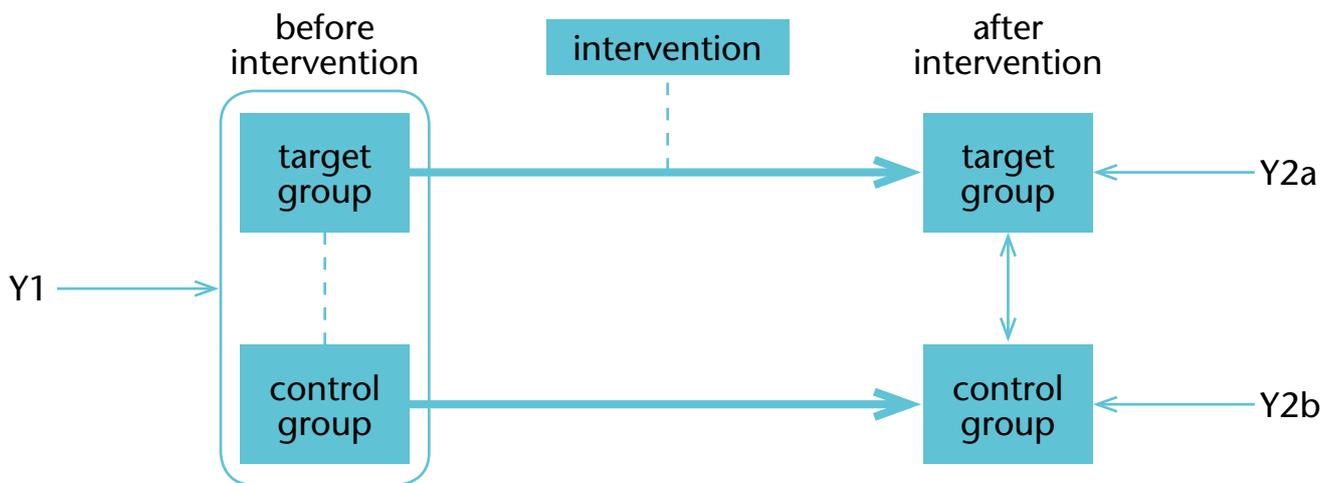
These methods are trying to answer to the question: how would things differ without the quality service? The hypothesized situation is called counterfactual. This is one of the most crucial elements of an assessment study. A poor design of the counterfactual damages the credibility of the study's results. Therefore, it is very important to properly establish the counterfactual and to elaborate on the reasons for such a selection – if the reader does not agree with the realism of the counterfactual, he will hardly believe in the outcomes of the study.

If a quality infrastructure service concerns to a small neighborhood in the outskirts of a given city, the perfect counterfactual would be: the same small neighborhood in the same period of time without receiving the mentioned service. Since it is not possible to have the two situations simultaneously, there is no perfect counterfactual, only approximations.

There are two ways of constructing the counterfactual:

- By comparison with a similar society that did not receive the intervention. This is the control group approach used in the experimental and quasi-experimental approaches

Figure 1: The control group approach



- By comparison with what would be the situation of the society that was affected by the quality service if there had been no intervention. This is the non-experimental approach used in contingent evaluation and hypothetico-deductive methods. Especially the study by INTI is very clear about the construction of a counterfactual as such. Similarly, LATU's study analyzes the trends concerning the quality of milk in Uruguay as a consequence of the various interventions. In this case it is more difficult to define a before and after intervention because interventions in the milk sector by quality services have been happening for many decades, and the data that is available considers only a more recent period. This reinforces the need of establishing a data collection system even before a given intervention.

What distinguishes these two approaches is that the control group approach requires the existence of a group of people that is not receiving the intervention, in the same period of time, and that shares the same characteristics as the treatment group in the beginning. On the other side, the non-experimental approach is less strict as it does not require a comparison group and can be applied in interventions that occur nationwide. The construction of the counterfactual is more complex as it requires speculating about how the situation would be if the quality service would not exist. Normally, in these situations, it is analyzed what how the evolution of the indicators changed from before to after the intervention, i.e. if now a certain indicator is increasing / decreasing at a faster / slower pace than before.

For this reason the control group approach is more powerful in order to establish a causal relation between the intervention and the impacts as it better controls for other factors influencing the evolution of the variables. However, it is less feasible. The non-experimental approach is more flexible and viable for certain quality services, either when it is not possible identify a control group or if the hypothesized impacts are not signaled through direct changes in certain socio-economic and environmental indicators.

