The Economic Impact of Standards in the context of developing countries

A Cebr report for the International Organization for Standardization (ISO)

August 2023

Authorship and acknowledgements

This report has been produced by Cebr, an independent economics and business research consultancy established in 1992. The views expressed herein are those of the authors only and are based upon independent research by them.

The report does not necessarily reflect the views of the International Organization for Standardization (ISO).

London, August 2023

Contents

Acknowledgements

Cebr and ISO would like to thank the following National Standardisation Bodies (NSBs) for their valuable contribution to the research. The production of this report would not have been possible without the considerable time and effort that was volunteered to provide data on the stock of standards in each country.

- *Associação Brasileira de Normas Técnicas* (ABNT)
- *Instituto Colombiano de Normas Técnicas y Certificación* (ICONTEC)
- *Badan Standardisasi Nasional* (BSN)
- Bureau of Standards Jamaica (BSJ)
- *Association Sénégalaise de Normalisation* (ASN)
- Uganda National Bureau of Standards (UNBS)

Executive Summary

- Standards help create more efficient markets, facilitate international trade, and support innovation.
- Previous research has examined the positive impact of standards on economic growth, though this has mostly focused on developed countries. The purpose of this study is to add to this evidence base by examining the impact of standards on the economic prosperity of six developing countries: Indonesia, Uganda, Senegal, Brazil, Colombia, and Jamaica.
- One of the key objectives of this report was to review the research process, provide our professional view on the application and effectiveness of the methodology in each of the selected countries, and present any conclusions, lessons learned, and recommendations for future application.
- Our analyses span a range of different time periods. The longest time series, Colombia, covers the years 1990 to 2019, whereas our shortest time series, Jamaica and Uganda, both span from 2001 to 2019.
- We follow the economic intuition from the ISO methodological framework to explore the impact of the stock of standards on labour productivity in a developing context through a two-stage approach based on the Cobb-Douglas production function.
- The two-stage approach involves a set of two equations whereby we first consider the impact of standards on TFP, and then, within the second stage, the impact of TFP on labour productivity – thereby examining the indirect impact of standards on labour productivity, through an increase in TFP.
- However, for four of the six analyses (Brazil, Jamaica, Senegal, and Uganda), we did not follow the exact steps outlined within the ISO methodological guidance document. Instead of utilising a two-stage approach, we employ a single-stage approach which combines the set of two equations into a single model.
- As explained in the report, both the single-stage and two-stage regression models follow the Cobb-Douglas production function, as prescribed by ISO. The difference is that for the single-stage we are substituting the term for TFP from the Cobb-Douglas with our explanatory variables (such as standards) to directly model the impact of standards on labour productivity.
- **We find that an increase in the stock of standards is positively associated with an increase in labour productivity across all six countries over their respective periods.**
- At the higher end of the range of our results, we find that a 1% increase in standards in Indonesia is associated with a 0.16% increase in labour productivity during 1994-2019. At the lower end, for Jamaica, we find that a 1% increase in standards is

associated with a 0.02% increase in labour productivity. The rest of the results fall within this range.

- Note that the comparability of results between any two studies is limited due to the fact that there are differences in both the time periods considered, and the exact model specifications employed, as well as differences in the driving forces of economic growth across countries.
- Ultimately, we find that regardless of whether we employ a single-stage or a two-stage approach, the underlying economic intuition and framework through which the impact of standards is assessed, is similar.
- Overall, the results are strong and there are no major weaknesses with the prescribed ISO framework as applied to a developing context. Although there are some limitations present such as poor data availability, these are not a consequence of the framework. However, while we are confident in the robustness of the results presented within this study, caution as well as a sound understanding of the relevant limitations, is advised.

Chapter 1: Introduction

According to the International Organization for Standardization (ISO), standards are "the distilled wisdom of people with expertise in their subject matter and who know the needs of the organisations they represent". Simply put, a standard is the best way, as agreed by experts, of doing, thinking about or managing something. It could be about making a product, managing a process, delivering a service or supplying materials – standards cover a wide range of sectors.

Standards have long been associated with making an important contribution to economic growth and prosperity. The World Trade Organization (WTO) argues that standards are "necessary for the smooth functioning of anonymous exchanges – and, therefore, for the efficient functioning of the market".

In this section, we introduce this study, then present an overview of standards, and the main channels identified by the academic literature through which these contribute to economic growth – supporting productivity and efficiency within companies, facilitating trade, and acting as a catalyst for innovation.

1.1 Study overview

This study focuses on standards, such as those developed and published by ISO, which represent a collaboration between industry experts, government bodies, companies, academia, trade associations, and consumer groups. Through this cooperation, standards are developed to represent an industry-wide consensus on best practice.

Standards cover a wide range of activities undertaken by businesses in the production of their products or services and in supplying their customers. Table 1 below highlights a selection of flagship ISO standards.

Table 1: Examples of flagship ISO standards

Standard type	Purpose	Example
Quality management	To help work more efficiently and reduce product failures.	ISO 9000 family
Health & safety	To help reduce accidents in the workplace.	ISO 45001 – Occupational health and safety
Environmental management	To help reduce environmental impacts, reduce waste and be more sustainable.	ISO 14000 family
Energy management	To help cut energy consumption.	ISO 50001 – Energy management
Food safety	To help prevent food from being contaminated.	ISO 22000 – Food safety management
IT security	To help keep sensitive information secure.	ISO/IEC 27001 – Information security management

Source: ISO

It is widely accepted that standards are beneficial to economic performance. While it is relatively simple to see how standards can create efficiencies at the company level or in bilateral trade relationships, it is more difficult to prove these assumptions when applied to a national economy.

In 2021, the ISO Research & Innovation (R&I) Unit published a paper titled "Standards & economic growth: ISO members' research on the impact of standards on their national economies." This paper brought together the results of research conducted by ISO members to explore the contribution of standards to total factor productivity (TFP) and economic growth in a selection of countries. Using econometric modelling techniques, researchers were ultimately able to explain the share of economic growth that could be attributed to the changes in the net stock of standards.

In 2022, the R&I Unit published a companion document titled "Economic impact of standards – Methodological guidance." This set out a pragmatic framework, striking a balance between robustness and ease of application, and providing guidance to standards organisations on how to apply the prescribed methodology.

The methodology involves building a model of how changes in the net stock of standards over time cause an increase in total factor productivity (TFP) within a country. It has been successfully used by a number of ISO members to estimate the economic benefits of standards. However, the methodology has so far been used predominantly in developed countries, and there is a lack of data on its applicability and utility in and for developing countries.

TFP measures the overall efficiency with which inputs (labour and capital) are transformed into output in an economy or a firm, considering factors like technology and

Looking forward, in the context of the ISO Action Plan for developing countries 2021-2025 (APDC), this pilot project was commissioned to determine if the methodological guidance document is an effective tool in providing evidence of the economic benefits of standards in developing economies.

Cebr was chosen to implement the methodology in six developing countries: Brazil, Colombia, Indonesia, Jamaica, Senegal, and Uganda. As well as presenting results on the impact of standards on the economies of these six countries, one of the key objectives of this report was to review the research process, provide our professional view on the application and effectiveness of the methodology in each of the selected countries, and present any conclusions, lessons learned, and recommendations for future application. Therefore, we cover these points with a focus on identifying the additional data challenges that needed to be overcome in order to produce an accurate report.

The structure of this report is as follows:

- Chapter 1 introduces the topic of standards, the overarching aims of the study, and includes a discussion of standards in the context of the six developing countries.
- Chapter 2 details the prescribed ISO methodological framework.
- Chapter 3 covers Brazil and details the used methodological approach; the headline findings of Cebr's analysis as well as a discussion of their interpretation; a broader discussion around the applicability and effectiveness of the prescribed methodology; and a technical appendix with more comprehensive details regarding the econometric approach taken to produce the headline results.

- Chapters 4 to 8 cover the same topics as the Chapter 3 but in the context of Colombia, Indonesia, Jamaica, Senegal, and Uganda, respectively.
- Lastly, Chapter 9 brings together the findings from the previous six chapters as a concluding discussion of the overall effectiveness of the prescribed methodology in a developing context.
- Chapter 10 is the technical appendix which includes a glossary of key terms.
- Chapter 11 contains the bibliography with the relevant citations for all studies referenced throughout the report, in alphabetical order.

1.2 Standards in the six countries

Before describing the economic theory behind standards and the econometric analysis employed within our study, we first set out some context for each of the six countries which will help inform the results discussed later in this report. In this subsection, we briefly discuss the role of standards for each country; from the time standardisation was introduced as a concept in these countries, to when their respective National Standardisation Bodies (NSBs) were founded and officially recognised, to a discussion of how the stock of standards have evolved over time in Brazil, Colombia, Indonesia, Jamaica, Senegal, and Uganda.

1.2.1. Standards in Brazil

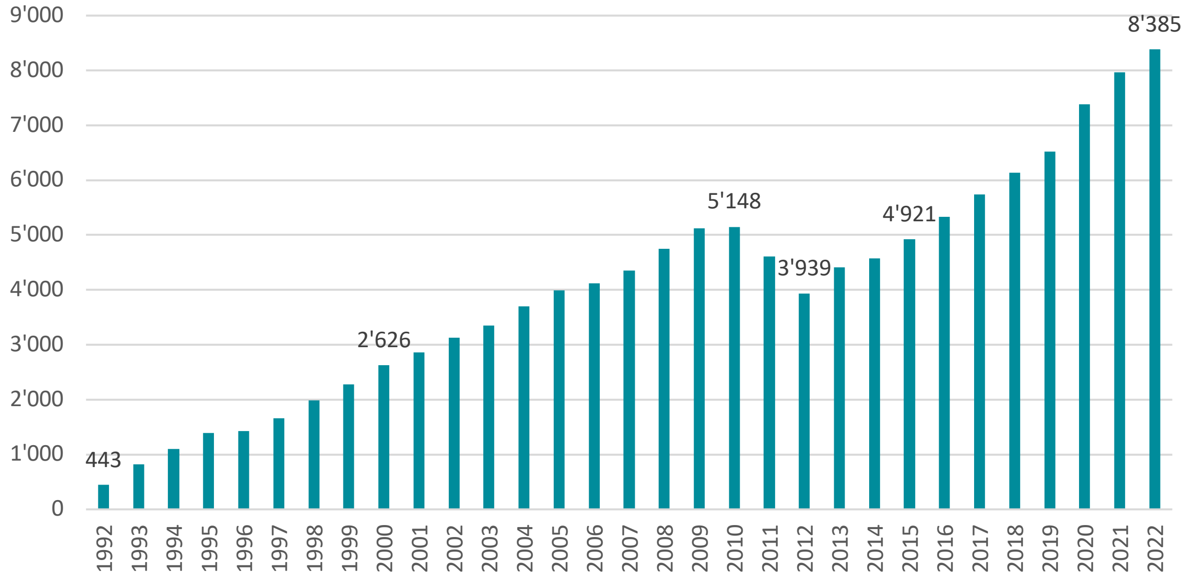
The history of standardisation as a formal process in Brazil started towards the end of its colonial period; it was elevated to a kingdom in union with Portugal in 1815, and achieved independence in 1825. While colonial Brazil lacked standardisation and technological advancements like Europe did during the same period, economic growth, regional specialisation, and the transmission of knowledge through informal means contributed to changes in productive techniques over time.

The development of railway transmission in Brazil after independence in the 19th century had at least created the conditions for standardisation to follow a pattern similar to that seen in England – an effort to standardise the steel material in locomotives, wagons, and bridges – but this did not materialise. It wasn't until the 20th century that the development of civil construction, particularly that of reinforced concrete, eventually led to the creation of a national standardisation organisation, the Associação Brasileira de Normas Técnicas (ABNT) in 1940.

ABNT is a founding member of the International Organization for Standardization (ISO), the *Comisión Panamericana de Normas Técnicas* (Pan-American Standards Commission, COPANT), and the *Asociación Mercosur de Normalización* (MERCOSUL Association for Standardization, AMN). Since ABNT was founded, it has also been a member of the International Electrotechnical Commission (IEC). Although it wasn't officially recognised by the Brazilian government until 1962, ABNT has been active in product certification and conformity assessment since 1950. It became the only recognised standardisation body in Brazil in 1992.

ABNT has kindly provided data on the annual net stock of active standards[1] in Brazil since 1992. There was steady growth from 1992 to 2010, with the average annual growth rate being 9.1%. Throughout this period, there were an average of 125 standards being withdrawn per year, however starting in 2010 the number of withdrawn standards equalled or exceeded the number of standards being added. From 2010 to 2017, the average number of withdrawn standards per year increased to almost 570 – driven by the peak average of 1,280 standards withdrawn during 2011–12. This resulted in a decrease in the net stock of standards, which began to recover after the peak of 2011–12 and reached 2010 levels again in 2016. This trend is presented in Figure 1.

Figure 1: The stock of standards in Brazil, 1992–2022.



Source: ABNT

1.2.2. Standards in Colombia

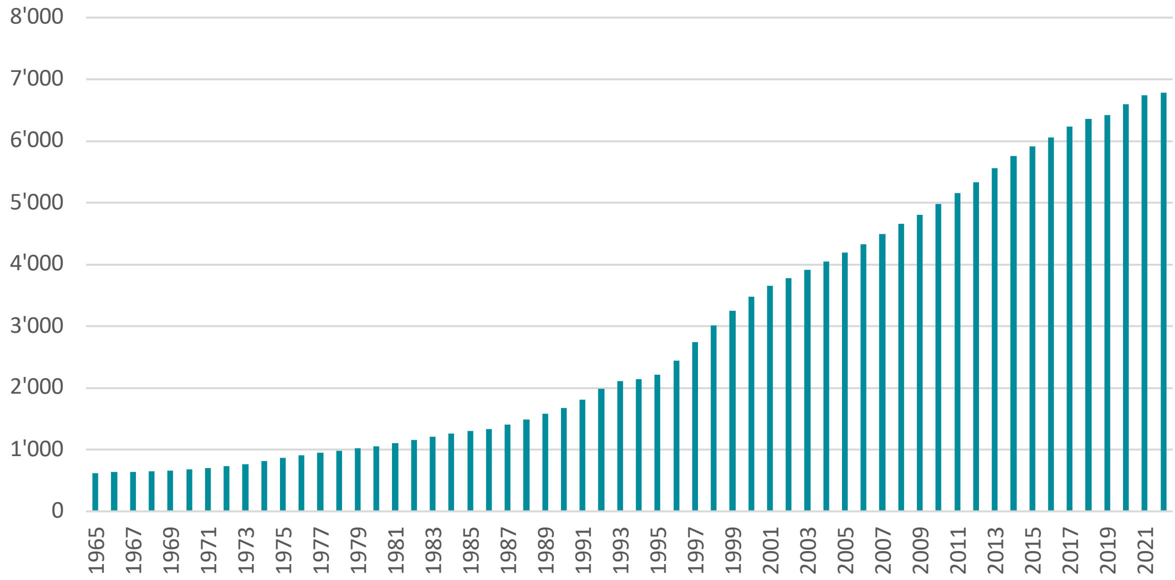
The Colombian Institute of Technical Standards and Certification (*Instituto Colombiano de Normas Técnicas y Certificación*, or ICONTEC) was founded in 1963 by a small group representing the private sector, who saw the need to create an organisation that worked on technical standards, with the stated goal of improving the productivity and competitiveness of national industry. ICONTEC became a member of ISO the same year and, a year later, received the first official support by the Colombian Government to become the Advisory and Coordinating Body for Standards (*Organismo Asesor y Coordinador en Normalización*). However, it was not until 1984 that the Government recognised it as the National Standardisation Body (*Organismo Nacional de Normalización*), as well as the official representative of the country to the various international and regional standard organisations.

ICONTEC publish detailed data on standards on its website, providing information for the specific date when a technical standard was adopted, reapproved, or annulled. This allows us to easily calculate the annual stock of active standards in Colombia since 1965;

1 The stock of active standards is defined as the "sum of all published standards up to the end of a specific year minus the sum of standards that has been withdrawn up to the end of that year".

this trend is presented in Figure 2. The 1990s saw the highest average increase in the net stock of standards per year (7.5%) and, by the end of the decade, there were twice as many standards as in 1990. In the period since then, from 2000 onwards, the net stock of standards has increased at an average of 3.3% per year, which is lower than the 4.0% during the period between 1965–1989.

Figure 2: The net stock of standards in Colombia, 1965–2022



Source: ICONTEC

1.2.3. Standards in Indonesia

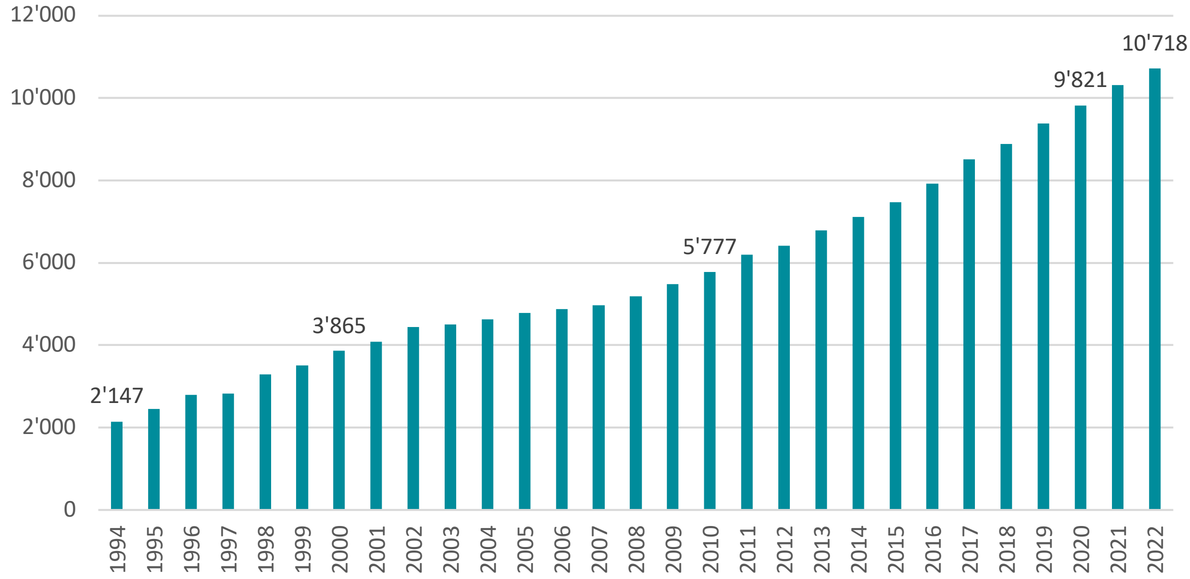
The development and application of standards in Indonesia can be traced back to Japanese and even Dutch colonial periods, where standardisation was used as a means of supporting colonial economic activities.

More recently, Indonesia has been represented as a member of ISO since 1955. However, it was only in 1973 that standardisation was placed as a strategic priority in supporting national development by the Indonesian government as they established the "National System Development for Standardization".

In 1984, the National Board of Standards (DSN) was founded with the main task of establishing standardisation policies, carrying out coordination and fostering cooperation in the field of national standardisation. This organisation served as the precursor to the National Standardisation Body (BSN) that was created in 1997 and remains the leading non-ministerial government agency for standardisation in Indonesia to date, with the main task of fostering and coordinating all standardisation and conformity assessment activities across the 17,000 islands that constitute the world's largest archipelagic state.

BSN has kindly provided data on the annual stock of active standards in Indonesia since 1970, with continuous data starting in 1994. This trend is presented in Figure 3. Since the mid-1990s, the pace of standards development in Indonesia has been steady, with the net stock of standards increasing at an average of 6.1% year-on-year.

Figure 3: The net stock of standards in Indonesia, 1994–2022.



Source: BSN

1.2.4. Standards in Jamaica

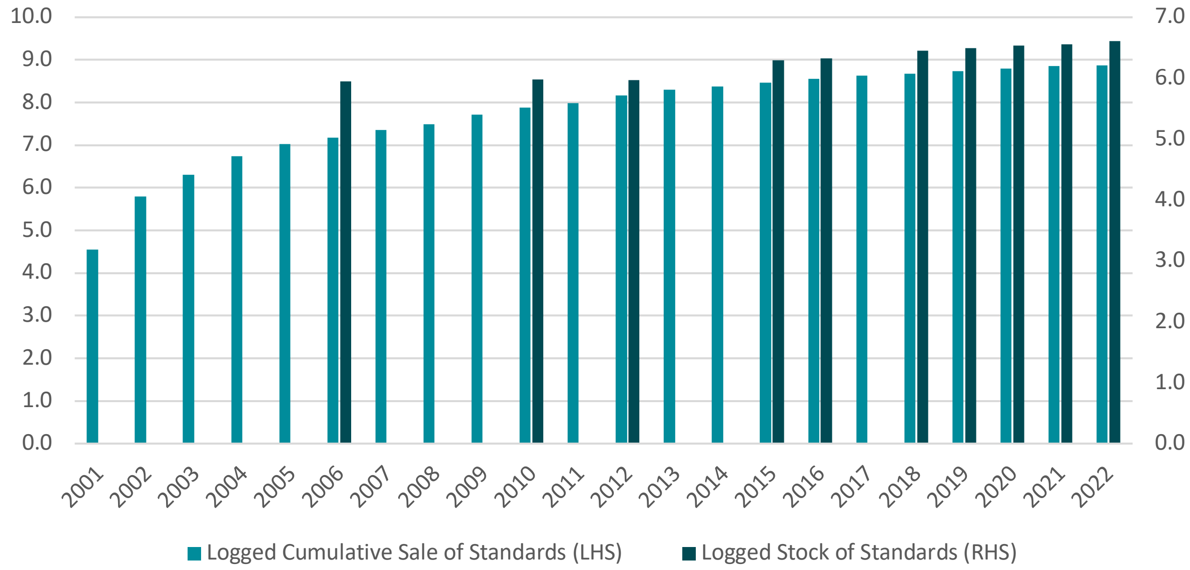
The organisation responsible for overseeing standards in Jamaica is the Bureau of Standards Jamaica, or BSJ. The following is an excerpt from the BSJ's website regarding its foundation and role:

> The Bureau of Standards Jamaica is a statutory body established by the Standards Act of 1969 to promote and encourage standardisation in relation to commodities, processes, and practices. However, over the years, its role has expanded to include the provision of services in relation to conformity assessment (certification, testing and calibration) and metrology. Its main activities include: facilitating the development of standards and other requirements to which particular commodities services, practices and processes must comply; conducting tests and calibrating instruments; certifying products and management systems; providing industrial training and promoting research and education in standardisation.