Table 4: Comparison of different approaches

Impact Evaluation Design	Counterfactual Approach	Most appropriate to estimate:	Examples of possible impacts estimated with the method	Case Study
Experimental	Control group approach (selected and surveyed before the intervention)	Socio-economic impacts	Increase in profits of the exporting companies	INDECOPI, Peru
Quasi Experimental	Control group approach (selected and surveyed after intervention)	Socio-economic impacts	Increase in salaries of workers	GRADE, Peru
Contingency Valuation	Non-experimental approach	Environmental impacts Impacts of services without market price	Utility derived from better air quality	INMETRO, Brazil
Hypothetico-deductive	Non-experimental approach	Impacts on production efficiency Macroeconomic studies	Decrease on the penalties incurred by violating a technical regulation due to better calibration of measurement instruments GDP growth due to the creation of standards	CENAMEP, Panama; INTI, Argentina

Once having defined the counterfactual and the indicators required, it is necessary to collect data. The data may be already available in existing reports, e. g. about the income of households in a region, prevalence of diseases, structure of the labor market; must be created through the construction of a survey; or, is derived through tests in laboratories, for instance, when information about the increase in accuracy of measuring instruments or procedures is required.



3rd Stage: interpreting results

The impacts of an intervention are signaled by indicators. However, indicators are not the impacts themselves. The causal relation between the existence of a project and changes in certain elements of social, economic and environmental reality is to be demonstrated in the third stage.

On the one side, there are other factors influencing the behavior of the indicator. The researcher has to present how the influence of other factors were removed or diminished, i.e. how to read the signals given by each indicator. On the other side, the results may vary throughout time and population groups. These differences provide information about the effectiveness of the quality service when the conjecture or the target groups differ. This information shall be utilized in order to produce policy recommendations concerning the design of strategies and practical use of quality services. For instance, if a quality service is producing very different impacts in two different regions, it means that it is serving two different purposes. Therefore, there should be two different strategies, implying that the handling of the quality service should vary according to the region.

When a project is not reaching the desired outcome, through the analysis of all the information gathered during the first and second stage, the researcher is to present the reasons for such failures, come up with an alternative use of the quality service. For example, if a certain service is not accompanied by complementary quality services, the outcomes of its activities may be considerably lost. Under these circumstances, an important policy recommendation by an impact study concerns to the design of the quality infrastructure, which are complementary quality services that need to be developed in order to improve results, and this information may not only be obtained by reading the indicators, but also can be derived from interviews or by reviewing literature on the topic.

As already mentioned, the counterfactual is never exactly “what would have had happened without the intervention”. Therefore, identifying the limitations of the counterfactual provides a better insight about the impacts of a service. For instance, there may be slight socio-economical differences between the control and treatment group that may lead to an over or underestimation of the impacts, or there may have been certain external factors influencing the two groups differently during the period that is taken in consideration. The credibility of an impact study is improved when such factors are presented to the reader.

At this stage, one has also to analyze whether the public interests of an intervention are safeguarded. As already mentioned, this requires the listing of the players that win and lose from the existing project. Apart from that, it is necessary to frame such benefits and losses within the strategic objectives associated with the quality service and whose impacts sometimes can only be fully realized in the middle-long run which require a forward looking examination. With such problematization, one aims at giving a better understanding concerning policy making, effectively contributing for the improvement of the system. An impact assessment as such, able to address the strategic reasoning underlying a quality service, is more adequate to respond to the matters that concern to policy makers, and therefore is more likely that will gain visibility.

Important to notice is that there is a lot of relevant information collected during the whole process of constructing an impact study which is contributive for the interpretation of the results and to establish policy recommendations. The quantitative analysis is very important in order to assess the relation of benefits of a project with its costs, and to demonstrate to various stakeholders how they are influenced by the existence of a certain quality service. However, the quality of an impact assessment study greatly depends on the information collected through less formal means than surveys, data analysis or by reviewing the literature. Such information plays an important role while establishing the reasoning underlying the causal relation between services and impacts, and for the production of meaningful policy recommendations.



Box 5: A guideline for impact assessment studies on quality infrastructure services

1st stage: Creating an impact theory

- 1) Brainstorm: Within the institution discuss and make a list of possible impacts.
- 2) Stakeholders: Identify the stakeholders (companies, households, specific communities, general population etc.)
- 3) Participatory mapping: Interview a small number of stakeholders (short questionnaire inquiring about the impacts they felt since the intervention has taken place, and ranking them in terms of importance.
 - a) if the stakeholders are companies the interviews can be made through email;
 - b) if the stakeholders are households / local communities, small group discussions can be made with the help of local NGOs to identify possible impacts – 1 or 2 group discussions, each with 8 to 12 community members (preferably with different positions in the community)
- 4) Indirect Impacts: Identify other possible impacts that may not be felt directly by stakeholders (e. g. related with environment), or about spillovers that stakeholders may not acknowledge (e. g. third-parties benefiting from the intervention), or any other types of indirect effects.
- 5) Create the Impact Theory:
 - a) Impacts of the intervention (define the intervention or group of interventions).
 - b) Impacts on what (specific issues at an economic, social and environmental level)?
 - c) Impacts on who (match different stakeholders with specific impacts)?
 - d) Impact how (try to define the causal mechanisms)?
- 6) Fill the summary matrix (in annex): Be clear about what you want to prove.



2nd stage: Testing the impact

- 1) Matching impacts with indicators: corresponding to the possible impacts that were defined in the 1st stage, indicators are to be found that would sanction them (e. g. lower prevalence of diarrhea – number of children in hospitals with diarrhea per month)
- 2) Data collection:
 - a) If there is available data that can sanction the impacts hypothesized use it (e. g. employment rates, diarrhea, co2 emissions, GDP growth).
 - b) If data is not available, design a questionnaire, define the quantity and variety of stakeholders to be surveyed – if possible, work with local organizations that are already implemented on the field.
- 3) Measuring Impacts:
 - a) Control group approach: Create 2 groups.
 - The treatment group: receives the intervention
 - The control group: does not receive intervention.

The control group should share a socio-economic situation similar to the treatment group and be as much as possible immune to the effects of the intervention.

In order to measure the impacts, one has to compare the indicators that were selected between the control group and the intervened group – the differences about the evolution of such indicators since the intervention should sanction the impacts

Select 2 periods:

- Before the intervention
 - After the intervention
- b) Non-experimental approach
 - i) Use the contingency evaluation method
 - ii) Use the hypothetico-deductive approach, e.g. compare the evolution of the indicators (through a time-series regression) that you selected between the period before intervention and the period after the intervention (e.g. by using a dummy variable).
- 4) Control for other factors: third variables / events may cause two variables (i.e. the intervention and a specific indicator) to correlate without existing any causality, e. g. if in the period after an intervention prices in the international markets behave differently than before intervention, the exports revenue may increase or decrease regardless the intervention; if an intervention intends to increase exports, and when estimating the impacts of the intervention one does not include a variable for the floatation of the prices, they will be biased (i.e. overestimated or underestimated according on the evolution of prices).



3rd stage: Interpreting the results

- 1) Limitations of the study: Identify the limitations of the study – which other factors may be influencing the results but that were not related with the intervention, if people are overestimating the impacts, if the control group and the treatment group have different characteristics, etc.
- 2) Triangulation: Compare all the information gathered – the results from the survey or analysis of indicators (the 2nd stage) with the information that was collected during the interviews, group discussions, and reviewing the literature (the 1st stage).
- 3) Understand unexpected impacts (or lack of them): Compare your expectations (the theory that you created) with the results that you got (when verifying the theory) and debate why they differed. Use this opportunity to learn how the intervention can be improved and produce policy recommendations.
- 4) Conclude: Establish impacts that can be considered as clear outcomes of the interventions. Establish some that could not be confirmed by the data / indicators but that in interviews or with other methods were found to be relevant to stakeholders. Establish the hypothesized impacts that you could not find any significance at all.



Conclusions

Systematizing the methodologies to be applied in impact assessment studies in the field of quality infrastructure at first requires a deep understanding of the roles that these institutions have within society. In this article, it was argued that quality infrastructure is a part of national innovation systems, and a theory of impacts was delineated, which aimed at comprising a broad range of possible effects resulting from the functioning of quality systems. Quality infrastructure needs to be understood as an institutional system given the enormous complementarities and interdependencies between the various quality services. This imposes a challenge to researchers, as it is needed to identify which impacts result from the integration of various activities and which are a consequence of a single service.

The right choice of method depends on the kind of effects that are expected, the indicators and the quality of data available. Four general approaches have been identified for this type of studies: experimental, quasi-experimental, contingency valuation, hypothetico-deductive. They follow different logics, answer to different methodological problems, and pose specific challenges in order to avoid biased estimations.