A Standards Council made up of 14 Government appointed individuals is responsible for the general administration of the organization as well as policy direction.

BSJ has kindly provided data on the annual stock of active standards in Jamaica since 2006. This trend is presented in Figure 4 – with the cumulative sale of standards overlayed – however this data is incomplete with a number of missing years. As a result, later in this report, we will discuss the use of 'cumulative sale of standards' as a key variable, rather than the stock of standards as prescribed by the methodological guidance document.

Figure 4: Data for the stock of standards vs the cumulative sale of standards in Jamaica, 2001–2022.



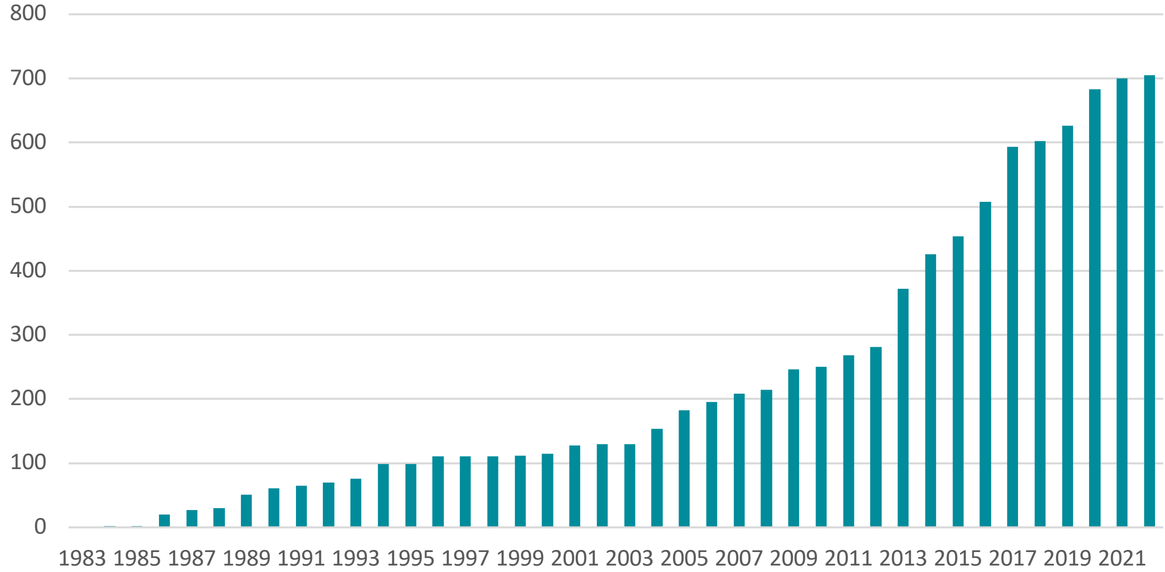
Source: BSJ

1.2.5. Standards in Senegal

The Institut Sénégalais de Normalisation was established in March 1978, and later became the Association Sénégalaise de Normalisation (ASN) in July 2002, following an institutional reform. The ASN, which is under the administrative supervision of the Ministry of Industrial Development and Small and Medium Industries, is responsible for implementing the Senegalese Government's policy on standardisation and quality infrastructure, as well as representing Senegal in standards development bodies at sub-regional, regional and international levels. The ASN is mainly tasked with the development of national standards, the promotion of quality, providing product certification and quality training.

ASN has kindly provided data on the annual net stock of active standards in Senegal since 1983. It can be seen that the growth in the stock of standards has been accelerating over the past 3 decades, with an average annual growth rate of 6.5% between 1990–2000, reaching 7.7% in the period 2001–2011 before increasing even further to an average growth of 9.6% annually over the last 10 years. This trend is presented in Figure 5.

Figure 5: The net stock of standards in Senegal, 1983–2022.



Source: ASN

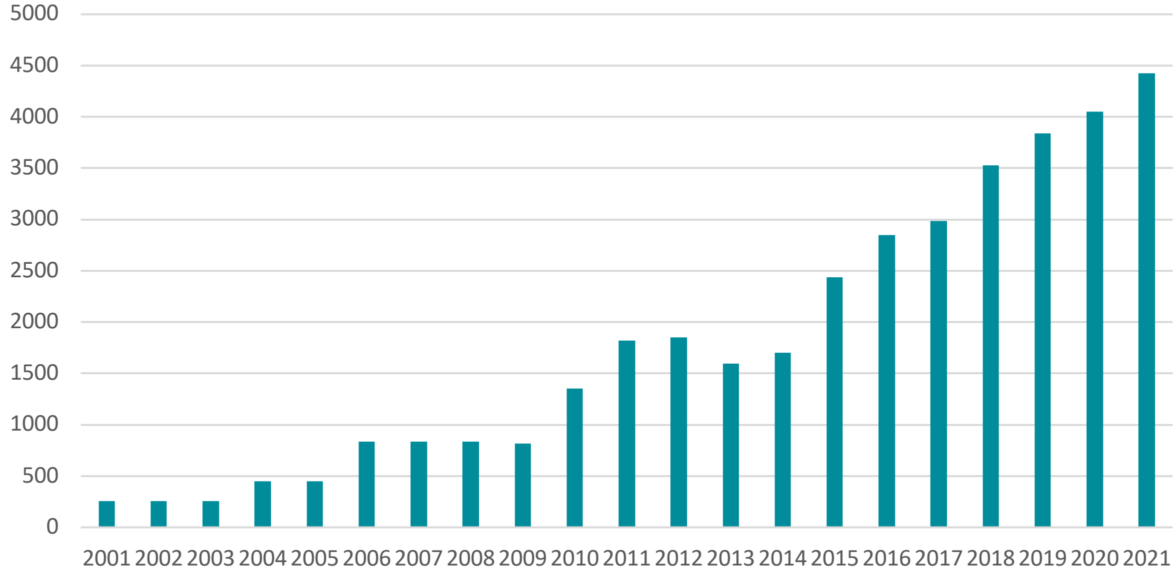
1.2.6. Standards in Uganda

Operational since 1989, the Uganda National Bureau of Standards (UNBS) is a statutory body under the Ministry of Trade, Industry and Co-operatives. The mandate of the UNBS is the following:

- Formulation and promotion of the use of standards;
- Enforcing standards in the protection of public health and safety and the environment against dangerous and sub-standard products;
- Ensuring fairness in trade and precision in industry through reliable measurement systems;
- Strengthening the economy of Uganda by assuring the quality of locally manufactured products to enhance the competitiveness of exports in regional and international markets.

UNBS has kindly provided the standards catalogue for Uganda from 2001 to 2021, which we used to estimate the stock of standards. In 2021, there were 4,427 active standards in Uganda. While this represents a 17-fold increase compared to the stock of standards 20 years ago, it can be seen that the growth in the stock of standards has decelerated over the past 2 decades, with an average annual growth rate of 20.2% between 2001–2010 before decreasing to an average growth of 9.3% annually over the period 2011–2020. This is presented in Figure 6.

Figure 6: The net stock of standards in Uganda, 2001–2021.



Source: UNBS, Cebr analysis

1.3 Economic theory behind standards

Standards can serve many purposes, including to help industries overcome a range of challenges that would otherwise result in a less optimal outcome for businesses, policymakers, and consumers. Swann (2000) provides a widely-accepted categorisation of standards based on the economic issues they solve. This classification indicates that standards have a direct or indirect role in enhancing the productivity and efficiency of businesses by reducing production costs, expanding market opportunities, and improving the overall effectiveness of producing goods and services, amongst other benefits.

A brief description of different types of standards and their respective impacts is summarised in Table 2 below. Note that these impacts and concepts are explained in further detail below.

Table 2: Summary of types of standards classified according to the economic challenges they solve

Type	Positive impacts	Negative impacts
Facilitating interoperability of products and processes	• Network externalities • Avoids lock-in of old technologies • Increases choice of suppliers • Promotes efficiency in supply chains	• Can lock in old technologies in the case of strong network externalities
Efficient reduction in the variety of goods and services	• Generates economies of scale • Fosters critical mass in emerging technologies and industries	• Can restrict choice • Can increase market concentration • Can lead to premature selection of technologies
Ensuring quality and	• Helps avoid adverse selection • Creates trust • Reduces transaction costs	• Can be misused to raise rivals' costs

Type	Positive impacts	Negative impacts
promoting efficiency		
Efficient distribution of technical information	• Helps reduce transaction costs by helping to eliminate information asymmetries • Diffuses codified knowledge	• Can result in excessive influence of dominant players on regulatory agencies

Source: Swann (2000)

Facilitating interoperability of products and processes

Standards help with interoperability and compatibility of products and services. This is particularly true in the case of information and communications technologies. Economic theory identifies two main economic phenomena through which standards influence producer and customer behaviour: switching costs and network effects (or network externalities).

Switching costs refers to the costs, monetary or otherwise, that agents face when switching from a particular product or service once they have already invested in another. These often 'lock in' agents or customers to continue purchasing from a single firm because it is costly to switch or purchase from multiple suppliers. These barriers to switching have the effect of limiting competition in the market. Standards help to reduce switching costs by making it easier for customers to move between suppliers, thus improving choice and lowering the overall cost of investment for the customer.

The idea behind network effects is that it is desirable to choose a system that is widely used by others. This applies, for example, to the introduction of the telephone or to social media – the more people connected to the same 'network', the greater the incentive to join said network for those who have not done so already.

In a market where both switching costs and network effects exist, there is a risk that the market can get locked in to inferior designs since there is less incentive to switch to something better that is not widely used, and it is costly to do so anyway. Interoperability or compatibility standards help to expand market opportunities by increasing the network effects. When network effects are important to the buyer, there is a greater incentive for the seller to produce a good (or product) that conforms to the "industry standard", because with strong network effects the buyer is less likely to find the alternative attractive. This increases competition in the market since no one company controls the "industry standard", but the seller still has an incentive to conform to the standard as it is better to have a share of a large market than a monopoly of a tiny one. An example of this are telecommunications networks, where anyone connected to one network can call anyone regardless of the network which they are connected to. This increases the attractiveness of being connected to at least one of them because it means being able to call anybody on one's own network and on any other network. With network externalities making it so attractive to be connected, it is in the interest of communications providers to ensure interoperability between their networks, as it increases the size of the total market, allowing them to achieve a higher turnover.

Strong network effects can lead to an obvious issue whereby customers get locked-in to older and less effective technologies. Firms in sectors such as engineering, design, or finance, can get stuck with highly specialized software systems as these often require specialised training for their use. Since competing software packages will operate differently, these require different skill sets and firms become stuck with their current system to avoid business disruptions and re-training costs – leading to firms continuing to use the same software for extended periods, even if newer software would be more efficient.

Efficient reduction in the variety of goods and services

Standards serve to efficiently align the expectations of buyers and sellers in a given market. If different versions of products need to be produced for each market, costs are likely to be higher for both consumers and producers. So in effect it exploits economies of scale to avoid having markets with an infinite amount of minimally differentiated goods.

While it may seem unintuitive that decreasing the variability of goods and services can be a net benefit, ultimately it's necessary for markets to function efficiently. The alternative is an infinite amount of minimally differentiated products which provide no value and only serve to overcrowd the market and confuse both buyers and sellers. A good example to demonstrate this is clothing sizes, where you have restricted but still universal size standards that everyone adheres to, as opposed to having, for example, different trousers for every tenth of an inch of a difference in waist or length measurements.

Swann (2000) argues there is another, more important role for the efficient reduction in the variety of products which benefits producers as much as customers: standards can reduce the risks faced by suppliers, even if this means that they face more competition. They can have a significant impact on the development of a new technology market during its early stages. By promoting coherence and alignment among early adopters, standards can shape the future direction of the technology.

An example of a standardised product is the USB port, which was introduced by industry to provide a universally compatible way to supply power to all kinds of devices, such as computers, phones or other similar devices.

Ensuring quality and promoting efficiency

Standards can help customers with facing a large number of different products and services without having to know in detail which is better suited for their purposes.

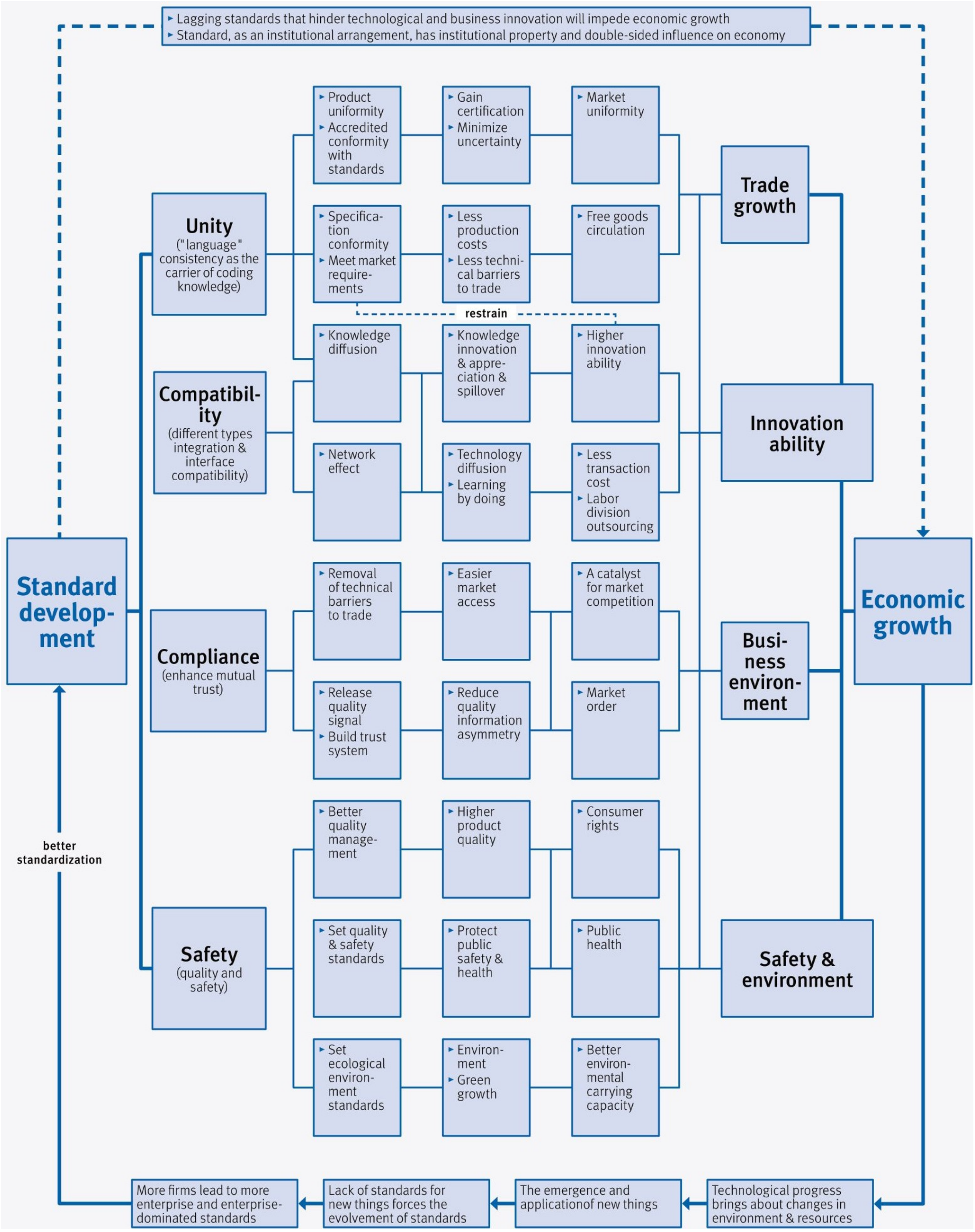
There are several economic theories, such as Gresham's law or Akerlof's market for lemons, which show the consequences of agents in a market being unsure or unable to assess the quality of a good. These circumstances where there is asymmetric information between buyers and sellers can often lead to severe market failures whereby high-quality sellers are driven out of the market as buyers cannot distinguish between high- and low-quality goods, pricing them out of the market.

Quality standards can help overcome this market failure by acting as a signalling tool to buyers so that they can confidently identify high- and low-quality goods before purchase, thus helping the high-quality seller to sustain a price premium. It also helps reduce transaction and search costs. By reducing uncertainty on the part of the buyer, this decreases the risk to the buyer, as well as the costs, in terms of time and money, of finding a suitable product.

Efficient distribution of technical information

This fourth category can be thought of as a hybrid of the three preceding categories. Standards help diffuse technical knowledge by making information readily accessible. At the private sector level, they enable manufacturers and service providers to ensure that their products or services perform as expected, reducing the risks to them (e.g. compensation or litigation costs) and to the buyer. As a result, the buyer can buy with confidence and without needing to evaluate each product individually, reducing the costs of each transaction and allowing markets to work better. Figure 7 below shows the transmission channels visualised by Zhang *et al.* (2019), that are based on a very similar framework to that proposed by Swann (2000): standards influence macroeconomic growth through four main characteristics (named here as unity, compatibility, compliance, and safety) which largely align with the four categories detailed in Swann (2000).

Figure 7: The effect of standards on an economy



Source: Zhang et al. (2019), ISO

1.4 Detailed examples of channels through which standards boost economic prosperity

The main way in which standards boost economic growth is through creating a better business environment that enables a more optimal production and allocation of goods and services across the economy. The four categories presented by Swann (2000) discussed in detail above complement each other to create a more efficient market; by ensuring both suppliers and consumers have mutual trust and symmetrical information. Standards facilitate economies of scale by letting the market decide on the optimal variability of goods and services and by improving the quality of products.

The section below explores in detail the economic literature in two areas – trade and innovation – where standards have an interesting and nuanced role in supporting positive economic outcomes.

The role of standards in facilitating international trade

Standards play an important role in facilitating international commerce by reducing Technical Barriers to Trade (TBT). These barriers can result from legal requirements enacted by countries to ensure the safety of products, to protect the environment, inform consumers, or for reasons of national security. However, if these requirements are used and applied arbitrarily, they could represent hidden restrictions on international trade. This is why international agreements such as the World Trade Organization (WTO) 1995 Agreement on Technical Barriers to Trade (TBT) exist. By recognising and adapting international standards as the basis for technical regulations, these unnecessary barriers can be avoided.

The academic literature provides strong evidence that the use of international standards, that allow companies to sell their products and services without the need to adapt them for each new market, can serve as a significant driver for trade. Swann (2010) reviewed the body of empirical work on how international standards impact trade and found that there is often, but not always, a positive relationship between international standards and trade. The general consensus from the literature is that international standards are supportive of trade, by supporting compatibility, reducing transaction costs, and acting as a signalling tool for quality to customers.

The literature shows that companies which use international standards tend to be more likely to export products and services. And this is especially the case for firms in developing countries (Goedhuys and Sleuwaegen, 2016). They found that firms in 89 developing or transition countries that use International Standards Certification (ISC) are more likely to export, and to export on a larger scale. The estimated impact of ISC is passed on through two channels: productivity and transaction cost economies. Notably, their findings suggest that international standards matter more for the export participation of domestic companies than for foreign ones, and that this effect is strongest for companies based out of countries that are characterised by severe institutional voids.[2]

These studies build on the findings from the rest of the literature, such as Swann (2000), that identified four main channels through which standards enhance trade:

a **Standards drive trade by providing a signal of quality to consumers and trade partners**

A robust system of standardization at the national level that enhances quality perceptions can foster non-price competition, where firms vie based on attributes such as product quality, delivery, and customer service. The chance for domestic exporters to compete on par with foreign firms on the quality front can potentially boost trade. Moreover, transparency is improved, enabling buyers and sellers to make informed purchasing decisions, thereby reducing transaction costs and enhancing competitiveness.

b **International standards create a 'common language' for potential trading partners**

The implementation of standards can effectively overcome technical barriers that may have previously hindered trade. Through the establishment of international standards, such as those for product measurements, compatibility is ensured and a universal standard is created for producers worldwide. This fosters a reduction in production costs and helps to eliminate trade barriers, allowing for greater competitiveness and lower prices that can be passed on to customers. Consequently, the implementation of standards is likely to stimulate international trade.

c **Standards support international commerce by lowering barriers to trade, reducing production costs and offering opportunities for economies of scale**

Reducing trade barriers, particularly technical ones, enables companies to reach a larger global customer base, creating opportunities for economies of scale. Furthermore, by guaranteeing compatibility, standards can boost demand for complementary products and services. For instance, the creation and ongoing enhancement of mobile phones have sparked the development of ancillary products and services, such as accessories, tethered devices, and applications.

d **Standards encourage trade by reducing transaction costs**

The compatibility of standards facilitates the possibility of outsourcing or offshoring specific tasks to more efficient external producers or service providers. This leads to a differentiation of supply chains in manufacturing and service industries, enabling firms to specialize in their core competencies. For example, a

2 This refers to the lack of institutional mechanisms such as independent public accountants who audit corporate financial statements, financial analysts who analyse and disseminate information, regulatory agencies and courts which protect the interest of public investor, that exist in advanced economies to solve the information and agency problems which would otherwise make it harder for buyers and sellers to conduct transactions in product, labour, and capital markets.

company may contract a supplier with lower input costs to manufacture their products while focusing on design, sales, and marketing. Suppliers benefit from access to industry-specific information and technology. The primary contractor benefits from producing and selling their product at lower unit costs while concentrating on their core strengths.

Standards and innovation

The literature on the effects of standards on innovation can be broken down into the direct and indirect effects of standards on innovation. Swann and Lambert's (2017) review of the literature indicates mixed observations regarding the direct effects. While they can have a supportive effect, they can also be constraining, sometimes even simultaneously. As a result, businesses may be sceptical about the role of standards in driving innovation. On the other hand, the indirect effects of standards are generally positive, and they may offer the greatest benefit from standardization. Standards induce favourable changes in the economic environment that can encourage innovation (Blind and Gauch, 2008; Wiegmann, 2019; and Lorenz *et al.* 2019, among others). Although these effects may not be immediately apparent to business observers, they are greater in overall importance.

By enabling and facilitating innovation – despite not directly contributing to the creation of innovative products and services – standards can act as a catalyst for innovation. This view is summarized by Blind (2009) as follows:

- → The standardisation process reduces the time to market for inventions, research results and innovative technologies;
- → Standards themselves promote the diffusion of innovative products, which is most important for the economic impact of innovation;
- → Standardisation levels the playing field and therefore promotes competition, and consequently innovation;
- → Compatibility standards are the basis for innovation in network industries;
- → Standards set the minimum requirements for environmental, health and safety aspects and consequently promote trust, especially in innovative products.

Blind (2009) argues that governments should take measures to encourage and facilitate the positive effects of standards on innovation, while also limiting or preventing the negative effects. These negative effects may include overly prescriptive technical standards, which require time and effort, and may inadvertently disclose too much relevant knowledge to competitors, thereby increasing the level of competition and disincentivising innovation (see Aghion *et al.* 2005); the risk of the consensus-based approach in standards development to prioritize a "best available" standard, which may be inferior to alternative, undiscovered solutions (see Uotila *et al.* 2017); and the potential for standards to create a "lock-in" effect that hinders the adoption of follow-on technologies (Ho and O'Sullivan 2017). There are other economic disadvantages of standards on innovation; the significant implementation costs of standards and the standardisation process mean that there are fewer resources available for research and innovation (Manders *et al.* 2016).

Recent literature, such as Blind *et al.* (2017), has expanded on this topic to explore how the impact of standards on innovation depends on the uncertainty of markets, and the extent to which this is closely interlinked with regulations. In this context, market uncertainty results from sources like competition, consumer behaviour or technological complexity. Blind *et al.* find that formal standards lead to lower innovation efficiency in the case of low market uncertainty, and high innovation efficiency in the case of high uncertainty in the market. Notably, regulation causes the opposite effect. One way to interpret this would be that, since developing countries are likely to have higher market uncertainty, we would expect the relationship between standards and innovation to be stronger in the context of this report.

Although the positive effects of standards on innovation are well established, the empirical evidence on this topic is not as unambiguous as it is for how standards can help facilitate trade, especially in developing markets. Further research and empirical evidence are needed to gain a better understanding of the effects of standards on innovation in practice, and the extent to which these differ from theory.

1.5 Previous similar research

There is an extensive literature on the impact of standards on specific countries or regions. ISO has published a report on this topic, summarising some of the literature (*Standards and economic growth: ISO members' research on the impact of standards on their national economies*, 2021).

Specifically, we will focus on the relationship between the stock of standards in a given country and its economic output, as measured by either GDP output or labour productivity.

This subsection serves as a benchmark for the results from our analysis, which are presented later in this report. It highlights some of the main studies from the literature, pointing out their respective scopes, as well as the methodological similarities and differences between them, and how they relate to our own econometric analysis.

As seen in Table 3 below, we see a wide range of results from the key relevant studies on the relationship, or in economic terms 'elasticity', between the stock of standards and economic output. Note that the results from the relevant row (see the column headed 'Stock of standards elasticity') should be interpreted as "for every 1% increase in the stock of standards, there is an associated X% increase in labour productivity or GDP output".

Table 3: Overview of results from previous studies on the productivity effects of standardisation

Country / Region	Organisation	Publication year	Period of analysis	Estimated function	Stock of standards elasticity	Control for patents?	Control for recessions?	Other controls?
Australia	Standards Australia	2012	1982 - 2010	Labour productivity	0.15	Yes	No	Time trend
Canada	CBoC	2007	1981 - 2004	Labour productivity	0.356	No	Yes	No
Canada	SCC	2021	1981-2019	Labour productivity	0.056	No	No	Time trend
France	AFNOR	2009	1950 - 2007	GDP output	0.12	Yes	Yes	No
Germany	Blind *et al.*	2011	1961-1996	GDP output	0.18	Yes	Yes	Imported licenses
Germany	Blind *et al.*	2011	2002 - 2006	GDP output	0.18	Yes	Yes	Imported licenses

Nordic countries	Menon	2018	1976 - 2016	Labour productivity	0.105	Yes	Yes	Time trend
South Africa[3]	-	2016	1972-2011	Labour productivity	0.07	-	-	-
UK	DTI Economics	2005	1948-2002	Labour productivity	0.05	Yes	No	Time trend
UK	Cebr	2015	1921 - 2013	Labour productivity	0.11	No	Yes	No

Source: Cebr

The time period covered across the literature varies widely, with the oldest sample going back to 1921 and the most recent to 2019. Beyond the difference in the dependent variable – all except the studies in Germany and France used labour productivity for output, matching the ISO methodological guidance – the econometric specifications do not differ too significantly across the studies. In terms of the main control variables (other included variables that explain changes in the primary variable of interest), the UK and Canada studies do not control for patents, and the Australian study does not control for recessions. Note that the South African study is not publicly available, and Cebr could not verify what control variables were used.

In terms of results, we see a wide range of values for the key elasticity. At the top end, the Conference Board of Canada (CBoC) estimated the elasticity to be 0.356% in Canada between 1981 and 2004. However, this value is significantly higher than the rest of the literature presented in this section. This study does not control for patents or any other variables such as a time trend, which might explain why the estimated effect of standardization is much greater than with the other studies.[4]

At the lower end, a more recent Standards Council of Canada (SCC) study and a UK study found the elasticity of standards on labour productivity to be approximately 0.5% in Canada and the UK, respectively. In the case of the UK study by DTI Economics, the time period examined spans half a century, ending in 2002, whereas the more recent SCC study considered the period between 1981 and 2019. However, the control variables used in either study must be assessed in order to infer whether these figures are likely to be over- or under-estimated. The 2021 SCC study does not include patents or any other control variables beyond a time trend variable, whereas the DTI Economics study controls for both patents and a time trend.

The elasticities of the other studies (excluding the South African study) fall within the range of 0.11%-0.18%. An earlier Cebr study examined the impact of standards in the UK

3 Note that the South Africa study is not publicly available so Cebr could not verify the organisation or details about its control variables or model specification. As such, these fields have been left deliberately blank.

4 This is because if we believe that patents play a role in explaining part of the growth in output, then by not controlling for it within our model this positive relationship may be absorbed into the other explanatory variables' coefficients (therefore leading to an overestimate). Similarly, if a variable which we believe has a negative effect on output is excluded from the model, then this may lead to an underestimate as this negative relationship is unaccounted for.

economy from 1921 to 2013 and found the elasticity of labour productivity to be 0.11%, though this study did not control for patents or a time trend. Menon Economics looked at the Nordic countries between 1976–2016 and, controlling for patents, recessions, and a time trend, found the elasticity of standards to be 0.105%. Standards Australia found the elasticity of standards on labour productivity to be 0.15% in Australia between 1982 and 2010, with the main control variables being patents and a time trend. Blind *et al.* and the Association Française de Normalisation (AFNOR) – in the case of Germany and France, respectively – used GDP as the dependent variable for output and found that the elasticity of the stock of standards on this to be 0.18% and 0.12%, respectively. Both studies controlled for patents and recessions, and Blind *et al.* further controlled for imported licenses.

There are other studies not included here that also assess the impact of standards on economic growth, but they are not considered relevant because their econometric specifications differ significantly from the methodology proposed by ISO, which this study is tasked with evaluating for developing countries. To name one such example, Blind *et al.* (2021) looked at eleven EU-15 countries between 1981 and 2014 using panel cointegration techniques and found elasticities between 0.02% and 0.15% across different models. Other studies, such as BERL (2011), assessed the impact of standards on total factor productivity in New Zealand and found an elasticity of 0.10%. While there is value in highlighting these other studies, making direct comparisons between their results is not recommended. The main reason for this being that the structural specifications used vary significantly, and they differ from the proposed ISO methodology.

Comparability between previous research and this study

The first and most important thing to note is that the literature on this topic has been almost exclusively focused on advanced economies. As a reminder, the purpose of this study is to assess the ISO methodology for economic impact analyses of standards in developing countries. So these results should be interpreted in that context. Chapters 3-8 contain discussions on our results, and the extent to which many of the econometric specifications discussed here hold for each of the six developing countries examined.

Our study is one of the first major analyses to examine the effect of standards on the economic output of developing countries, after the South Africa study from 2016. This is particularly interesting as the structure and linkages between certain sectors of the economy may not be as deeply entrenched in a developing context. Factors such as weaker institutional quality, higher levels of corruption, or a weaker regulatory framework or rule of law may negatively affect the channels through which standards can contribute to elevated economic prosperity.

On the other hand, standards may have a greater impact on prosperity in developing countries if they allow rapid technological progress by “importing” standards from advanced economies, allowing for accelerated progress towards a more mature stage of economic development.

Due to these structural differences, there are likely to be valid economic reasons as to why our coefficients are of a different magnitude to the ones discussed here. In some cases we may be able to easily diagnose the causes of the elasticity differences – for example, if the structural specification is not the same or if different control variables are used. On the other hand, further research may be required to validate certain results.

Chapter 2: Summary of the ISO Methodological Framework for Modelling the Impact of Standards on Economic Growth

For a comprehensive description of the methodological framework suggested by ISO, we recommend reading the document titled *"Economic impact of standards - Methodological guidance"*, published by ISO's Research & Innovation (R&I) Unit which can be found online. This provides a summary of the literature, the key economic concepts, details around the assumptions made within the methodology, as well as a comprehensive step-by-step guide to the prescribed approach.

Within this subsection, we will present a summary of the general framework such that this report acts as a standalone document where a reader can follow the steps taken to produce the upcoming results. Greater technical details are included within the Appendix, where the reader will also find a glossary of key technical terms used throughout this report.

The fundamental mathematical model behind the analysis is known as the Cobb-Douglas production function. This equation sets out that the ability of an economy to produce output (i.e. goods and services) at any point in time is determined by the following:

- The number of people working (labour);
- The quantity of capital (i.e. equipment; tools etc.) available to support this work; and
- A final term (known as total factor productivity) which captures all other factors (knowledge, technological advancements, efficiency improvements etc.) which drive economic progress above and beyond changes in the quantity of labour and capital.

Formally, the Cobb-Douglas production function is defined as:

Equation 1: The Cobb-Douglas production function with constant returns to scale.

$$Y_t = A_t L_t^{\beta} K_t^{\alpha}$$

This is read as: Output (Y) is the product of total factor productivity (A), labour (L) and capital (K), all at time (t).

Capital and labour have, as exponents, their respective elasticities to output (α and β). These elasticities measure the responsiveness of output to a change in levels of either labour or capital used in production, all else being equal. Here, $\beta = 1 - \alpha$, hence these elasticities sum to 1 as we are assuming constant returns to scale (or CRS). CRS occurs when increasing the inputs used in production (labour and capital) leads to a proportionate increase in output.[5] In simple terms, it means that if we double the amount of resources available (the inputs) for production, we will double the amount we produce (the outputs). This assumption is relatively common within econometric analysis and is discussed further within Section 3.3.1 of the report.

5 This differs from increasing or decreasing returns to scale, when a change in the quantity of inputs leads to greater than or less than proportional changes in the outputs, respectively.

Following the prescribed mathematical manipulation, this Equation is then rearranged[6] and expressed as a function of labour productivity, serving as the first key equation:

Equation 2: The log-linearised Cobb-Douglas production function, rearranged as a function of labour productivity.

$$ln\left(\frac{Y_t}{L_t}\right) = ln(Labour\ Productivity_t) = \beta_1 ln\ (A_t) + \beta_2 ln\left(\frac{K_t}{L_t}\right) + \epsilon_t.$$

Labour productivity is defined as output (Y_t) per worker (L_t) per year t.

Now, we are in a position to define total factor productivity, A, more formally. For ease of exposition, we assume that TFP is a function of standards plus all other necessary control variables, and we have produced our second key equation:

Equation 3: Formal definition of TFP as a function of standards, patents,

$$\ln(A_t) = \gamma_0 + \gamma_1 \ln\ (Stock\ of\ Standards_t) + \gamma_2 \ln(Patents_t) + \cdots + \gamma_n \ln(n_t) + \mu_t,$$

where the ellipses plus the $\ln(n_t)$ term represent all required control variables alongside the stock of standards. Control variables are variables that are not necessarily of interest to the study's aims, but are nevertheless controlled (i.e. included in the model) because they may influence the outcomes of our dependent variable (in this case, output). They are used to ensure that the model is unbiased, and the effect of standards on TFP is appropriately isolated, relative to these other potential causes.

Within the Introduction, we highlighted that ISO defines standards as "the distilled wisdom of people with expertise in their subject matter and who know the needs of the organisations they represent". Therefore, the stock of standards is an important component of TFP because it provides an indication of the extent to which this distilled wisdom is disseminated throughout the economy. The ISO methodological framework provides some suggestions for the additional control variables that should be considered. However, the exact specification of Equation 3 is ultimately determined by the practitioner.

Our goal if following this approach precisely, is to first estimate the magnitude of the effect of standards on labour productivity. Equation 2 and Equation 3 represent the core structure of the prescribed ISO methodological framework and are the starting points from which analysis and evaluation takes place. Through this, a practitioner would identify an equation for standards on TFP (to determine the effect of standards on TFP), as well as an equation for TFP on labour productivity (to determine the effect of TFP on productivity).[7] However as discussed further in the respective subsections within Chapters 3-8, following the exact steps from this framework was not feasible for all country analyses.

6 Full explanation of the steps taken here are shown in the Technical Appendix.

7 As a worked example, if we found that the key coefficient in both of these cases was 0.5 (i.e., a 1% increase in the stock of standards is associated with a 0.5% increase in TFP, and that a 1% increase in TFP is associated with a 0.5% increase in labour productivity), then we would multiply 0.5 by 0.5 and infer that a 1% increase in the stock of standards is associated with a 0.25% increase in labour productivity.

Chapter 3: The Economic Impact of Standards in Brazil

3.1 Summary of the Used Methodological Approach

We were able to successfully apply the theoretical economic framework prescribed by the ISO methodology, but we had to alter the step-by-step process through which we arrived at the estimate for the impact of standards on labour productivity in Brazil. **Instead of employing a two-stage model whereby standards are assumed to indirectly impact labour productivity through an increase in TFP, we use a single-stage model where we explicitly estimate the direct impact of standards on labour productivity.**

Although the ISO methodology works for Brazil, we opted to use a single regression model because, due to data-driven limitations that specifically affect Brazil, the single-stage model performs much stronger than the two-stage model as laid out by ISO.

Another deviation from the ISO methodology is that we excluded patents from our model due to data limitations.

Our original approach followed the ISO methodology with the exception of the exclusion of patents as a variable. To estimate the impact of increasing the stock of standards on economic growth in Brazil, Cebr initially estimated the following two equation systems:

Equation 4: The log-linearised Cobb-Douglas production function, rearranged as a function of labour productivity.

$$ln(Labour\ Productivity_t) = \beta_0 + \beta_1 ln\,(A_t) + \beta_2 ln\left(\frac{K_t}{L_t}\right) + \epsilon_t$$

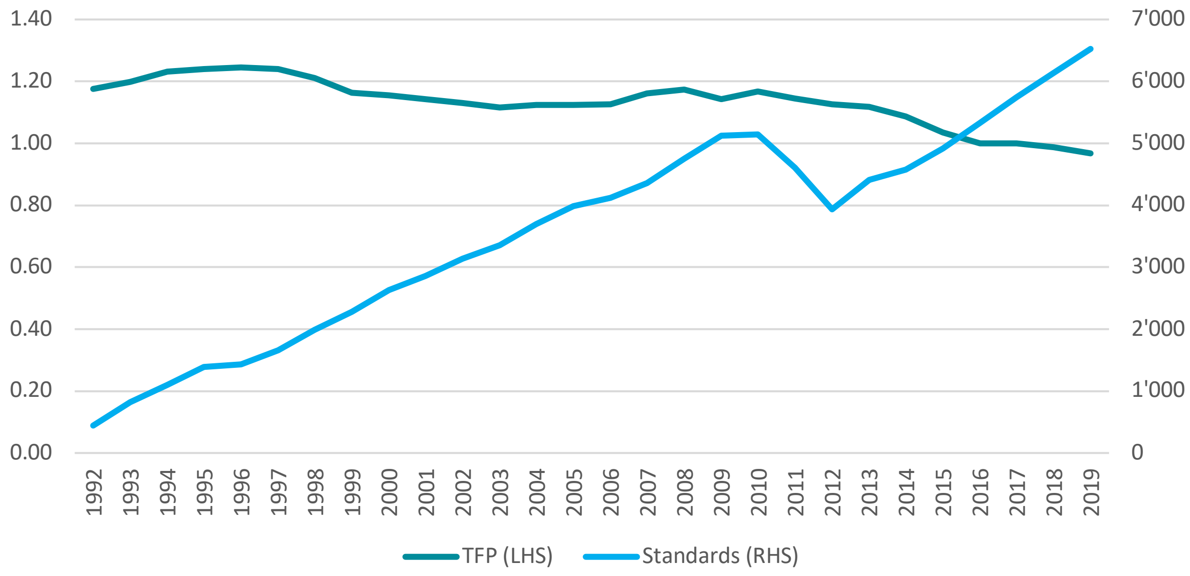
Equation 5: Original specification to isolate the effect of increasing standards on total factor productivity in Brazil.

$$ln(A_t) = \gamma_0 + \gamma_1 ln\,(Standards_t) + \gamma_2\, ln(FX_t) + \gamma_3 t + \mu_t$$

Where $Standards$ denotes the net stock of standards, FX_t represents the Brazilian real (BRL)-US dollar (USD) exchange rate, and t is a linear time trend variable. Note that there are gaps in the data for patents with a considerable number of missing datapoints. Moreover, as it currently stands, cumulative patents granted is highly correlated to the stock of standards. When one independent variable is excessively linearly correlated with another independent variable, this gives rise to multicollinearity, which makes it hard to determine their separate influences when both are included in the equation. For this reason, we had to drop patents as a variable in Equation 5.

More broadly, Brazil has an underlying productivity problem, with an overall downtrend in TFP, while over the same period, the stock of standards has increased – as can be seen in Figure 8 below.

Figure 8: TFP index (LHS) and net stock of standards for Brazil (RHS), 1992–2019[8]



Source: Penn World Tables, ABNT

A 2018 study by the World Bank found that TFP has actually contributed negatively to GDP growth in Brazil on average over the 1996-2015 period. If we fail to capture the true drivers of declining TFP in the model as control variables, the model would incorrectly suggest a negative relationship between standards and productivity. Unfortunately, the reasons for declining TFP in Brazil are linked to several interconnected factors that cannot be measured due to data limitations or the unquantifiable nature of these factors. As detailed in a 2018 study by the IMF, these include poor competitiveness, low infrastructure quality, high cost of doing business, low efficiency of the financial sector and limited openness to trade. Due to data limitations in measuring these factors, we included a linear time variable in Equation 5, denoted by t, to attempt to capture the general declining trend in TFP as a result of these unquantifiable factors.

Another difference from the ISO prescribed methodology is the presence of a constant (β_0) in the functional form of Equation 1, without which the effect of TFP on labour productivity is shown to be statistically insignificant.

Given the limitations encountered using the 2SLS method, a technically more robust model can be found using a single equation to estimate the direct effect of standards on labour productivity. Index of political stability and the exchange rate are found to be significant predictors of labour productivity alongside stock of standards. This model, discussed in more detail below, is more analytically robust than the two-stage model. It performs better than the two-stage model in terms of adjusted R-squared, significance levels of the coefficients, VIF or AIC scores. For a more detailed discussion of this, please see the Technical Appendix.

However, although the step-by-step process may be different from the one set out by ISO, conceptually both are still attempting to do the same thing – they should be interpreted

8 TFP is indexed to 2017 (i.e. 2017 = 1).

as different algebraic rearrangements of the same core model: the Cobb-Douglas production function. Whereas the two-stage approach leaves in terms for both capital and labour as well as TFP (A), with the single equation seen below we maintain capital and labour within the model through the k term (which denotes the capital-employment ratio), and then we simply substitute TFP with our list of explanatory variables (including standards), which we explain below.

The one caveat to note about this altered model is that by removing the TFP term and substituting it with the explanatory variables discussed, we are in effect no longer directly quantifying the explicit role of TFP. As a reminder, TFP is essentially the "catch-all" term for everything that affects economic output that's not capital or labour. It will include the specific explanatory variables we use – such as standards – but it is likely to include many other external factors that aren't estimated or accounted for in our model (these include poor competitiveness, low infrastructure quality, and others discussed above, which are harder to quantify). As such, although the single-stage model we have used is the best at estimating the isolated impact of standards on labour productivity, it is more limited when it comes to identifying the relationship between TFP and labour productivity.

Equation 6: Used single-regression specification to isolate the effect of increasing standards on labour productivity in Brazil.

$$\ln(y_t) = \beta_0 + \beta_1 \ln(std_t) + \beta_2\, pol_t + \beta_3\, FX_t + \beta_4 \ln(k_t) + \epsilon_t$$

where y_t represents labour productivity; β_0 is a constant, or intercept; std_t denotes the net stock of standards; pol_t is the political stability indicator from the World Bank's Worldwide Governance Indicators (WGI); FX_t represents the Brazilian real (BRL)-US dollar (USD) exchange rate; k_t is the capital-employment ratio; and ϵ_t is the residual part of TFP.