The impact assessment experiences within this project, as for instance the case study of Pisco certification in Peru (in the Annex), have clearly shown that often, and particularly in the context of developing countries, data collection mechanisms are lacking to provide the necessary information for rigorous quantitative impact assessment studies. For this reason, it is recommended that the collection of data is implemented as early as possible in the impact assessment process, ideally even before the quality service intervention has started in order to generate the base line scenario against which the impact of quality infrastructure can be measured.

Impact assessment studies are important to bring the discussion about quality infrastructures to the public arena. By assessing the impacts of quality services, these studies provide information about the contributions of quality infrastructure for the accomplishment of various social, economic and environmental goals. Often quality systems are implemented to serve long-term strategic objectives of policy makers. Consequently, an impact assessment study has to include also a forward-looking analysis and provide advice on the design of quality services and their integration with respect to those strategic goals. In order to make quality infrastructure more visible, impact studies have to convey a message specifically adapted to their direct target groups by responding to their immediate concerns.

Simultaneously, the discussion shall also communicate to a larger audience, to reach citizens not directly affected by a quality service. This is necessary for two reasons. On the one hand, the kind of objectives that can be achieved through the means of quality infrastructure may be of interest for various organizations and individuals, still unaware of its existence. On the other hand, in order to avoid a bad design of quality infrastructure and decrease its misuse (e.g. empowering certain economic agents against the overall welfare interests) it is necessary to increase the accountability of quality services to societies.

As the number of impact studies on quality services increases, more information about the problems associated with this kind of studies and regarding the appropriate assessment methodologies will be available. There is still scope to improve the guideline here proposed, to provide more details regarding the design of impact assessment in this field. This study is a first attempt of addressing the particulars of a quality system and shall be upgraded with the lessons derived from future impact studies.



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Annex: Summary Matrix

Summary Matrix			
1. Describe the intervention(s):			
2. Institutions involved:			
3. Region / cities / communities affected:			
4. Which stakeholders are likely to be directly affected:	List Impacts: (Rank by importance for stakeholders, from higher to lower)	Indicators:	Time range: (short, medium, long)
a)	1		
	2		
	3		
	4		
	5		
	6		
b)	1		
	2		
	3		
	4		
	5		
	6		
c)	1		
	2		
	3		
	4		
	5		
	6		
5. Indirect effects:	Stakeholders affected:	Indicators:	Time Range:
a)			
b)			
c)			
d)			
6. External factors that may have changed the impacts of intervention (political, economical, institutional, exogenous, other) and rank by the expected magnitude:			
a)			
b)			
c)			
Negative influence:			
a)			
b)			
c)			



PTB in brief

A globalized international economy calls for globalized metrology. This is why the orientation and impact of PTB, the national metrology institute of Germany, is not restricted to the national borders.

PTB with its 1,800 staff members is rather a „global player“ in the world of metrology and faces the responsibility involved for society, economy and science. The international tasks of PTB include cooperation in all kinds of metrological organizations (the Meter Convention being the most prominent example) and cooperation with national metrology institutes all over the world. Furthermore, the PTB International Technical Cooperation advises and supports the conceptual design and practical implementation in the establishment of the quality infrastructure in developing and transition countries.

The clients of the Technical Cooperation projects are above all the Federal Ministry for Economic Cooperation and Development, (BMZ), which finances the majority of projects with PTB participation, but also the European Union, the World Bank and other organizations. For the implementation of projects a network of strategic partners is available.

All in all, the global networking of PTB has one major objective: the international harmonization of quality infrastructure and its mutual acceptance.

About the Chair of Innovation Economics at the Berlin Institute of Technology

The Chair of Innovation Economics at the Berlin Institute of Technology was established in 2006. It studies a broad spectrum of topics in innovation economics and focuses on the interrelation between regulation, which includes standardization as an instrument of self-regulation, and innovation.

A first and obvious research area is the analysis of the influence of regulatory framework conditions on innovation activities. To measure this variety of impact dimensions both on a macroeconomic, a sectoral or industry level and on a microeconomic and company level, various innovation indicators are used ranging from the expenditures for research and development, scientific publications to patent applications and trademark registrations.

A second and still emerging field of studies is the analysis of challenges of progress in science and technology, but also of market changing structures for existing regulatory framework conditions. Here, especially the identification of new topics relevant for standardization is a main field of activity.