The political stability indicator from the WGI project measures perceptions of the likelihood of political instability and/or politically motivated violence, including terrorism. There is extensive evidence from the literature on how political stability, and the lack thereof, impacts labour productivity (see Faust, 2007; Klein and Luu, 2007; Alston *et al.,* 2011; and Alexandre *et al.*, 2022). For Brazil, this was found to be a significant predictor for labour productivity. We also include the US dollar exchange rate to function as a proxy for the international competitiveness of the Brazilian economy. Lastly, we include the capital-employment ratio to control for the changing capital stock per employee in Brazil over the period analysed.

This combination was found the be the best performing model to describe the impact of standards on Brazilian productivity with an adjusted R-squared of 0.89.[9]

3.2 Findings

3.2.1. Quantitative results

The analysis reveals a strong and significant relationship between standards and labour productivity. Our regression result for Brazil tells us that **a one percent increase in the net**

9 We include a more detailed discussion on model diagnostics in the technical appendix.

stock of standards is associated with a 0.149 percent increase in labour productivity, where labour productivity is measured as real GDP per worker. This headline figure is taken directly from the coefficient for standards from Table 4 below, which presents results for the modelling specification from Equation 6 above.

Table 4: Summary results for Brazil, 1995–2019

Term	Coefficient	Standard Error	t-statistic	p-value	Significance
Intercept	-2.295	0.541	-4.243	0.000	***
ln Cap-Emp	0.718	0.095	7.560	0.000	***
Ln Standards	0.149	0.022	6.921	0.000	***
Political stability	0.058	0.033	1.739	0.097	*
FX	0.273	0.042	6.562	0.000	***

Source: ABNT, World Bank, IMF, and Cebr analysis

Note: Asterisks *, **, and *** are added to denote a significant relationship at the 10%, 5%, and 1% levels, respectively.

Equation 6 reveals that all of the explanatory variables in our model are positively related to labour productivity. Crucially, the coefficient β_1 suggests that **a one percent change in standards is associated with a 0.149 percent change in labour productivity**.

All coefficients are significant at the 1% level or higher, except for political stability which is only significant at the 10% level. For more detailed statistical information regarding these results, please see the Technical Appendix.

3.2.2. Discussion

Contribution of standards to economic growth

The findings in Section 3.2.1 above posit that a one percent growth of the stock of standards is associated with an increase in labour productivity of 0.149 percent across Brazil. In terms of economic growth this has the following implications:

- Between 1995 and 2019, the net stock of standards in Brazil grew by an average of 6.7% year-on-year, while the average year-on-year growth of labour productivity was 0.56% – which is very low compared to other countries. Applying the elasticity of standards to labour productivity (0.149) to the average growth in the stock of standards, we find that standards are associated with approximately 178% of the average labour productivity growth.

- If we unpack this finding, we find that standards are associated with, on average, 0.99 percentage points of growth in labour productivity during the period. But, as mentioned above, labour productivity only grew by 0.56% per year on average. What this means is that while standards contributed 0.99 percentage points to labour productivity growth, other external factors that are not estimated or accounted for in our model were bringing down labour productivity growth such that its net growth was lower than its contribution from standards.

- Although this result is on the higher end of the range of values seen across the literature, it is only slightly higher than the findings from the France or Germany studies, which found that standards were associated with 0.9 and 0.8 percentage points of the growth in the output for these countries, respectively.
- As mentioned below, this is in large part due to the shorter time frame due to data limitations, which makes these estimates much more sensitive to outliers and disturbances during the time period we are considering. An example given below is that if instead of anchoring our analysis in 2019, we did so in 2013 before the economic crisis which affected Brazil during the mid-2010s, the share of labour productivity growth attributable to standards would change from 178% to 96%.
- For the purposes of expressing the findings in monetary terms, if it is assumed that the estimated impact is constant over time, standardisation at the national level would be associated with approximately R$54.5 billion of the R$123.5 billion of GDP growth recorded in 2019 (World Bank, 2019 prices).[10]

Table 5: Comparison of relevant summary results of national studies[11]

Country	Brazil	Canada	France	Germany	Nordic	UK	UK
Publication year	**2023**	2007	2009	2000	2018	2005	2015
Analysis period	**1995-2019**	1981-2004	1950-2007	1961-1990	1976-2016	1948-2002	1921-2013
Estimated function[12]	**LP**	LP	GDP	GDP	LP	LP	LP
Elasticity of stock of standards	**0.149**	0.36	0.12	0.07	0.11	0.05	0.11
Share of labour productivity growth	**178.4%**	17.0%	27.1%	30.1%	39.5%	13.0%	37.4%
Growth rate of GDP, % p.a.	**2.2%**	2.7%	3.4%	3.3%	2.5%	2.5%	2.4%
Share of GDP growth	**44.1%**	9.2%	23.5%	27.4%	28.0%	11.0%	28.4%
Contribution of standards to GDP growth, % points	**0.99%**	0.3%	0.8%	0.9%	0.7%	0.3%	0.7%

Source: Standards Council of Canada (2007), AFNOR (2009), DIN (2000), Menon (2018), DTI (2005), and Cebr analysis

In the case of Brazil, from 1995 to 2019 standards contributed, on average, 0.99 percentage points to growth in labour productivity, but labour productivity grew by less than this over the period analysed. This suggests that the share of labour productivity growth attributed to the role of standards is over 100%, which may seem counterintuitive. What this means is that while standards contributed 0.99 percentage points to growth in labour productivity, other

10 As a point of reference, this figure converts to approximately $13.6 billion out of $30.8 billion in GDP growth in 2019, based on the 2019 US dollar exchange rate.

11 Note that not all the studies from Table 3 are presented here; only those that estimated the share of labour productivity of GDP growth associated with standardisation are included in this table. For a similar comparison with the other developing countries assessed within this study, see Section 9.1.

12 LP = Labour Productivity. GDP = Gross Domestic Product.

factors were contributing to negative growth in labour productivity which brought its “net” annual growth over the period to a mere 0.56%.

The figures derived above should be treated with caution. The extrapolation to estimate the share of labour productivity growth and GDP growth attributable to the increase in standards is based on a point-to-point analysis between 1995 and 2019 where we assume a constant growth rate of these variables between these years, notably a 0.56% annual growth in productivity. In reality, labour productivity growth has been more volatile. Anchoring the analysis in 2019 as opposed to 2013, for example, right before the economic crisis of the mid-2010s began, results in the low average productivity growth of 0.56%, compared to 1.03% for the period up to and including 2013. This has the effect of overestimating the share of productivity growth attributed to standards, as we see in Table 5 above with the estimated share of 178%, compared to 96% if we anchored the analysis between 1995 and 2013.

Given the shorter time series for Brazil compared to the other country studies – except Canada, all have at least 50 years’ worth of data – the results above are not directly comparable because the average growth in labour productivity in Brazil is much more sensitive to outliers and disturbances during the time period we are considering. That said, while the interpretation of the above extrapolated estimates should be made with caution, the underlying elasticity of standards on labour productivity derived from our model remains a reliable and robust estimate. Our model uses a robust estimation method that is designed to be more resilient to outliers and data irregularities. For more detailed information on the regression method used in our model, please see the Technical Appendix for Brazil (Section 3.4).

A 2018 study by the World Bank explores some of the underlying issues discussed above. Among other things, it finds that over the period 1996–2015, TFP was a drag on growth on average, meaning it had a *negative* contribution. The results of the analysis show that over time the Brazilian economy has not grown as a result of improvements in productivity, and that labour’s contribution has actually been declining steadily. When compared to other countries, it is clear that Brazil’s growth has been heavily dependent on labour accumulation, which over the period has been very large in Brazil and far above any other comparator (which includes developing economies from the Latin American and Caribbean region as well as Asia). This appears to be caused by a misallocation of resources: with some of the causes being barriers to competition, including a highly distorted policy environment and limited trade integration, as well as financial market distortions. Furthermore, the study finds that this misallocation of resources has been increasing over time, with capital misallocation being substantially larger than labour misallocation. Overall, these results highlight that productivity has contributed little to growth in Brazil, and that growth has been driven by demographics and higher employment levels. When we combine these insights with our shorter time series that is more sensitive to outliers and disturbances, it becomes clearer how we could achieve a result which implies such a high contribution of standards to both labour productivity and GDP growth.

Having said all this, we should stress that the estimated elasticity for the isolated impact of standards on labour productivity is robust and reliable. It is the implied share of growth for both labour productivity and GDP growth that is attributable to standards where caution should be applied. Because Brazil is not a highly developed economy and we are not looking at a very long time series, the average growth in the economy during the period assessed is inherently more volatile and highly susceptible to outliers and shocks.

Despite the less than intuitive results from our analysis above, the intuition behind the impact of standards on economic growth is still the same. Standards can enhance labour productivity by increasing output per employee at individual firms. This can be achieved through various mechanisms such as improving production activity and efficiency, ensuring quality and precision, and spreading technical information and best practices. These improvements in organisational performance lead to cost savings, enabling firms to achieve higher output per worker. Additionally, standards allow firms to build on their strengths and specialise, leading to better division of labour, economies of scale, and increased output per staff member.

Moreover, we should note that the explicit transmission channels through which standards have an impact on productivity and economic growth is ambiguous. Standards have an interdependent role in driving labour productivity along with other knowledge factors such as higher levels of education and training, advances in technology and increased innovative efforts. By interdependent we mean that standards play a mutually dependent and complementary role alongside other factors, such as those mentioned above, in facilitating productivity growth. Beyond standards having a direct impact on labour productivity, they are also associated with driving these other knowledge factors, and these then result in an increased value of standards. Equally, an improvement in the other knowledge factors leads to standards playing a more efficient role in boosting labour productivity.

Limitations and Caveats

For reasons of transparency and accountability, as well as to avoid any inappropriate conclusions being made, it is important to highlight some of the key limitations of this research.

First and foremost, our **analysis is exclusively focused on the assessment of the correlation between standards and productivity, rather than causality**. Correlation between variables simply means that they are related, and that as one variable changes the other does as well, but it does not mean that the change in one of the variables (e.g. productivity) is *caused* by the change in the other variable (e.g. standards). Causality, or causation, is when there is a causal relationship between two variables, i.e. that the change in one variable is caused by a change in the other. Further research would be valuable to be able to establish a *causal* relationship between the standards and labour productivity. That is, the identification of a direct cause-and-effect relationship between the two variables in Brazil.

We have also not considered the direction of causality between the variables and cannot pass comment on the potential for endogeneity for the stock of standards in the context of Brazil. In other words, this study does not attempt to investigate which of standards or growth drives the other, merely that they are connected and, when one changes, so does the other.[13] An example of the two-way relationship between standards and growth is highlighted by a logic model produced by Zhang *et al.* (2019). They suggest that additional growth and technological progress brings about changes in environment and resources, which in turn leads to the emergence and application of new goods and services. The resulting lack of standards for new products forces the evolution of standards, while more firms lead to more enterprise and enterprise-dominated standards. Ultimately, there is potential for a virtuous cycle between standards and economic growth, but the applied framework does not account for this two-way relationship. Further research is required here.

Furthermore, **the analysis period of 1995 to 2019 is relatively short, covering only 25 periods** of continuous data. According to the methodological guidance document produced by ISO, the very lower bound (or minimum recommended amount) for the number of

13 Moreover, endogeneity is simply a term in econometrics which describes when a variable of interest (such as standards) is affected by other variables in the analysis. This can be problematic as it may lead to biased and unreliable estimates of the effect of standards (with endogeneity we cannot be sure whether our model is saying that standards have a positive effect on growth, or if it is some other explanatory variable).

observations is likely to be somewhere around 15, and it is preferable to have at least 30 periods of data such that the Central Limit Theorem applies.[14]

While we have continuous data for standards between 1992 and 2022, we only have data for the Capital-Employment ratio from 1995 up until 2019, so there is a constraining factor on the period of analysis due to the availability of data from the Penn World Tables. To an extent, this is not a critical issue, as data for 2020 onwards will have Covid-19 related challenges. However, it does place a limit on the period of analysis, with the most recent year being 2019. The average number of observations in the other studies referenced in Table 5 is 50. Since this study has an observation period of 25 years, this analysis is on the threshold of what can be considered statistically robust.

Cebr is also keen to urge a degree of caution when interpreting these findings. Crucially, **the relationship between standards and productivity is somewhat of a 'black box'** and we have not attempted to incorporate a quantitative assessment of the mechanisms through which standards generate increased productivity. In other words, while we have determined that standards increase productivity, we have not determined *how* or *why* they do so. It is beyond the scope of this report to develop a richer understanding of these mechanisms and their effects, but studies at the company level, using firm-level data derived from surveys or case studies, have been conducted in the past and can assist here.[15]

Lastly, it should be recognised that that standards alone do not drive productivity. Rather, they play a mutually dependent and complementary role in facilitating growth of productivity, along with other types of knowledge such as enhancements in education and progressions in technology. While we have attempted to control for key other potential explanatory factors, the model does not explicitly control for **all other** potential contributors to labour productivity. The model is instead an attempt to isolate the impact of standards on productivity.

3.3 Review of ISO Methodological Framework

3.3.1. Applicability and Effectiveness

To evaluate the applicability and effectiveness of the prescribed methodological framework, we first consider the key assumptions that are made to apply the used single-stage regression approach[16] – which, as discussed above, only differs from the two-stage approach laid out by ISO in terms of the step-by-step process – and discuss whether these assumptions are

14 For datasets with less than 15 observations, it is harder to estimate the coefficients that describe the relationship between our variables of interest, and it can also lead to wider confidence intervals around the estimated coefficients (confidence intervals five us a range within which we are reasonably confident that the true value lies).

15 These include DIN (2000), Conference Board of Canada for the Standards Council of Canada (2007), AFNOR (2009), BERL Economics for The Standards Council of New Zealand (2011) and Menon Economics (2018).

16 Two-stage least-squares (or 2SLS) is a common regression analysis technique which is used when the dependent variable's error terms are correlated with the independent variables. By using a two-step approach, 2SLS helps us isolate the true effect of standards on productivity by effectively removing the influence of other variables.

appropriate in this context. Then secondly, we consider whether we have been able to follow the same system of equations to estimate the indirect effect of standards on labour productivity.

The six explicit assumptions made by the methodology are as follows:

- Assumption 1: A stock of standards is a credible proxy for the extent to which standards are effectively utilised in the country.
- Assumption 2: The Cobb-Douglas production function is appropriate as an approximate model.
- Assumption 3: There is a one-way relationship between standards and economic growth.
- Assumption 4: The appropriate transmission mechanism from standards to economic growth resides in an increase in total factor productivity.
- Assumption 5: Data on standards, labour, capital, productivity, and any other variables is available.
- Assumption 6: The economy exhibits constant returns to scale.

Assumption 1: Stock of standards as a credible proxy

The assumption that the stock of standards is a credible proxy for the extent to which standards are effectively utilised is borne out of pragmatism. Across the literature, this is the accepted approach despite its limitations. For example, while it is true that a significant number of standards may indicate that a country is committed to promoting and maintaining standards, it does not guarantee that these standards are effective.

Beyond simply the quantity of standards, effective standards concern the quality, relevance, implementation, and enforcement of standards in an economy. On one level, a large stock of standards may generate a degree of confusion among stakeholders, making it difficult for organisations to determine which standards are relevant to their needs. Furthermore, the standards may not be effective in achieving their intended goals if they are poorly written, outdated, or not based on the best available science or research.

In addition, the introduction of each new standard may not produce a proportional economic benefit. The assumption that the stock of standards is a robust representation of how standards contribute to the economy is equivalent to the assumption that each standard contributes an equivalent benefit to the economy. This assumption is unlikely to fully hold because newer standards are expected to offer greater benefits than older standards in the national catalogue. Furthermore, the impact of standards on the economy is also generated by the breadth of their use, and thus, some standards are more widely used, and thus more impactful.

Ultimately, while there are limitations to Assumption 1, these are not unique to the Brazilian context and the stock of standards is the best available option for our research.

Assumption 2: Cobb-Douglas production function is appropriate as a model

Economists use production functions to describe what can be produced given a set of inputs, which are typically simplified into capital and labour. Different combinations of capital and labour can be used to produce the same output. The example given by the ISO guidance document suggests that to make a hole in the ground, one can use a person and a spade, two people and two smaller spades, or one person and an excavator. This reflects a microeconomic phenomenon where capital and labour are substitutable. Any macroeconomic model must be consistent with this, and the Cobb-Douglas form is one of the most widely used and practical models within the field.

The use of the Cobb-Douglas production function as an approximate model is a pragmatic middle ground between an ideal world where economic models perfectly describe reality, and the real world where the model must be workable (i.e., linear, in this case).

The major strength of the Cobb-Douglas production function is its ease of use. However, there is a great deal of contradiction within the academic literature with respect to the empirical validity of the Cobb-Douglas functional form. On one hand, Miller (2008), Abidemi (2010), Adetunji *et al.* (2012) and Husain (2016) provide some support evidence for the specification of the model. While on the other hand, papers such as Fraser (2002), and Gechert *et al.* (2019) cast some doubt on the appropriateness of the Cobb-Douglas production function.

In the specific context of a developing economy, there may be some issues that are not present in other contexts, e.g., limited factor mobility (i.e. factor inputs such as labour, capital, or land cannot easily switch between alternative uses without a loss of efficiency). The Cobb-Douglas model assumes a high level of capital and labour mobility, which may not be present in a developing economy. For example, labour may be immobile due to limited access to education and training or a poor infrastructure system, while capital may be concentrated in a few large firms or industries.

For this particular report on the economic impact of standards on productivity in Brazil, we have employed a Cobb-Douglas production function for our model, though it has been rearranged into a different set-up from the one in the prescribed within the ISO methodological guidance note (see Section 3.1 for more information).

Therefore, although we have a slightly altered Cobb-Douglas production function as our model (relative to the algebraic manipulation in the ISO methodological guidance note), we were able to use the recommended underlying economic framework. As such we find that Assumption 2 is sensible, even if it may be a slightly weaker assumption in the developing context given the general challenges discussed above. The weaknesses outlined above should not categorically prevent the application of this methodology in any given country.

Assumption 3: There is a one-way relationship between standards and growth

We have already discussed Assumption 3 in the section above and concede that while this assumption has its limitations, it is made because it allows the presented methodology to be simple enough for most countries to adopt, given capacity and capability constraints.

Therefore, this is a limitation of the framework more broadly, but it has no consequences for the applicability and effectiveness of the framework in the developing context specifically.

Assumption 4: Standards impact economic growth through an increase in TFP

Within ISO R&I's methodological guidance document, a logic model is presented that describes the theory behind the effects of standards on an economy, ultimately linking the development of standards with economic growth. It highlights the main mechanism through which standards improve economic growth: unity, compatibility, compliance, and security.

Then, through factors such as product and market uniformity, knowledge and technology diffusion, reduced technical barriers to trade, easier market access, enhanced consumer rights, economic growth is driven by four key channels: trade growth, innovation ability, business environment, plus safety and environmental protection. Zhang *et al.*'s logic model was in fact developed as part of a study into the effects of standards development on economic growth in China.

It is also worth noting that there may be some drags to economic growth through the application of standards. For example, overly burdensome standards could lock in old technologies or lead to premature selection of technologies, which would be an inefficient allocation of resources. On top of this, standards have the potential to restrict choice and increase market concentration, especially if dominant players can wield excessive influence on regulatory agencies. While these linkages are a possibility, on a net basis, there is compelling evidence to suggest that standards have a positive impact on productivity and growth.

As mentioned, there is an argument to suggest that in the developing context, there are greater frictions to overcome across the transmission mechanism compared to a more advanced economy. More broadly, however, the critical point for this project is that the *intuition* behind the linkages considered by Zhang *et al*. appears appropriate. Unless we directly test these linkages, we cannot say with certainty whether this hypothesis is correct.

Nonetheless and as discussed, because we have decided not to use the two-stage approach for our analysis of Brazil, there is no explicit role for TFP within our model. So we cannot know whether our estimated impact of standards on economic growth occurs through an increase in TFP. Evidence of the structure of Brazil's economy and its trends over the last few decades, with the significant structural shock caused by the debt crisis of the early 1980s – which began a steady downward trend for TFP from which it has not recovered at all – suggests that TFP has been a drag on growth in Brazil. Over the period from 1996 to 2015, Qian, Thompson Araujo, and Nucifora (2018) found that TFP actually had a negative contribution to economic growth.

By contrast, our analysis shows that standards had a positive impact on growth throughout the same period. As we have calculated this through a rearranged Cobb-Douglas model, with the sole change being the replacing of the TFP term with further explanatory variables (such as standards), implicitly the only mechanism through which standards impacts growth logically is via an increase in TFP. The combined conclusion of this is that standards act to increase TFP, but the other structural challenges have nonetheless led to TFP declining. So in the absence of standards increasing, TFP would have declined further, and it is this differential that results in the growth that we see in the productivity figures.

However, given the external factors which make up TFP that cannot be estimated or accounted for in our model, we are using a single-stage model without explicit calculation of the impact of standards on TFP, then the impact of TFP on labour productivity. As such, while this assumption about standards positively impacting growth through TFP, which is then dragged down by other external factors, seems like a reasonable hypothesis, we cannot definitely prove whether our above assertion is true.

Assumption 5: Data on the relevant variables is available

The fifth assumption of the framework is that data on standards, labour, capital, productivity, and any other required variables is available for the country in question.

We did not encounter any major issues with regards to the data available for Brazil that would have kept us from carrying out our analysis. Data sources such as the World Bank, IMF, FRED, and the Penn World Tables provide comprehensive coverage for the country, however the main issue was with the length of the time series that were available. Crucially, we were only able to obtain reliable Capital-Employment ratio data (taken from the Penn World Tables) up to 2019, while patents data did not extend to periods before 2004. Note, however, that this is an issue across the entire study and applies to all the other countries assessed (Colombia, Jamaica, Senegal, Uganda, and Indonesia).

Furthermore, to measure the impact of standards on labour productivity accurately, data on labour productivity itself should be consistent and reliable, and this, in turn, largely rests on the availability of robust data on GDP and employment. While GDP figures were sourced reliably from the IMF, employment statistics were, however, not directly available. Labour market indicators have not been published for long enough and as consistently by the relevant official bodies in Brazil as they usually are in developed countries through household or labour force surveys. As an alternative, we sourced employment figures for Brazil from the International Labour Organization (ILO), which produces modelled estimates of labour market indicators using a series of econometric models. These estimates are generally designed to provide a view of labour market trends, in the countries and years for which country-reported data are unavailable. The ILO advises that estimates for countries with very limited labour market information have a high degree of uncertainty and hence should not be considered as "observed" data, and great care needs to be applied when using these data for analysis, especially at the country level.

We could not incorporate all relevant variables into our models across the full period of analysis. In the case of patents specifically, including it in our models limited the analysis we could carry out since the data only goes back to 2004, meaning that our time series would be cut relatively short. Consequently, we were presented with a trade-off between including all relevant variables as outlined in the ISO methodology guidance or having a longer time series. After robustly testing the available options, the most favourable approach was to drop patents as a control variable in order to substantially increase the length of the data series.

Overall, despite the data limitations mentioned here and discussed in more detail elsewhere, the prescribed ISO methodological approach could be followed in the case of Brazil as there were enough alternative options.

Assumption 6: The economy exhibits constant returns to scale

Lastly, the Cobb-Douglas model assumes a constant returns to scale (CRS), which means that increasing inputs will result in a proportional increase in output. While this assumption may be defensible at the global level (as it assumes that at any one time, many firms will be enjoying increasing returns to scale, while others will be experiencing decreasing returns to scale), it may not hold for all countries, especially in the developing context.

For example, in a developing economy, there may be infrastructure constraints, limited labour mobility, inadequate education and training, weak regulatory frameworks, or the inability to efficiently use additional inputs which could create pressures that generate decreasing returns to scale.

On the other hand, developing economies may exhibit increasing returns to scale through high labour mobility, [17] through lower per-unit production costs and high international

17 Depending on the country, labour mobility may be a strength or a weakness. On one hand, a country with a large, young population will have a sizeable pool of workers to deploy in the regions or industries where they can be the most productively efficient. On the other hand, capacity constraints such as lack of housing stock,

competitiveness, through increasing marginal returns to investment in factors such as education, health, and welfare while the economy is still 'young', or through relatively high returns to capital which make developing economies attractive to foreign investors.

We discuss this topic in more detail within the Technical Appendix for Brazil (Section 3.4). The limitations of the CRS assumption discussed in the appendix are generally accepted across the literature and on balance, we recommend that this assumption is sufficiently robust and defensible in the context of Brazil.

Summary

Overall, the framework has been successful in providing evidence of the impact of standards on labour productivity in Brazil. Although we could have followed the exact steps suggested within the guidance document – with the exception of the use of patents as an explanatory variable – and produce robust and significant estimates for the impact of standards on TFP and labour productivity, using a single-stage regression approach proved to be a better model than the two-system of equations approach.

There are some limitations present such as poor data availability, however these limitations are not a consequence of the prescribed framework, nor is the data sufficiently sparse that a model cannot be produced. Overall, whilst we are confident in the robustness of the results presented within this study, caution as well as a sound understanding of the relevant limitations, is advised.

3.3.2. Recommendations for Future Research

Our recommendations for future research centre around addressing the limitations of this study and overcoming the gaps in data availability.

Uncovering 'black box' variables

One important criticism of generalised macroeconomic models such as the one used in this study – and by most of the other national level studies in this space – is that **the relationship between standards and productivity is treated as something of a 'black box'**. There is one notable difference between our model and our original one which followed the exact ISO process step-by-step: by substituting in our explanatory variables into the TFP term (A) we are altering our model from estimating the indirect impact of standards on labour productivity (though an increase in TFP) to being an estimate of the direct impact of standards on productivity. Although we know the magnitude of this impact, we still definitively do not know the underlying mechanisms through which this occurs.

The academic literature shows compelling evidence to suggest that standards enhance productivity and economic growth at the national level. In practice, this means that standards will help drive companies and their associated supply chains to operate more efficiently, thus reducing costs, expanding revenue opportunities, and ultimately allowing companies and sectors to become more productive and profitable.

On one hand, we can use our economic intuition and critically assess the credibility of the linkages suggested within Zhang *et al.*'s logic model in the context of Brazil. However, on the other hand, we do not quantitatively assess the mechanisms by which standards generate

lack of education and training, or an inadequate rail and road infrastructure may limit the ability of this labour to be efficient.

increased productivity within this study. Other studies in the space have been conducted at the company level using sector- or firm-level data derived from secondary sources, primary surveys, or case studies.[18]

To the authors' knowledge, ABNT does not have detailed, granular data that incorporates statistics on standards by sector. If such data were to exist, **this would be an area to explore as it could potentially allow more granular analyses to take place. Without such data, it will be difficult to identify and assess quantitatively the** key channels through which standards manifest and ultimately drive productivity and growth in Brazil.

Identifying the direction of causality between standards and productivity

Secondly, **an assessment of the direction of the relationship between standards and productivity** would be an insightful avenue for further research. There is a virtuous cycle between standards and economic growth – whereby standards drive growth which subsequently drives standards which drives further growth, and so on – however, we have not tested this relationship as part of this study.

The prescribed framework does not account for this two-way relationship for reasons of methodological simplicity. While the quality of results may not be affected by the choice to model the relationship between standards and economic growth as one-way, there is still additional insight that could be gained from future research.

For example, one common option is to find a 'cointegrating' relationship between the key variables whereby there exists a stable long-run statistical relationship. Statistical tests can confirm if this relationship is non-spurious and whether it exists between standards and productivity. A similar approach was applied by Cebr in a 2015 study assessing the contribution of standards to UK productivity.

Other options are to use methods such as a Granger causality test which assesses whether one time series is an effective forecaster of another. This test is somewhat of a misnomer as it does not provide insight into a true cause-and-effect relationship. Rather, if standards were found to Granger-cause productivity, then this would demonstrate that historic increases in standards are related to increases in productivity today.

This is by no means an exhaustive list of econometric methods that could be used to extend beyond correlation analysis, but these more advanced techniques would require expansions to the prescribed methodological approach. Given that one of ISO's core aims is to expand the evidence base across developing economies, we would recommend that (if it is found to be the best model) the prescribed framework be applied as an initial starting point due to its relative simplicity, while the more advanced techniques are applied in further studies.

Reducing data deprivation

Lastly, one of the key limiting factors of this research was data deprivation. As highlighted by ISO, statistical models are only as good as the data that goes into them. In this instance, we were unable to include patents as a control variable due to insufficient historic data, despite it being a potentially important regressor to assess. Even if it was dropped from the final model, the fact that we could not comprehensively test whether patents are a statistically significant variable in determining productivity alongside standards is a notable shortcoming of the

18 These include DIN (2000), Conference Board of Canada for the Standards Council of Canada (2007), AFNOR (2009), BERL Economics for The Standards Council of New Zealand (2011) and Menon Economics (2018).

research. Therefore, we see it as important to use this report as a call-to-action for data collection agencies – both national and supranational bodies alike – to continue their work to expand data libraries, with a particular focus on developing economies.

The concept of data deprivation is not new. Data serves as the foundation for meaningful policymaking, efficient resource allocation, and effective public service delivery. By improving the statistical coverage of the developing world, there will be more opportunities for robust economic analyses to contribute to the literature and advance society's collective knowledge base.

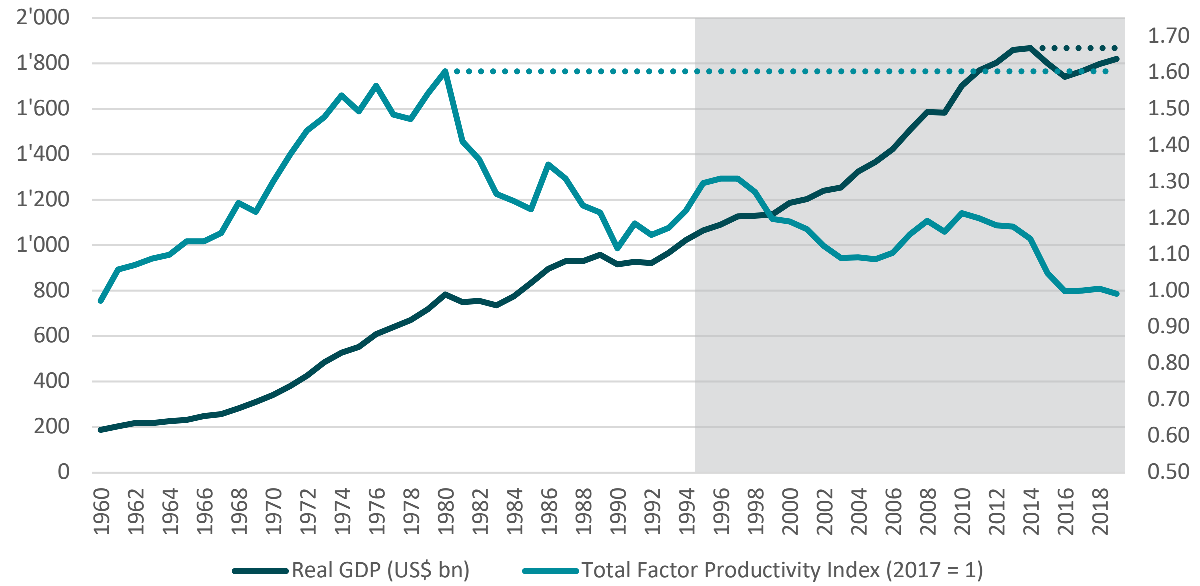
In general terms, a good example of this point is via the informal (or shadow) economy. The International Monetary Fund defines the 'shadow economy' to represent "illegal activities and unreported income from the production of legal goods and services, either from monetary or barter transactions, that would be taxable were they reported to the tax authorities." The livelihoods of individuals in developing economies often depends on these informal economic transactions.

In 2021, Elgin *et al*. introduced a comprehensive dataset of informal economic activity across more than 160 economies for the period 1990-2018. For Brazil, they estimate that in 2018, the size of the informal economy represented 33.4% of official Brazilian GDP, a slight decrease from 38.8% in 1990.

The implication of this phenomenon is that official statistics are not able to accurately account for the large swathes of economic activity occurring within the informal sector. This means that empirical studies such as this may not be reflective of the "true" state of the economy because they are entirely reliant upon these official statistics such as GDP, capital stock, and labour force participation. Therefore, the relationships between key variables that are established in the model – in this case, standards, TFP, and labour productivity – may behave differently or break down altogether in the real world.

In the context of this study, improved data availability would be very useful, especially because, like much of Latin America, the Brazilian economy suffered a significant structural shock in the during the 1980s due to the debt crisis, often called *'the lost decade'*. Productivity measures have all declined in relative terms to what they were like before this economic crisis. Figure 9 below presents the full time series for TFP in Brazil, taken from the Penn World Tables. The effect of the crisis in the early 1980s is clearly observable in terms of both TFP and real GDP (also presented in the chart). The grey shading indicates the period that is covered within our analysis, 1995–2019.

Figure 9: Real GDP (constant 2015 US$, LHS) and TFP index for Brazil (2017 = 1, RHS), 1960–2019



Source: Penn World Tables, World Bank, and Cebr analysis

In terms of real GDP, it was not until the mid-1980s that the economy recovered to pre-crisis levels. There were other economic crises throughout the period: in the early 1990s, late 1990s, early 2000s, late 2000s, and mid-2010s. As for TFP, the trend since 1980 has followed a steady downturn. This was likely caused by the debt crisis of the early 1980s, which followed a prolonged – but ultimately unsustainable – period of very high growth (Qian, Thompson Araujo, and Nucifora, 2018). Optically, there are also notable differences for TFP and GDP trends between the pre- and post-debt crisis periods. Using some very basic analysis techniques, we can compare the correlation coefficient between real GDP and TFP for the periods 1960-1980 and 1984-2019. The results from Table 6 below demonstrate the stark differences between the periods.

Table 6: Pearson correlation coefficient for real GDP and total factor productivity

Period	Person Correlation Coefficient[19]

19 The range of possible values for this coefficient are -1 to +1. As a rule of thumb, a coefficient of 0 to ±0.3 indicates a weak relationship between the two variables; a coefficient of ±0.4 to ±0.6 indicates a moderate relationship between the two variables; and a coefficient of ±0.7 to ±1 indicates a strong relationship between the two variables.

1960 – 1980 (pre-debt crisis)	0.940
1984 – 2019 (post-debt crisis)	-0.591

Source: Penn World Tables, World Bank, and Cebr analysis

This should be interpreted as there being other external factors that affect TFP but are not captured within our model which are driving this downwards trend for TFP since the 1980s. Because we cannot explicitly estimate or account for these external factors, we decided to use a single-stage regression model. However, the underlying causes driving the decrease in TFP which influenced our decision to substitute TFP with our explanatory variables remain not fully quantifiable.

3.4 Technical Appendix: Brazil

3.4.1. Detailed methodology and results

In this sub-section, we present detailed results of the regression analysis, with accompanying explanation of the specific techniques used. These results are included for reasons of accountability and transparency. All technical shortcomings and limitations are made clear to help ensure that the results of this study are used appropriately.

As explained in Section 3.1 , our goal was to estimate the impact of increasing the stock of standards on economic growth in Brazil using a two-equation system, as prescribed by the ISO methodological guidance. However, we found that we could not do this at a sufficiently robust level, so we opted for a single-stage regression approach. For completeness, below we present how the Cobb-Douglas production function can be rearranged to produce the key regressor equations for the first- and second-stage models, which we ultimately chose not to implement. Table 7 presents the full results for the first of these equations.

$$Y_t = A_t L_t^{1-\alpha} K_t^{\alpha}$$

Step 1 – linearise the Cobb-Douglas above by taking natural logarithms:

$$ln(Y_t) = ln(A_t L_t^{\alpha} K_t^{1-\alpha}) = ln(A_t) + (1-\alpha)\, ln(L_t) + \alpha\, ln(K_t) + \epsilon_t$$

Step 2 – rearrange as a function of labour productivity:

$$ln(Y_t) - ln(L_t) \;\; = ln(A_t) + \alpha\, [ln(K_t) - ln(L_t)] + \epsilon_t$$

Step 3 – as above but expressed in used form:

$$ln\left(\frac{Y_t}{L_t}\right) = ln(Labour\ Productivity_t) = \beta_1 ln\,(A_t) + \beta_2 ln\left(\frac{K_t}{L_t}\right) + \epsilon_t$$

Step 4 – TFP variable isolated and expressed as a function of standards plus other necessary control variables:

$$\ln(A_t) = \gamma_0 + \gamma_1 \ln\,(Standards_t) + \gamma_2 \ln(Patents_t) + \cdots + \gamma_n \ln(n_t) + \mu_t$$

Step 5 – augmented specification to sidestep the 2SLS framework:

$$ln\left(\frac{Y_t}{L_t}\right) = \gamma_0 + \gamma_1 ln\,(Standards_t) + \gamma_n ln(n_t) + \beta_2 ln\left(\frac{K_t}{L_t}\right) + \epsilon_t$$

Single-stage regression model

We opted to use a single-stage regression as opposed to following the ISO methodology (see Section 3.1 for an explanation and the reasons why this was deemed more appropriate for Brazil). For clarity, the model we used is once again presented below. It contains the net stock of standards as the independent variable, alongside the political stability indicator, the BRL-USD exchange rate, and the capital-employment ratio as the control variables.

Equation 7: Used single-regression specification to isolate the effect of increasing standards on labour productivity in Brazil.

$$\ln(y_t) = \beta_0 + \beta_1 \ln(std_t) + \beta_2\, pol_t + \beta_3\, FX_t + \beta_4 \ln(k_t) + \epsilon_t$$

Below we present the full regression results for our model.

Table 7: Full regression results for Equation 6

Dependent Variable:	ln Labour Productivity
Method:	Ordinary Least Squares, HAC standard errors
Date:	1995-2019
Observations:	25

Overall Fit			
Multiple R	0.95364	AIC	-177.54
R Square	0.90944	AICc	-172.87
Adjusted R Square	0.89133	SBC	-171.44
Standard Error	0.02627		

ANOVA	df	SS	MS	F	p-value
Regression	4	0.13865	0.03466	50.21052	0.00000
Residual	20	0.01381	0.00069		
Total	24	0.15246			
Term	**Coefficient**	**Std. Error**	**t-statistic**	**p-value**	**VIF**
Intercept	-2.295	0.541	-4.243	0.000	
Ln Cap-Emp ratio	0.718	0.095	7.560	0.000	1.564
Ln Standards	**0.149**	**0.022**	**6.921**	**0.000**	3.793
Political stability	0.058	0.033	1.739	0.097	1.342
FX	0.273	0.042	6.562	0.000	3.589

Source: Penn World Tables, World Bank, IMF, and Cebr analysis

Note: Asterisks *, **, and *** are added to denote a significant relationship at the 10%, 5%, and 1% levels, respectively.

This model specification performs well and is effective at describing the isolated impact of standards on labour productivity. The adjusted R-squared value and the highly significant F-statistic demonstrate the strength of the model. On top of this, there is no strong evidence to suggest that there is multicollinearity; the highest VIF score is 3.8, which is below the relatively strict threshold of 5.[20]

The Gauss-Markov theorem shows that when certain conditions are satisfied, OLS coefficients will be the Best Linear Unbiased Estimates; hence, BLUE. When the assumption for homogeneity of variance is violated within the ordinary least squares regression method, the regression coefficients will not be BLUE. While they do remain unbiased, i.e., they will be correct on average, but they will not be efficient since they no longer have minimum variance, i.e., they will not be the 'best'. Therefore, it is important to test for heterogeneity of variance, commonly known as heteroscedasticity within statistics, to ensure that the model coefficients are the 'best'.

To do this we performed the Breusch-Pagan test to determine if heteroscedasticity was present in our model. The p-value for this test was 0.14, which is above the threshold of 0.05, so we reject the null hypothesis that there is heteroscedasticity present within our data; this suggests that the OLS coefficients will be BLUE.

Additionally, we computed a Durbin-Watson test for our model and found that there is evidence of autocorrelation in our model. As such, we used Heteroscedasticity and Autocorrelation Consistent (HAC) standard errors, as introduced by Newey and West (1987) to correct for the serial correlation present in our residuals.

Autocorrelation is the degree of correlation of the same variables between two successive time intervals. It measures how the lagged version of the value of a variable is related to the original version of it in a time series. Autocorrelation is a problem because it leads to inefficient estimates (i.e., they do not have minimum variance) hence our confidence in the result is lowered if autocorrelation is present and not accounted for. In other words, the coefficients from our variables remains unchanged, it is just the interpretation of the standard errors which changes our confidence that these coefficients are consistent. The HAC standard errors adjust the confidence intervals to correct for this autocorrelation, hence solving for autocorrelation within the regression model.

3.4.2. Limitations and Caveats

The first thing to note in terms of the wider study is that, in the case of Brazil, the model from the ISO prescribed two-stage approach is not as robust as the single-stage regression from our used methodological approach. This does not mean the ISO methodology does not work for Brazil, just that the single-stage approach is better equipped at answering the central question we are assessing: what is the impact of standards on labour productivity?

Aside from this conceptual discussion about different methodological approaches to this question, there are no major practical limitations or weaknesses with our analysis as it relates to Brazil. Nonetheless, there are some caveats which we discuss below.

The main limitation of this analysis is the small number of observations driven by the lack of historical data for most of the variables of interest. While this is not a significant issue in and

20 For reference, a VIF score of greater than 5 but less than 10 is not typically considered to be a strong sign of high multicollinearity, rather it indicates evidence that there may be moderate correlation between some of the variables. But even then, VIF scores alone do not tell the whole story, and should not be interpreted as being definitive proof.

of itself – the number of observations is still over 25 – it makes the model weaker and can make inference harder if it is not optimally specified.

As part of the preliminary testing stage, we carried out several checks to get a sense of the data and make sure we were correctly specifying our model. One of the more simple but effective tools at an early stage is to plot the data (such as by looking at correlograms and plots of the residuals) to get a better understanding of any trends present in the data, as well as any outliers which might affect our results. Beyond this, we used tools such as the Durbin-Watson test, the Augmented Dickey-Fuller (ADF) test, or the Breusch-Pagan and White tests to test for autocorrelation, stationarity, and heteroscedasticity, respectively.

There is some autocorrelation present in the data. This is often an issue when doing time series analysis and occurs when serially correlated determinants of our dependent variable (labour productivity) are not included as explanatory variables (or regressors). This is not always an issue; if these factors are not correlated with the regressors included within our model, then serially correlated errors would not violate the necessary assumption of exogeneity – meaning that our estimate would still be unbiased and consistent. However, autocorrelation does mean that the 'normal' standard errors (which are typically homoscedasticity-only and heteroscedasticity-robust) are invalid. And if this is not dealt with, then it would affect inference and could lead to results being reported as statistically significant when in reality they are not. To overcome this issue, we use the HAC standard errors, which correct this by essentially adjusting the confidence intervals such that the thresholds for statistical significance change and so does the inference.

Although there is some multicollinearity present in the data – meaning that some of the control variables are correlated with each other – our final model does not show cause for concern: its highest VIF is less than 4, so there is no strong evidence that multicollinearity persists in our chosen econometric specification.

Moreover, the assumption about constant returns to scale, or CRS, (see Section 3.3) is worth discussing further. The empirical literature on the extent to which CRS is a realistic characteristic that countries exhibit is relatively sparse and slightly ambiguous. McCombie and Roberts (2007) showed that the values for returns to scale depend on how these are estimated and that these often yield significantly different results. In the case of Colombia, Golany and Thore (1997) found that, using data from a National Bureau of Economic Research study by Barro and Wolf (1989), Brazil had increasing returns to scale (RTS) during 1970-1985. This finding is supported by Oliveira *et al.* (2006), which finds that Brazil exhibited increasing returns to scale during 1976-2000 albeit with some structural limitations. These findings are further corroborated by Astorga *et al.* (2003). They also found that Brazil exhibited increasing RTS using new data from the Oxford Latin American Economic History Database, which allowed the authors to study the whole 20th century.

Lastly, it has been touched upon in the discussion around Assumption 4 in Section 3.3 , but it deserves further discussion here. The main weakness in switching from a two-stage model to a single-stage model is that we are no longer explicitly estimating the role of TFP as it relates to standards and labour productivity. While our estimate for the direct impact of standards on labour productivity is robust and comes from a stronger model, we lose some useful context – we cannot prove that the positive impact of standards on labour productivity growth occurs through an increase in TFP. However, we should also stress that given the special circumstances seen for Brazil, with its declining TFP even when real GDP, labour productivity, and the stock of standards have all been growing, there are other external factors which have been acting as a drag on TFP. Keeping these external factors, which we cannot estimate or control for, including a term for TFP in our model overcomplicates the goal of this study: this very fact is the reason why we opted for a single-stage regression model. As such, our estimate for the impact of standards on labour productivity is more robust, even if as a result we know less about TFP's explicit role in *how* standards lead to an increase in labour productivity.

3.4.3. Sensitivity Testing

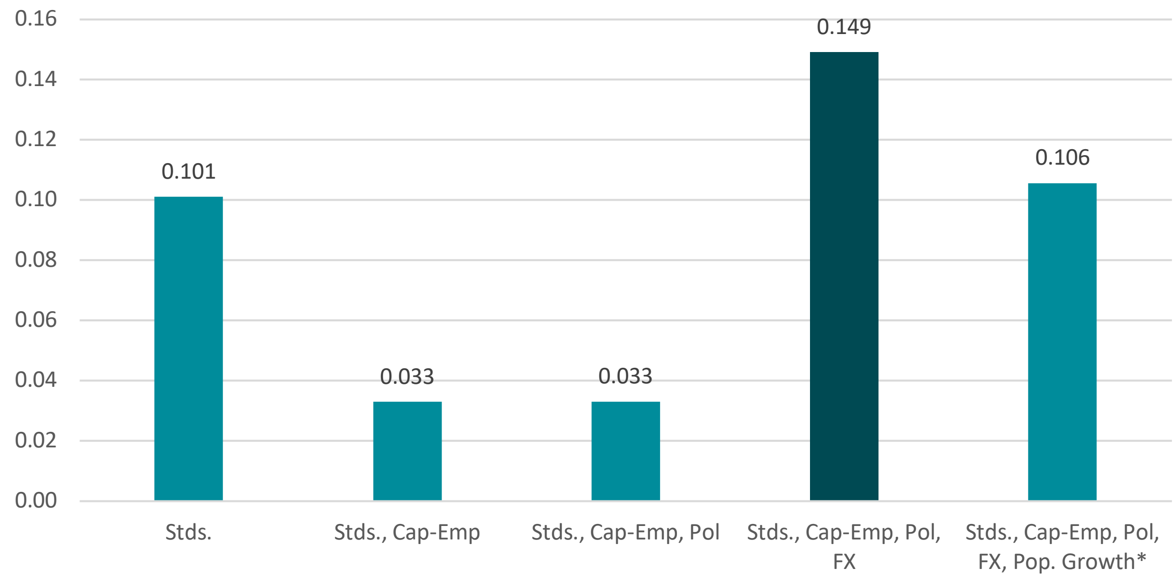
In this subsection, we highlight the consistency of estimator for standards depending on control variables. We gradually add new variables and change the structural specification of the regression model. We also discuss the results of various indicators, such as p-value, VIF, adjusted R-squared, and AIC, to show that our specification is the best model.

We chose the highlighted equation because this performs the best – the adjusted R-squared is the highest while the F-statistic is significant. Figure 10 shows the coefficients for the impact of standards on labour productivity for each of the different models. Table 8 then shows how statistically significant these coefficients are, as well as a series of other sensitivity indicators.

Our model has the joint highest and lowest adjusted R-squared and AIC, respectively. Typically, the higher (lower) the adjusted R-squared (AIC) the better. The VIF for the last model, which includes population growth as an additional explanatory variable, is close to 10 – indicating that there is strong evidence the model exhibits multicollinearity. Moreover, the p-value for standards is over the 10% threshold, meaning that the impact of standards is not even statistically significant.

As discussed elsewhere in this report, we cannot control for patents due to very limited data availability. The data for this begins only in 2004 and as such would reduce our number of observations to 16, which is just above the very lower bound for what is considered an acceptable sample in statistics.

Figure 10: Coefficient for standards from several different econometric specifications.



Source: Cebr analysis

*Note: This equation was not found to be significant, even at the highest accepted level of 10%.

Table 8: Key indicators for the different econometric specifications[21]

Econometric specification	β_1	p-value	VIF	Adj. R-squared	AIC
Stds.	0.101	0.0001		0.29	-133.107
Stds., Cap-Emp	0.033	0.0437	1.348	0.71	-154.845
Stds., Cap-Emp, Pol	0.033	0.0485	1.349	0.70	-152.889
Stds., Cap-Emp, Pol, FX	0.149	0.0000	3.793	0.89	-177.537
Stds., Cap-Emp, Pol, FX, Pop. Growth*	0.106	0.1022	9.645	0.90	-178.499

Source: Cebr analysis

*Note: This equation was not found to be significant, even at the highest accepted level of 10%.

21 Note that the columns for β_1, p-value, and VIF relate specifically to our variable for standards, whereas adjusted R-squared and AIC refer to the overall specifications.

Chapter 4: The Economic Impact of Standards in Colombia

4.1 Summary of the Used Methodological Approach

For Colombia, the ISO methodological framework works and is valid. We were mostly successful in fully applying it as prescribed, albeit with some notable adjustments which we discuss below. We were able to implement the two-stage approach proposed by ISO, though the second stage equation had a different econometric specification to that from the ISO methodology.

To estimate the impact of increasing the stock of standards on economic growth in Colombia, Cebr estimated the following two equation systems:

Equation 8: The log-linearised Cobb-Douglas production function, rearranged as a function of labour productivity.

$$ln(Labour\ Productivity_t) \ = \ \beta_1 ln\ (A_t) + \ \beta_2 ln\left(\frac{K_t}{L_t}\right) + \ \epsilon_t$$

Equation 9: Used specification to isolate the effect of increasing standards on total factor productivity in Colombia.

$$\begin{aligned} ln(A_t) \ = \ & \gamma_0 + \gamma_1 ln\ (Standards_t) + \ \gamma_2\ ln(US\$\ Exchange\ Rate_t) \\ & + \ \gamma_3 ln(Population\ Growth_t) + \ \gamma_4 ln(Lending\ Rate_t) + \mu_t \end{aligned}$$

In this latter equation, to represent technological progress and explain movements in total factor productivity in Colombia, we use the US dollar spot exchange rate for Colombia; the population growth in Colombia over the period; and finally the country's lending rate as the control variables alongside the stock of standards. This combination was found the be the best performing model to describe the evolution of TFP in Colombia with an adjusted R-squared of 0.78.[22] Before we go on to explain in detail why it is that we chose these specific variables for our second-stage equation, we should note that we did not include patents because, among other things, the data only goes back to 2004. So whatever improvement in the fit of the model brought by the inclusion of patents as one of the explanatory variables is lost by the significant shortening of our time series (see Assumption 5 in Section 4.3 for further details).

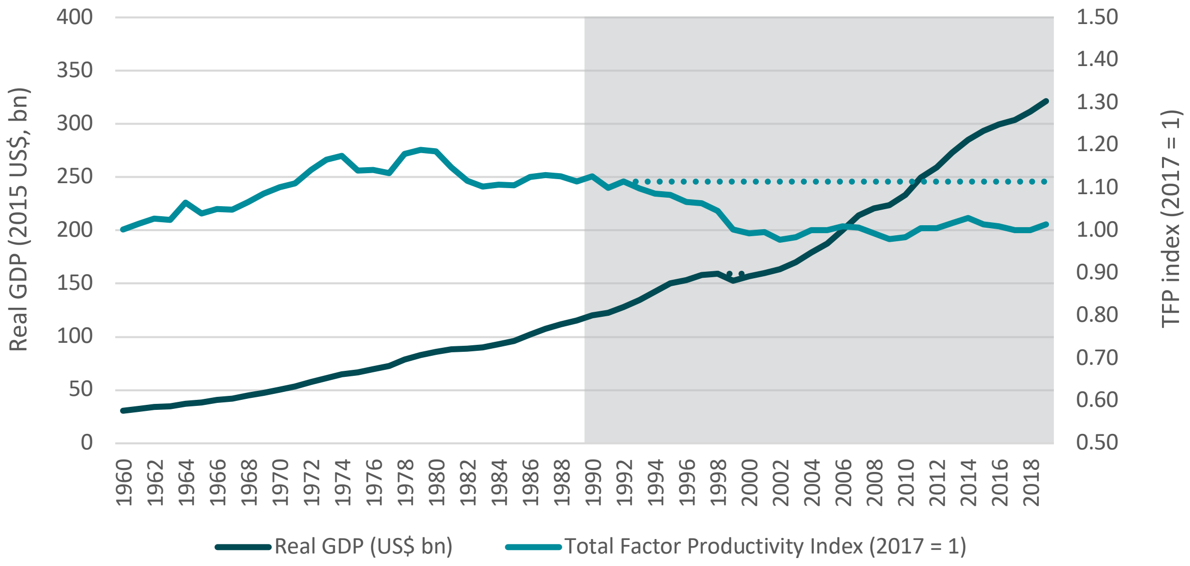
In short, the population growth is used to control for the changing population and demographics of Colombia (for example, the influx of migrants from neighbouring Venezuela after the political and economic crisis towards the end of the period analysed). It also serves as a proxy for the violence and crime in Colombia (this relationship is explored in more detail below). The exchange rate and lending rate variables are used to account for the structural changes of the Colombian economy, which underwent a series of massive political and economic reforms during the early 1990s, the biggest economic crisis in the country in a century during the late 1990s, followed by a period of slow growth. Below is a detailed explanation of the context behind why these variables are relevant.

There are several things to note about the variables used here, beginning with the trend for TFP. Total factor productivity in Colombia suffered a significant structural shock during the

22 We include a more detailed discussion on model diagnostics in the technical appendix, however in the context of this research, the adjusted R-squared value of 0.78 is strong.

1980s and early 1990s from which it has not yet recovered. Figure 11 below presents data for TFP from the Penn World Tables, alongside the times series for real GDP (as measured in constant 2015 US$). The grey shading indicates the period that is covered within our analysis, 1990–2019.

Figure 11: Real GDP (LHS) and total factor productivity index for Colombia (RHS), 1960–2019[23]



Sources: Penn World Tables, World Banks, and Cebr analysis

On one hand, Colombian GDP has been increasing steadily in real terms since 1960, except for an observable downturn in 1998-2000 due to an economic recession – the worst since the beginning of the 20th century (Osorio and Perez-Reyna, 2018). On the other hand, TFP peaked during the 1970s, plateaued throughout the 1980s, and eventually declined after the early 1990s.

There is not a single perfect explanation for why Colombian TFP still has not recovered, or gotten close to the peak level from the 1970s. This is particularly puzzling given that, at first glance, the diverging point between the trend for TFP and real GDP seems to occur around the time that Colombia introduced a new constitution in 1991, along with sweeping reforms on trade, labour, and financial liberalisation (Osorio and Perez-Reyna, 2018).[24] However, it is unreasonable to think that these reforms had a negative causal effect on TFP; in fact, we would expect the opposite to be the case. Fajnzylber and Lederman (1999) tested whether the economic and political reforms had a positive or negative impact on TFP in several Latin American and Caribbean countries using several different econometric specifications and found that in Colombia these had a positive effect in all but one of their models, though none of these results were statistically significant in the case of Colombia.

23 GDP is measured in constant 2015 US$, and TFP is indexed to 2017 (i.e. 2017 = 1).

24 Among other things, these included establishing the independence of its central bank as well as the introduction of a fully floating exchange rate for the first time in the country's history in 1999. This marked the recently independent Central Bank stopping interventions in the exchange rate market, allowing the Colombian peso to be set by the foreign exchange market.

There are several reasons why TFP may have peaked by the 1980s and declined since then. Notably, much of Latin America suffered a big debt crisis during the early 1980s caused by the culminating effects of large amounts of foreign debt that greatly exceeded their capacity to repay them.[25] This could potentially help explain why TFP decreased around this time, though Colombia was one of the least affected countries in the region, thanks in part to its conservative macroeconomic policies from 1966 to the early 1980s (Osorio and Perez-Reyna, 2018). Other factors, such as an increase in coffee prices in the late 1970s – which represented a considerable share of the economy at the time – may have also impacted the economy; first through a boom due to the higher prices, and then followed by an increase in government spending as a result of the increase in tax revenues from coffee.

This increase in government spending had to be readjusted after the debt crisis, and fiscal spending was drastically reduced in 1984 (Osorio and Perez-Reyna, 2018). Later, the coffee production crisis of 1986–87 forced the Colombian government to move away from coffee and the import substitution policies that characterised trade at the time, which had been maintained by an overvalued peso and fiscal spending. The Colombian government started liberalising trade and financial markets shortly thereafter, following a series of failed policies aimed at stabilising the economy. The financial liberalisation reforms were followed by a massive inflow of currency, which the domestic economy was not well equipped to handle. The subsequent inflation led to trade also being liberalised, with most barriers and tariffs being eliminated. This led to cheaper and better-quality imports being made available, which the domestic producers were unprepared to compete with. Economic growth began to decline and unemployment increased – the unemployment rate increased from 10.2% in 1990 to 20.5% in 2001.

To account for these events which significantly affected GDP and productivity, we included two control variables in our model: the spot exchange rate between the US dollar and the peso, and the lending rate in Colombia.

The other major story of the 1980s in Colombia was the unprecedented rise in drug-related violence caused by the booming cocaine industry – Colombia was the largest cocaine producer in the world during this decade (Sissoko and Thompson, 2019). There is empirical evidence, such as Cardenas (2006), which suggests that it was this increase in drug-related criminality which led to the implosion of productivity by diverting capital and labour to unproductive activities. This explanation is supported by cross-country evidence that shows that Colombia's underperformance, especially in the 1990s, is explained by its high homicide rate (see Cardenas, 2006; Vargas, 2003; Querubin, 2003; Riascos and Vargas, 2011). To this end, we tried to incorporate various crime and violence indicators into our model. Unfortunately, the main two variables we explored including as one of the control variables – homicide rate as well as the Political Stability and Absence of Violence/Terrorism indicator from the Worldwide Governance Indicators dataset – did not improve the model or increase its explanatory power. Furthermore, the data for these does not go back far enough, so they reduced our time series. Given these reasons, we decided not to directly include any violence or crime related variables into our model.

Interestingly, we can account for some of this violence and crime by including a variable for Colombia's population growth. Donohue and Levitt (2001) introduced and popularised this relationship by showing that the legalisation of abortion led to a decrease of crime in the US 15-20 years later. Inversely, other studies such as Huang *et al.* (2015), suggest that crime also has a positive causal effect on population growth. In the case of Colombia, the literature indicates that violence and crime and population growth are indeed connected (see Salazar,

25 This period is often known as *La Década Perdida* ('The Lost Decade').

2014; Salazar, 2016; Sandoval-Garrido, 2021; Urrego Ospina, 2022). Notably, there is good data on the population growth rate of Colombia for the full period of analysis. Therefore, we decided to include population growth rate as an explanatory variable to account for the changing population and demographics in Colombia. Based on the evidence from the literature discussed above, we also include population growth as a proxy of sorts for the violence and crime in Colombia, though this relationship is complex and population growth is not a perfect proxy for violence and crime.

To illustrate how GDP, which has for the most part seen steady growth, and TFP have diverged over time, we present the correlation coefficients between these two variables for two sets of different periods: pre- and post-reforms, and pre- and post-peak drug-driven violence. The results from Table 9 below highlight how the divergence between the trends is most stark when the cut-off year is based on the violence and crime trends as opposed to the economic reforms of the 1990s.

Table 9: Pearson correlation coefficient for real GDP and total factor productivity

Period	Person Correlation Coefficient[26]
1960 – 1990 (pre-reforms)	0.607
1991 – 2019 (post-reforms)	-0.447
1960 – 1979 (pre-peak violence)	0.947
1980 – 2019 (post-peak violence)	-0.735

Source: Penn World Tables, World Bank, and Cebr analysis

Although these events, particularly the peak in violence in 1980, appear to explain when the divergence between GDP growth and TFP occurred, we should stress that the Pearson correlation coefficients do not measure causality in any way and should not be interpreted as such. They are simply a useful tool often used to help visualise some of the underlying trends in the data and, given this information, can help us to construct a better econometric specification.

Ideally, we would have had data going back to before both of these events, so that we could properly account and control for these structural and deep shocks to Colombia. Given the constraints due to this limited data availability, our model represents the best econometric specification for Colombia.

4.2 Findings

4.2.1. Quantitative results

The analysis reveals a relatively weak and significant relationship between standards and labour productivity. Our regression result for Colombia tells us that **a one percent increase in the net stock of standards is associated with a 0.057 percent increase in labour productivity,** where labour productivity is measured as real GDP per worker. To arrive at this headline figure, we combine the key coefficients from Table 10 and Table 11 below. These

26 The range of possible values for this coefficient are -1 to +1. As a rule of thumb, a coefficient of 0 to ±0.3 indicates a weak relationship between the two variables; a coefficient of ±0.4 to ±0.6 indicates a moderate relationship between the two variables; and a coefficient of ±0.7 to ±1 indicates a strong relationship between the two variables.

two tables present results, following the modelling specification outlines in Equation 8 and Equation 9, above.

The key quantitative results, utilising these equations can be seen below.

Table 10: Summary results for Equation 8, 1990–2019

Term	Coefficient	Standard Error	t-statistic	p-value	Significance
Ln TFP	**1.235**	0.253	4.887	0.000	***
Ln K/L	0.423	0.062	6.831	0.000	***

Source: Penn World Tables, World Bank, IMF, and Cebr analysis

Table 11: Summary results for Equation 9, 1990–2019

Term	Coefficient	Standard Error	t-statistic	p-value	Significance
Intercept	-0.305	0.199	-1.532	0.139	Insig.
ln std	**0.046**	0.024	1.966	0.062	*
ln pop growth	0.027	0.014	1.928	0.066	*
exchange rate	139.239	23.817	5.846	0.000	***
ln lending rate	0.016	0.014	1.134	0.269	Insig.

Source: ICONTEC, FRED, Penn World Tables, and Cebr analysis

Note: Asterisks *, **, and *** are added to denote a significant relationship at the 10%, 5%, and 1% levels, respectively.

Within the first stage of the analysis, Equation 8 reveals that both TFP and the capital-to-labour ratio are positively related to labour productivity. Crucially, the coefficient β_1 suggests that **a one percent change in TFP is associated with a 1.235 percent change in labour productivity**.

Then, within the second stage of the analysis, Equation 9 reveals that standards also have a positive relationship with TFP, though the relationship is not especially strong. The coefficient γ_1 suggests that **a one percent change in the net stock of standards in Colombia is associated with a 0.046 percent change in TFP**. The product of β_1 and γ_1 is then used to deduce the indirect impact of standards on labour productivity, thus generating the 0.057 result.

For completeness, both highlighted coefficients in the above summary tables are significant at the 10% level or higher. Table 10 provides summary results for the log-linearised[27] Cobb-Douglas equation, while Table 11 shows the regression results for the effect of standards on total factor productivity. For more detailed statistical information regarding the two Tables below, please see the Technical Appendix in Section 4.4 .

27 Log-linearisation here means converting the Cobb-Douglas production function (a nonlinear equation) into a new, linear equation expressed in logarithms, or logs.

4.2.2. Discussion

Contribution of standards to economic growth

The findings from the subsection above posit that a one percent growth of the stock of standards is associated with an increase in labour productivity of 0.057 percent across Colombia. In terms of economic growth this has the following implications:

- Between 1990 and 2019, the net stock of standards in Colombia grew by an average of 4.7% year-on-year, while the average year-on-year growth of labour productivity was 1.3%. Applying the elasticity of standards with respect to labour productivity (0.057) means that standards are associated with approximately 0.27 percentage points of the average labour productivity growth of 1.3% a year.
- The result suggests that standardisation is associated with 21.6% of the growth in labour productivity and 7.9% of GDP growth in Colombia during the period 1990 to 2019.
- For the purposes of expressing the findings in monetary terms, if it is assumed that the estimated impact is constant over time, standardisation at the national level would be associated with approximately Col$2.9 trillion of the Col$37.5 trillion of GDP growth recorded in 2019 (World Bank, 2019 prices).[28]

Table 12: Comparison of relevant summary results of national studies[29]

Country	Colombia	Canada	France	Germany	Nordic	UK	UK
Publication year	**2023**	2007	2009	2000	2018	2005	2015
Analysis period	**1990-2019**	1981-2004	1950-2007	1961-1990	1976-2016	1948-2002	1921-2013
Estimated function[30]	**LP**	LP	GDP	GDP	LP	LP	LP
Elasticity of stock of standards	**0.057**	0.36	0.12	0.07	0.11	0.05	0.11
Share of labour productivity growth	**21.6%**	17.0%	27.1%	30.1%	39.5%	13.0%	37.4%
Growth rate of GDP, % p.a.	**3.4%**	2.7%	3.4%	3.3%	2.5%	2.5%	2.4%
Share of GDP growth	**7.9%**	9.2%	23.5%	27.4%	28.0%	11.0%	28.4%
Contribution of standards to GDP growth, % points	**0.3%**	0.3%	0.8%	0.9%	0.7%	0.3%	0.7%

28 As a point of reference, this figure converts to approximately $0.9 billion out of $11.4 billion in GDP growth in 2019, based on the 2019 US dollar exchange rate.

29 Note that not all the studies from Table 3 are presented here; only those that estimated the share of labour productivity of GDP growth associated with standardisation are included in this table. For a similar comparison with the other developing countries assessed within this study, see Section 9.1.

30 LP = Labour Productivity. GDP = Gross Domestic Product.

Source: Standards Council of Canada (2007), AFNOR (2009), DIN (2000), Menon (2018), DTI (2005), and Cebr analysis

Standards can enhance labour productivity by increasing output per employee at individual firms. This can be achieved through various mechanisms such as improving production activity and efficiency, ensuring quality and precision, and spreading technical information and best practices. These improvements in organisational performance lead to cost savings, enabling firms to achieve higher output per worker. Additionally, standards allow firms to build on their strengths and specialise, leading to better division of labour, economies of scale, and increased output per staff member.

However, caution should be taken when interpreting these estimates as standards have an interdependent role in driving labour productivity along with other knowledge factors such as higher levels of education and training, advances in technology and increased innovative efforts. By interdependent we mean that standards play a mutually dependent and complementary role alongside other factors, such as those mentioned above, in facilitating productivity growth. Beyond standards having a direct impact on labour productivity, they are also associated with driving these other knowledge factors, and these then result in an increased value of standards. Equally, an improvement in the other knowledge factors leads to standards playing a more efficient role in boosting labour productivity.

On the whole, the *relative* impact of standards on GDP growth is at the lower end of the range, in comparison to results from across the literature. To a certain extent, there is a limit to the comparability of such results due to the difference between the driving forces of economic growth in the developing versus the developed contexts, however Table 12 above presents a summary of results for other countries in the literature. This is not an exhaustive list of studies, rather these are selected results from the papers that provide details on the contribution of standards to economic growth.

Observing the penultimate row of the table, we can see that the relative contribution of standards to GDP growth in Colombia is the lowest contribution observed. For example, standards are associated with approximately 7.9% of GDP growth in Colombia, while this figure reaches as high as 28.4% in the most recent UK study.

One conceptual explanation for this may be that as Colombia is at a different stage of its economic development process than the other, more developed nations, its growth rate should be higher as it develops and catches up with the developed world. This would mean that, for a given percentage point contribution of standards to GDP growth, the relative share attributable to standards in Colombia would be lower due to other factors such as advances in technology, which help the Colombian economy grow faster and catch up, or converge, with highly advanced economies. However, this explanation does not seem as convincing as it might for other developing countries, such as Indonesia. The simple average[31] of the GDP growth rates across the other countries within this table is 2.8%. In comparison, Colombia observed an average growth rate of 3.4% across the observation period, which is the same level as France or Germany. In reality, the main factor underpinning the relatively lower share of GDP growth attributable to the development of standards may simply be that the coefficient we found in our analysis for Colombia is lower than for the other countries; therefore, it would be associated with a lower share of the GDP growth over the period studied.

This additional context demonstrates that despite the relatively low contribution of standards to GDP growth, a significant share of Colombia's GDP growth since 1990 is still attributable to the development of standards. Per conversations with ICONTEC, Colombia's NSB, reportedly

31 Note that we use "simple average" here to denote the arithmetic average (or mean).

there is a degree of standards piracy in the country, though this has not been quantified so there is no way to confirm or control for it in our study. But, as discussed in more detail in the next subsection, this could possibly be leading to our result being an underestimate.

Limitations and Caveats

For reasons of transparency and accountability, as well as to avoid any inappropriate conclusions being made, it is important to highlight some of the key limitations of this research.

First and foremost, our **analysis is exclusively focused on the assessment of the correlation between standards and productivity, rather than causality**. Correlation between variables simply means that they are related, and that as one variable changes the other does as well, but it does not mean that the change in one of the variables (e.g. productivity) is *caused* by the change in the other variable (e.g. standards). Causality, or causation, is when there is a causal relationship between two variables, i.e. that the change in one variable is caused by a change in the other. Further research would be valuable to be able to establish a *causal* relationship between standards and productivity. That is, the identification of a direct cause-and-effect relationship between the two variables in Colombia.

We have also not considered the direction of causality between the variables and cannot pass comment on the potential for endogeneity for the stock of standards in the context of Colombia In other words, this study doesn't attempt to investigate which of standards or growth drives the other, merely that they are connected and, when one changes, so does the other.[32] An example of the two-way relationship between standards and growth is highlighted by a logic model produced by Zhang et al. (2019). They suggest that additional growth and technological progress brings about changes in environment and resources, which in turn leads to the emergence and application of new goods and services. The resulting lack of standards for new products forces the evolution of standards, while more firms lead to more enterprise and enterprise-dominated standards. Ultimately, there is potential for a virtuous cycle between standards and economic growth, but the applied framework does not account for this two-way relationship. Further research is required here.

According to the methodological guidance document produced by ISO, the very lower bound (minimum recommended number) on the number of observations is likely to be somewhere around 15, and it is preferable to have at least 30 periods of data such that the Central Limit Theorem applies. The analysis period here covers data from 1990 to 2019; exactly 30 continuous periods. Therefore while certainly adequate for modelling purposes, the time series is slightly shorter than would be optimal (see for example some of the 50+ year samples in Table 12).

While we have continuous data for standards between 1990 and 2022, there is a constraining factor on the period of analysis due to the availability of general macroeconomic data for the Colombian economy. Given the issues discussed with respect to the decline in Colombian productivity after the 1980s, ideally we would have liked to model the impact of standards on the economy before and after the fact. At the other end of our period of analysis, notably, the Penn World Table time series for total factor productivity does not extend beyond 2019. To an extent, this is not a critical issue as data for 2020 onwards will have Covid-19 related

32 Moreover, endogeneity is simply a term in econometrics which describes when a variable of interest (such as standards) is affected by other variables in the analysis. This can be problematic as it may lead to biased and unreliable estimates of the effect of standards (with endogeneity we cannot be sure whether our model is saying that standards have a positive effect on growth, or if it is some other explanatory variable).

challenges, however it does place a limit on the period of analysis in 2019. The average number of observations in the other studies referenced in Table 12 is 50. Since this study has an observation period of 30 years, this analysis is on the threshold of what can be considered statistically robust.

Cebr is also keen to urge a degree of caution when interpreting these findings. Crucially, **the relationship between standards and productivity is somewhat of a 'black box'** and we have not attempted to incorporate a quantitative assessment of the mechanisms through which standards generate increased productivity. In other words, while we have determined that standards increase productivity, we have not determined *how* or *why* they do so. It is beyond the scope of this report to develop a richer understanding of these mechanisms and their effects, but studies at the company level, using firm-level data derived from surveys or case studies, have been conducted in the past and can assist here.[33]

Lastly, one must recognise that standards alone do not drive productivity. Rather, they play a mutually dependent and complementary role in facilitating the growth of productivity, along with other types of knowledge like enhancements in education and progressions in technology. While we have attempted to control for key other potential explanatory factors, the model does not explicitly control for **all other** potential components of TFP. The model is instead an attempt to disentangle the effects of standards from other complementary factors that drive productivity, recognising also the constraints of the available country-level data.

4.3 Review of ISO Methodological Framework

4.3.1. Applicability and Effectiveness

To evaluate the applicability and effectiveness of the prescribed methodological framework, we first consider the key assumptions that are made to apply this two-stage least-squares approach[34] and discuss whether these assumptions are appropriate in this context. Then secondly, we consider whether we have been able to follow the same system of equations to estimate the indirect effect of standards on labour productivity.

The six explicit assumptions made by the methodology are as follows:

- Assumption 1: A stock of standards is a credible proxy for the extent to which standards are effectively utilised in the country.
- Assumption 2: The Cobb-Douglas production function is appropriate as an approximate model.
- Assumption 3: There is a one-way relationship between standards and economic growth.

33 These include DIN (2000), Conference Board of Canada for the Standards Council of Canada (2007), AFNOR (2009), BERL Economics for The Standards Council of New Zealand (2011) and Menon Economics (2018).

34 Two-stage least-squares (or 2SLS) is a common regression analysis technique which is used when the dependent variable's error terms are correlated with the independent variables. By using a two-step approach, 2SLS helps us isolate the true effect of standards on productivity by effectively removing the influence of other variables.

- Assumption 4: The appropriate transmission mechanism from standards to economic growth resides in an increase in total factor productivity.
- Assumption 5: Data on standards, labour, capital, productivity, and any other variables is available.
- Assumption 6: The economy exhibits constant returns to scale.

Assumption 1: Stock of standards as a credible proxy

The assumption that the stock of standards is a credible proxy for the extent to which standards are effectively utilised is borne out of pragmatism. Across the literature, this is the accepted approach despite its limitations. For example, while it is true that a significant number of standards may indicate that a country is committed to promoting and maintaining standards, it does not guarantee that these standards are effective.

Beyond simply the quantity of standards, effective standards concern the quality, relevance, implementation, and enforcement of standards in an economy. On one level, a large stock of standards may generate a degree of confusion among stakeholders, making it difficult for organisations to determine which standards are relevant to their needs. Furthermore, the standards may not be effective in achieving their intended goals if they are poorly written, outdated, or not based on the best available science or research.

In addition, the introduction of each new standard may not produce a proportional economic benefit. The assumption that the stock of standards is a robust representation of how standards contribute to the economy is equivalent to the assumption that each standard contributes an equivalent benefit to the economy. This assumption is unlikely to fully hold because newer standards are expected to offer greater benefits than older standards in the national catalogue. Furthermore, the impact of standards on the economy is also generated by the breadth of their use, and thus, some standards are more widely used, and thus more impactful.

Moreover, in our conversations with Colombia's NSB, ICONTEC, it stated that there are two areas where an analysis such as this one would struggle to fully meet the goals of ISO's methodological framework. Firstly, most standards that are developed or adopted in Colombia are not purchased or used ever, and of the ones that are purchased or used, most of them are only done so once. Given this, the sale of standards could arguably be a better proxy for standards than the overall net stock. However, in the case of Colombia, the sale of standards data is so far very limited, with data starting only in the mid-2010s. This would not leave a sufficiently long period for analysis, and we have utilised data instead on the stock of standards.

Furthermore, another limitation pointed out by ICONTEC was that there are cases of standards piracy, whereby firms come together and share the standards that one of them has purchased for the whole group. Unfortunately, there is no data on the extent to which the piracy of standards is widespread or not, so there is no way for this to be tested empirically, and there is nothing that can be done to our econometric modelling to adjust for this phenomenon. But it is possible that our results may be underestimating the true impact of standards, given that this factor is missing from our analysis.

While these two areas may seem serious drawbacks, it is worth noting that these only undermine the analysis significantly if the extent to which these occur has changed significantly over the assessed period. As an example, if standards piracy and the sharing of standards has been consistent over time, then our dataset for the stock of standards in *relative terms* would still represent a good proxy for the actual utilisation of standards within Colombia. Equally, if it is true that the sale of standards is a better proxy for the utilisation of standards within the economy, but the ratio of the stock of standards to the sale of standards is reasonably consistent over time, then utilising the stock of standards as our key variable would not have significant drawbacks. Ultimately, these questions are very difficult to test with the data available at the time of writing.

Ultimately, while there are limitations to Assumption 1, the issues discussed at the start are not unique to the Colombian context, and those that are seemingly specific to Colombia (i.e. standards piracy and the use of sale or stock of standards) are nowhere near problematic enough that we would expect Assumption 1 to not hold in the case of Colombia. As such, we believe that the stock of standards is the best available option for our research.

Assumption 2: Cobb-Douglas production function is appropriate as a model

Economists use production functions to describe what can be produced given a set of inputs, which are typically simplified into capital and labour. Different combinations of capital and labour can be used to produce the same output. The example given by the ISO guidance document suggests that to make a hole in the ground, one can use a person and a spade, two people and two smaller spades, or one person and an excavator. This reflects a microeconomic phenomenon where capital and labour are substitutable. Any macroeconomic model must be consistent with this, and the Cobb-Douglas form is one of the most widely used and practical models within the field.

The use of the Cobb-Douglas production function as an approximate model is a pragmatic middle ground between an ideal world where economic models perfectly describe reality, and the real world where the model must be workable (i.e., linear, in this case).

The major strength of the Cobb-Douglas production function is its ease of use. However, there is a great deal of contradiction within the academic literature with respect to the empirical validity of the Cobb-Douglas functional form. On one hand, Miller (2008), Abidemi (2010), Adetunji *et al.* (2012) and Husain (2016) provide some support evidence for the specification of the model. While on the other hand, papers such as Fraser (2002), and Gechert *et al.* (2019) cast some doubt on the appropriateness of the Cobb-Douglas production function.

In the specific context of a developing economy, there may be some issues that are not present in other contexts, e.g., limited factor mobility (i.e. factor inputs such as labour, capital, or land cannot easily switch between alternative uses without a loss of efficiency). The Cobb-Douglas model assumes a high level of capital and labour mobility, which may not be present in a developing economy. For example, labour may be immobile due to limited access to education and training or a poor infrastructure system, while capital may be concentrated in a few large firms or industries.

While the Cobb-Douglas model can still provide insights into the relationship between inputs and outputs in a developing economy, it cannot fully capture the unique characteristics and challenges of all economies. Other models that allow for decreasing returns to scale or limited mobility of labour and capital may be more appropriate in this context, but further research is needed.

On balance, Assumption 2 may be slightly weaker in the developing context, however it is our view that it is a reasonable approach, and the above weaknesses should not categorically prevent the application of this methodology in any given country. The Cobb-Douglas production function is also effective given that it has allowed Cebr to expand the academic evidence base by conducting this analysis across 6 developing economies.

Assumption 3: There is a one-way relationship between standards and growth

We have already discussed Assumption 3 in the section above and concede that while this assumption has its limitations, it is made because it allows the presented methodology to be simple enough for most countries to adopt, given capacity and capability constraints.

Therefore, this is a limitation of the framework more broadly, but it has no consequences for the applicability and effectiveness of the framework in the developing context specifically.

Assumption 4: Standards impact economic growth through an increase in TFP

Within ISO R&I's methodological guidance document, a logic model is presented that describes the theory behind the effects of standards on an economy, ultimately linking the development of standards with economic growth. It highlights the main mechanism through which standards improve economic growth: unity, compatibility, compliance, and security.

Then, through factors such as product and market uniformity, knowledge and technology diffusion, reduced technical barriers to trade, easier market access, enhanced consumer rights, economic growth is driven by four key channels: trade growth, innovation ability, business environment, plus safety and environmental protection. Zhang *et al.*'s logic model was in fact developed as part of a study into the effects of standards development on economic growth in China. The linkages presented are universal and there is no evidence to suggest that they break down in the Colombian context. Based upon a review of the academic literature and our economic expertise, we see no compelling argument to dispute this assumption in the Colombian (or developing) context.

It is also worth noting that there may be some drags to economic growth through the application of standards. For example, overly burdensome standards could lock in old technologies or lead to premature selection of technologies, which would be an inefficient allocation of resources. On top of this, standards have the potential to restrict choice and increase market concentration, especially if dominant players can wield excessive influence on regulatory agencies. While these linkages are a possibility, on a net basis, there is compelling evidence to suggest that standards have a positive impact on productivity and growth.

As mentioned, there is an argument to suggest that in the developing context, there are greater frictions to overcome across the transmission mechanism compared to a more advanced economy. However, the critical point is that the *intuition* behind the linkages considered by Zhang *et al.* appears appropriate. Unless we directly test these linkages, we cannot say with certainty whether this hypothesis is correct. Within our study, the intuition of the TFP variable is to capture many of these complex and competing effects. Therefore, the assumption that the transmission mechanism from standards to economic growth resides in an increase in total factor productivity is sound.

Assumption 5: Data on the relevant variables is available

The fifth assumption of the framework is that data on standards, labour, capital, productivity, and any other required variables is available for the country in question.

We had no problems with the breadth of data sets that were available for Colombia. Data sources such as the World Bank, IMF, FRED, and the Penn World Tables provide comprehensive coverage for the country, however the main issue was with the length of the time series that were available. Crucially, we were only able to obtain reliable TFP data up to 2019, while patents data did not extend to periods before 2004. Note, however, that this is an issue across the entire study and applies to all the other countries assessed (Brazil, Indonesia, Jamaica, Senegal and Uganda).

Therefore, we could not incorporate all relevant variables into our models across the full period of analysis. In the case of patents specifically, including it in our models limited the analysis we could carry out since the data only goes back to 2004, meaning that our time series would be cut by half. Consequently, we were presented with a trade-off between including all relevant variables as outlined in the ISO methodology guidance or having a longer and more statistically robust time series. After testing the available options, the most favourable approach was to drop patents as a control variable in order to substantially increase the length of the data series.

Overall, despite the data limitations mentioned here and discussed in more detail elsewhere, the prescribed ISO methodological approach could be followed in the case of Colombia as there were enough alternative options.

Assumption 6: The economy exhibits constant returns to scale

Lastly, the Cobb-Douglas model assumes a constant returns to scale (CRS), which means that increasing inputs will result in a proportional increase in output. While this assumption may be defensible at the global level (as it assumes that at any one time, many firms will be enjoying increasing returns to scale, while others will be experiencing decreasing returns to scale), it may not hold for all countries, especially in the developing context.

For example, in a developing economy, there may be infrastructure constraints, limited labour mobility, inadequate education and training, weak regulatory frameworks, or the inability to efficiently use additional inputs which could all create pressures that generate decreasing returns to scale.

On the other hand, developing economies may exhibit increasing returns to scale through high labour mobility, [35] through lower per-unit production costs and high international competitiveness, through increasing marginal returns to investment in factors such as education, health, and welfare while the economy is still 'young', or through relatively high returns to capital which make developing economies attractive to foreign investors.

The empirical evidence on whether Colombia exhibits constant, increasing, or decreasing returns to scale is not particularly extensive, though there is some evidence that supports the idea above that, as Colombia is a developing economy, it may not meet the CRS assumption and instead exhibits increasing returns to scale. We discuss this topic in more detail within the Technical Appendix for Colombia in Section 4.4 . The limitations of the CRS assumption discussed in the appendix are generally accepted across the literature and on balance, we recommend that this assumption is sufficiently robust and defensible in the context of Colombia.

Summary

Overall, the framework has been very successful in elucidating the impact of standards on productivity in Colombia. We have been able to exactly follow the steps suggested within guidance document and produce robust and significant estimates for the impact of standards on TFP and labour productivity, using the two-system of equations approach.

35 Depending on the country, labour mobility may be a strength or a weakness. On one hand, a country with a large, young population will have a sizeable pool of workers to deploy in the regions or industries where they can be the most productively efficient. On the other hand, capacity constraints such as lack of housing stock, lack of education and training, or an inadequate rail and road infrastructure may limit the ability of this labour to be efficient.

We have presented a review of the key assumptions made by the framework in the context of Colombia and find that alongside the strong applicability of the framework, the effectiveness of the results is also relatively high given the quality of the model in explaining movements in total factor productivity.

There are some limitations present such as poor data availability, however these limitations are not a consequence of the prescribed framework, nor is the data sufficiently sparse that a sufficiently robust model cannot be produced. The most potentially significant issue is whether our dataset for the stock of standards, represents an effective proxy for the actual utilisation of standards within Colombia, given issues around piracy and questions on sale versus stock discussed previously. The issue of whether Colombia does, in fact, exhibit CRS is also another potential issue, given that the very little empirical evidence that exists on the topic indicates that it may exhibit increasing returns to scale instead. Overall, whilst we are confident in the robustness of the results presented within this study, caution as well as a sound understanding of the relevant limitations, is advised.

4.3.2. Recommendations for Future Research

Our recommendations for future research centre around addressing the limitations of this study and overcoming the gaps in data availability.

Uncovering 'black box' variables

One important criticism of generalised macroeconomic models such as the one used in this study – and by most of the other national level studies in this space – is that **the relationship between standards and productivity is treated as something of a 'black box'**. The academic literature shows compelling evidence to suggest that standards enhance productivity and economic growth at the national level. In practice, this means that standards will help drive companies and their associated supply chains to operate more efficiently, thus reducing costs, expanding revenue opportunities, and ultimately allowing companies and sectors to become more productive and profitable.

On one hand, we can use our economic intuition and critically assess the credibility of the linkages suggested within Zhang *et al.*'s logic model in the context of Colombia. However, on the other hand, we do not quantitatively assess the mechanisms by which standards generate increased productivity within this study. Other studies in the space have been conducted at the company level using sector- or firm-level data derived from secondary sources, primary surveys, or case studies.[36]

Identifying the direction of causality between standards and productivity

Secondly, **an assessment of the direction of the relationship between standards and productivity** would be an insightful avenue for further research. There is a virtuous cycle between standards and economic growth – whereby standards drive growth which subsequently drives standards which drives further growth, and so on – however, we have not tested this relationship as part of this study.

The prescribed framework does not account for this two-way relationship for reasons of methodological simplicity. While the quality of results may not be affected by the choice to

36 These include DIN (2000), Conference Board of Canada for the Standards Council of Canada (2007), AFNOR (2009), BERL Economics for The Standards Council of New Zealand (2011) and Menon Economics (2018).

model the relationship between standards and economic growth as one-way, there is still additional insight that could be gained from future research.

For example, one common option is to find a 'cointegrating' relationship between the key variables whereby there exists a stable long-run statistical relationship. Statistical tests can confirm if this relationship is non-spurious and whether it exists between standards and productivity. A similar approach was applied by Cebr in a 2015 study assessing the contribution of standards to UK productivity.

Other options are to use methods such as a Granger causality test which assesses whether one time series is an effective forecaster of another. This test is somewhat of a misnomer as it does not provide insight into a true cause-and-effect relationship. Rather, if standards were found to Granger-cause productivity, then this would demonstrate that historic increases in standards are related to increases in productivity today.

This is by no means an exhaustive list of econometric methods that could be used to extend beyond correlation analysis, but these more advanced techniques would require expansions to the prescribed methodological approach. Given that one of ISO's core aims is to expand the evidence base across developing economies, we would recommend that the prescribed framework is applied as an initial starting point due to its relative simplicity, while the more advanced techniques are applied in further studies.

Reducing data deprivation

Lastly, one of the key limiting factors of this research was data deprivation. As highlighted by ISO, statistical models are only as good as the data that goes into them. In this instance, we were unable to include patents as a control variable due insufficient historic data, despite it being a potentially important regressor to assess. Even if it was dropped from the final model, the fact that we could not comprehensively test whether patents are a statistically significant variable in determining productivity alongside standards is a notable shortcoming of the research. Therefore, we see it as important to use this report as a call-to-action for data collection agencies – both national and supranational bodies alike – to continue their work to expand data libraries, with a particular focus on developing economies.

The concept of data deprivation is not new. Data serves as the foundation for meaningful policymaking, efficient resource allocation, and effective public service delivery. By improving the statistical coverage of the developing world, there will be more opportunities for robust economic analyses to contribute to the literature and advance society's collective knowledge base.

In general terms, a good example of this point is via the informal (or shadow) economy. The International Monetary Fund defines the 'shadow economy' to represent "illegal activities and unreported income from the production of legal goods and services, either from monetary or barter transactions, that would be taxable were they reported to the tax authorities." The livelihoods of individuals in developing economies often depends on these informal economic transactions.

In 2021, Elgin *et al*. introduced a comprehensive dataset of informal economic activity across more than 160 economies for the period 1990-2018. In the case of Colombia, the size of the informal economy is very significant. In 2018, they estimated that the informal economy represented 30.2% of official Colombian GDP, a slight decrease from 35.4% in 1990.

The implication of this phenomenon is that official statistics are not able to accurately account for the large swathes of economic activity occurring within the informal sector. This means that empirical studies such as this may not be reflective of the "true" state of the economy because they are entirely reliant upon these official statistics such as GDP, capital stock, and labour force participation. Therefore, the relationships between key variables that are established in the model – in this case, standards, TFP, and labour productivity – may behave differently or break down altogether in the real world.

In the context of this study, improved data availability as well as a more developed academic literature would be very useful, especially given the context of the as yet unexplained decrease in TFP since the market, trade, and labour liberalisation brought about with the rewriting of the Colombian Constitution in 1991 (discussed earlier in this report in detail, see Section 4.1). Equally the discussed questions around the strength of our 'stock of standards' dataset could be counteracted by better data around either the extent of standards piracy, and a longer time series for the sale of standards.

4.4 Technical Appendix: Colombia

4.4.1. Detailed methodology and results

In this sub-section, we present detailed results of the regression analysis, with accompanying explanation of the specific techniques used. These results are included for reasons of accountability and transparency. All technical shortcomings and limitations are made clear to help ensure that the results of this study are used appropriately.

As explained in Section 4.1 , our goal is to estimate the impact of increasing the stock of standards on economic growth in Colombia using a two-equation system.

Table 13 presents the full results for the first of these equations.

Rearranging the Cobb-Douglas production function

Below we show in five steps how the Cobb-Douglas production function can be transformed and rearranged to produce the key regressor equations used in the first- and second-stage models:

$$Y_t = A_t L_t^{1-\alpha} K_t^{\alpha}$$

Step 1 – linearise the Cobb-Douglas above by taking natural logarithms:

$$ln(Y_t) = ln(A_t L_t^{\alpha} K_t^{1-\alpha}) = ln(A_t) + (1-\alpha)\, ln(L_t) + \alpha\, ln(K_t) + \epsilon_t$$

Step 2 – rearrange as a function of labour productivity:

$$ln(Y_t) - ln(L_t) \;\; = ln(A_t) + \alpha\, [ln(K_t) - ln(L_t)] + \epsilon_t$$

Step 3 – as above but expressed in used form:

$$ln\left(\frac{Y_t}{L_t}\right) = ln(Labour\ Productivity_t) = \beta_1 ln\,(A_t) + \beta_2 ln\left(\frac{K_t}{L_t}\right) + \epsilon_t$$

Step 4 – TFP variable isolated and expressed as a function of standards plus other necessary control variables:

$$\ln(A_t) = \gamma_0 + \gamma_1 \ln\,(Standards_t) + \gamma_2 \ln(Patents_t) + \cdots + \gamma_n \ln(n_t) + \mu_t$$

Step 5 – augmented specification to sidestep the 2SLS framework:

$$ln\left(\frac{Y_t}{L_t}\right) = \gamma_0 + \gamma_1 ln\,(Standards_t) + \gamma_n ln(n_t) + \beta_2 ln\left(\frac{K_t}{L_t}\right) + \epsilon_t$$

First-stage model

Equation 8: The log-linearised Cobb-Douglas production function, rearranged as a function of labour productivity.

$$ln(Labour\ Productivity_t) = \beta_1 ln\ (A_t) + \beta_2 ln\left(\frac{K_t}{L_t}\right) + \epsilon_t$$

Table 13: Full regression results for Equation 8

Dependent Variable:	ln Labour Productivity
Method:	Ordinary Least Squares, HC4 standard errors
Date:	1990-2019
Observations:	26

Overall Fit			
Multiple R	0.86265	AIC	-233.0
R Square	0.74417	AICc	-231.4
Adjusted R Square	0.72449	BSC	-228.9
Standard Error	0.01714		

ANOVA	df	SS	MS	F	p-value
Regression	2	8,402.2	4,201.1	688,238.3	0.000
Residual	24	0.146	0.006		
Total	26	8,402.3			

Term	Coefficient	Std. Error	t-statistic	p-value	VIF
ln_TFP	1.235	0.253	4.887	0.000***	1.005
ln_K/L	0.423	0.062	6.831	0.000***	1.005

Source: Penn World Tables, World Bank, IMF, and Cebr analysis

Note: Asterisks *, **, and *** are added to denote a significant relationship at the 10%, 5%, and 1% levels, respectively.

This model specification performs reasonably well and is effective at describing the relationship between total factor productivity and labour productivity. The adjusted R-squared value and the highly significant F-statistic demonstrate the strength of the model. On top of this, there is no evidence of multicollinearity as the VIF score is 1.

The Gauss-Markov theorem shows that when certain conditions are satisfied, OLS coefficients will be the Best Linear Unbiased Estimates; hence, BLUE. When the assumption for homogeneity of variance is violated within the ordinary least squares regression method, the regression coefficients will not be BLUE. While they do remain unbiased, i.e., they will be correct on average, but they will not be efficient since they no longer have minimum variance, i.e., they will not be the 'best'. Therefore, it is important to test for heterogeneity of variance, commonly known as heteroscedasticity within statistics, to ensure that the model coefficients are the 'best'.

To do this we performed the Breusch-Pagan test to determine if heteroscedasticity was present in our model. The p-value for this test was significantly higher than the threshold of

0.05 (0.68), suggesting that there is no evidence of heteroscedasticity within our data and that the OLS coefficients are BLUE. We also note that this test should only be used when the residuals are normally distributed. We applied the Shapiro-Wilk test and the D'Agostino-Pearson test to assess the normality of the data but found that the residuals were not normally distributed. Therefore, the results of the Breusch-Pagan test should be treated with a significant degree of caution.[37]

Ultimately, we could not rule out the potential for heteroscedasticity within our model. As a precautionary measure, we used Huber-White's robust standard errors approach which are also known as heteroscedasticity-consistent (HC) standard errors. Therefore, the coefficients in the summary results in Table 10 and the full results in

Table 13, are both produced using the most restrictive version of the approach; HC4 estimators.

This gives some degree of comfort with regards to the validity of the results, however we recommend that it may be more appropriate to use an alternative regression approach, such as Weighted Least Squares, to comprehensively address potential issues with heteroscedasticity within the data.

Second-stage model

Moving on to the second of the two equations, we use the US dollar spot exchange rate for Colombia, lending rate, and the national population growth rate for Colombia as the control variables alongside the stock of standards to represent technological progress and explain movements in total factor productivity in Colombia. As previously mentioned, this combination was found the be the best performing model to describe the evolution of Colombian TFP with an adjusted R-squared of 0.78 and an F-stat of 25.0.

Full regression results for this Equation are presented in Table 14 below. Crucially, note that we did not use an OLS regression here, and instead used the Cochrane-Orcutt procedure.

Equation 9: Used specification to isolate the effect of increasing standards on total factor productivity in Colombia.

$$\begin{aligned} ln(A_t) \; = \; & \gamma_0 + \gamma_1 ln\,(Standards_t) + \; \gamma_2\, ln(US\$\; Exchange\; Rate_t) \\ & + \; \gamma_3 ln(Population\; Growth_t) + \; \gamma_4 ln(Lending\; Rate_t) + \mu_t \end{aligned}$$

Table 14: Full regression results for Equation 9

Dependent Variable:	ln TFP
Method:	Cochrane-Orcutt procedure
Date:	1990-2019
Observations:	28

37 For completeness, we also applied White's test for heteroscedastic errors which produced a result to suggest that the variances for the errors are in fact equal. However, the validity of this result is also highly dubious given that this test should only be used on large samples, where ours is not.

Overall Fit			
Multiple R	0.90170	AIC	-245.5
R Square	0.81307	AICc	-241.5
Adjusted R Square	0.78056	BSC	-238.9
Standard Error	0.01151		

ANOVA	df	SS	MS	F	p-value
Regression	4	0.0132	0.0033	25.0099	0.0000
Residual	23	0.0030	0.0001		
Total	27	0.0163			

Term	Coefficient	Std. Error	t-Statistic	p-Value	VIF
Intercept	-0.305	0.199	-1.532	0.139	0
ln std	**0.046**	0.024	1.966	0.062*	6.391
ln pop growth	0.027	0.014	1.928	0.066*	1.232
exchange rate	139.239	23.817	5.846	0.000***	3.738
ln lending rate	0.016	0.014	1.134	0.269	4.363

Source: BSN, FRED, Penn World Tables, and Cebr analysis

Note: Asterisks *, **, and *** are added to denote a significant relationship at the 10%, 5%, and 1% levels, respectively.

We use a Cochrane-Orcutt regression procedure to address the problems of autocorrelation that were detected within the data using a Durbin-Watson test.

Autocorrelation is the degree of correlation of the same variables between two successive time intervals. It measures how the lagged version of the value of a variable is related to the original version of it in a time series. Autocorrelation is a problem because it leads to inefficient estimates (i.e., they do not have minimum variance) hence our confidence in the result is lowered if autocorrelation is present. The Cochrane-Orcutt regression procedure is a technique that takes serial correlation into account within the error term, hence solving for autocorrelation within the regression model.

One downside with this approach is that the transformation applied by the technique removes the first observation from the time series. Given that our sample is relatively small to start with, this is not optimal. However, the trade-off is worthwhile to obtain robust results that do not suffer from autocorrelation issues.

4.4.2. Limitations and Caveats

Although there aren't any major limitations or weaknesses with our model as discussed above, there are nonetheless some caveats, both conceptual and practical, that need to be discussed.

The main limitation of this analysis is the small number of observations driven by the lack of historical data for most of the variables of interest. While this is not a significant issue in and of itself – the number of observations is still over 25 – it makes the model weaker and can make inference harder if it is not optimally specified.

Moreover, there is some multicollinearity present in the data, meaning that some of the control variables are correlated with each other. In some cases where the degree of multicollinearity is high enough, this can cause problems when interpreting the results. However, this was resolved during the preliminary testing stage and, after having chosen the most appropriate control variables, the final model presented in the previous sections does not suffer from a degree of multicollinearity which would be expected to cause any issues (as evidenced by the low Variance Inflation Factor values, or VIFs, in

Table 13 and Table 14).

As part of the preliminary testing stage, we carried out several checks to get a sense of the data and make sure we were correctly specifying our model. One of the more simple but effective tools at an early stage is to plot the data (such as by looking at correlograms and plots of the residuals) to get a better understanding of any trends present in the data, as well as any outliers which might affect our results. Beyond this, we used tools such as the Durbin-Watson test, the Augmented Dickey-Fuller (ADF) test, or the Breusch-Pagan and White tests to test for autocorrelation, stationarity, and heteroscedasticity, respectively.

The assumption about constant returns to scale, or CRS, (see Section 4.3) is worth discussing in more detail. The empirical literature on the extent to which CRS is a realistic characteristic that countries exhibit is relatively sparse and slightly ambiguous. McCombie and Roberts (2007) showed that the values for returns to scale depend on how these are estimated and that these often yield significantly different results. In the case of Colombia, Golany and Thore (1997) found that, using data from a National Bureau of Economic Research study by Barro and Wolf (1989), Colombia had decreasing returns to scale (RTS) during 1970-1985. On the other hand, using data from the Penn World Tables for 1965-1990, Harris and Liu (1999) found that Colombia had increasing RTS. This finding is supported by Astorga *et al.* (2003), which also found that Colombia exhibited increasing RTS using new data from the Oxford Latin American Economic History Database, which allowed the authors to study the whole 20th century.

4.4.3. Sensitivity Testing

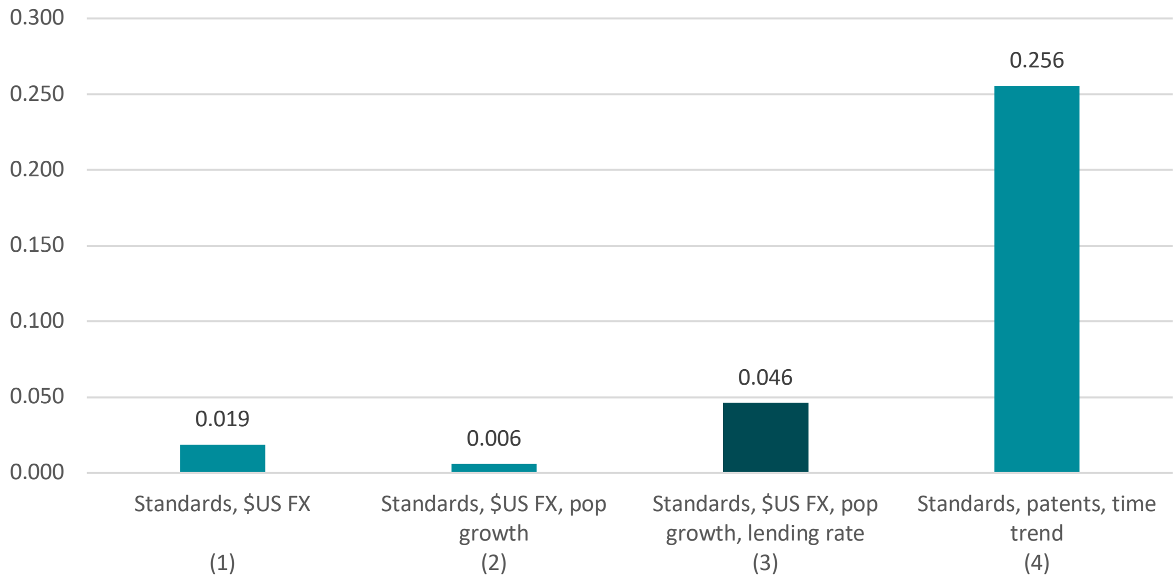
In this subsection, we highlight the consistency of estimator for standards depending on control variables. We present gradually add new variables and change the structural specification of the regression model. We can see that the model is relatively settled.

We chose the highlighted equation (3) because this performs the best: the adjusted R-squared is the highest (0.78, compared to 0.66 and 0.32 for models 1 and 2), while the F-statistic is significant.[38] There is also a degree of economic intuition here, and for the reasons laid out in detail on Section 4.1 , it is our view that model 3 is the best possible specification for Colombia. Note that we do not include other models we tested during the preliminary stage in the chart above as they tended to be misspecified, overfitted, or suffered from unacceptably high levels of multicollinearity.[39]

38 Models 1-3 all also have AIC statistics within the same range (-240's), therefore the quality of the models is relatively even.

39 This included negative coefficients for standards, adjusted R-squared values of 1, or VIFs of over 100.

Figure 12: Coefficients for standards from different models for Equation 9*



Source: Cebr analysis

*Note: The model on the right with patents and time trend as the explanatory variables goes back only to 2004, as opposed to 1990 for the other specifications, as discussed elsewhere in the report.

Following the methodological guidance by ISO, during the preliminary testing stage we used patents as a control variable as this was one of the key regressors. However, due to limitations on availability of historical data for patents in Colombia, the period covered in this alternative analysis only covered 2004 to 2019, despite continuous standards data for the period 1990 to 2019. Furthermore, the specifications which included patents suffered from a high degree of multicollinearity: the model on the right in

Figure 12 had a VIF of 14 for standards, which is more than twice as high as the second biggest, and higher than the commonly used threshold of 10. Therefore, as analysis would based upon just 16 observations, and even then, suffered from a higher degree of multicollinearity, it was our view that dropping patents as a control variable and extending the time period was the most robust approach in this case.

We cannot control for patents. This may not be too much of an issue because they were found to be an insignificant regressor for the period 2004 to 2019. But we have had to drop them due to data availability. We would expect that some of the effect of standards on TFP would be captured by patents. As a result, it is likely that our we are overestimating the effect of standards on TFP given the omission of patents.

Chapter 5: The Economic Impact of Standards in Indonesia

5.1 Summary of the Used Methodological Approach

We were successful in applying the prescribed ISO methodological framework to assess the economic impact of standards in Indonesia without the need to alter or augment it. This may have been necessary if we found, for example, that neither standards or standards and some other explanatory variable such as patents, were good at explaining the change in TFP. This happened to a certain extent with some of the other countries explored within this study, where, because TFP growth was negative over the period assessed, the implied estimate for the effect of standards on TFP was negative – since the stock of standards had grown while TFP had not, then these two would appear to be inversely related at first glance. However, by expanding the original ISO model to control for other factors, we can see that there were other variables that were omitted which explained the negative trend for TFP and, once accounted for, isolated the true impact of standards on productivity. However, in the case of Indonesia, this was not an issue.

Therefore, to estimate the impact of increasing the stock of standards on economic growth in Indonesia, Cebr estimated the following two equation systems:

Equation 10: The log-linearised Cobb-Douglas production function, rearranged as a function of labour productivity.

$$ln(Labour\ Productivity_t) \ = \ \beta_1 ln\ (A_t) + \ \beta_2 ln\left(\frac{K_t}{L_t}\right) + \ \epsilon_t$$

Equation 11: Used specification to isolate the effect of increasing standards on total factor productivity in Indonesia.

$$ln(A_t) \ = \ \gamma_0 + \gamma_1 ln\ (Standards_t) + \ \gamma_2\ ln(US\$\ Exchange\ Rate_t) + \ \gamma_3 Inflation\ Dummy_t + \mu_t$$

In this latter equation, to represent technological progress and explain movements in total factor productivity in Indonesia, we use the US dollar spot exchange rate for Indonesia and a dummy for the rate of inflation as the control variables alongside the stock of standards – below we explain why we chose these as our control variables. This combination was found the be the best performing model to describe the evolution of Indonesian TFP with an adjusted R-squared of 0.78.[40]

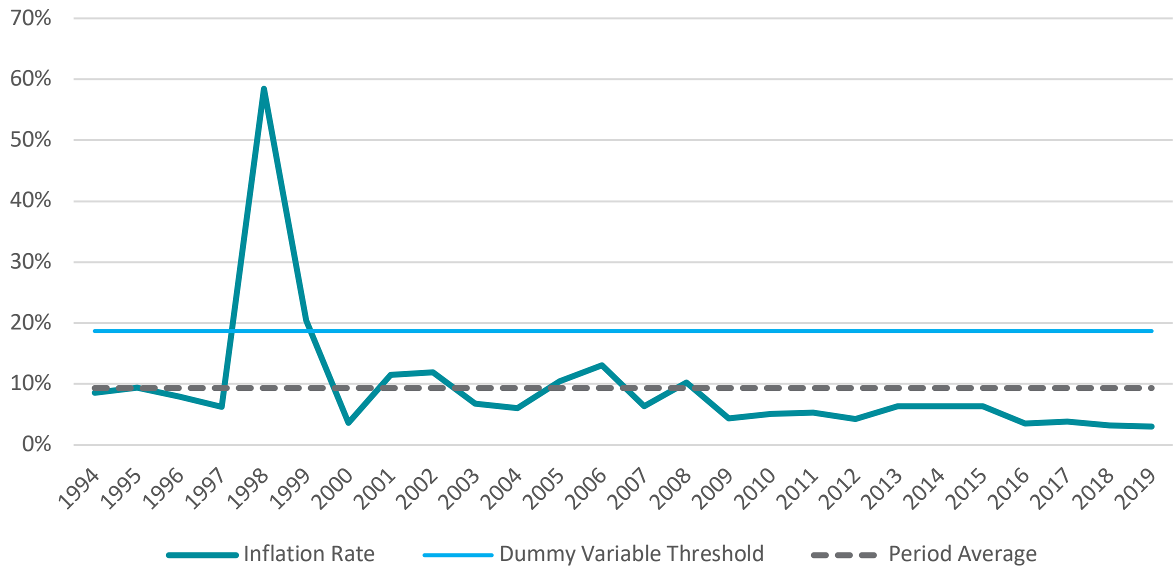
We have chosen to include the US dollar exchange rate to function as a proxy for the international competitiveness of Indonesia. Indonesia has one of the weakest currencies in the world in terms of its exchange rate with the US dollar. Since the 1990s in particular, the rupiah has seen significant depreciations of the US dollar exchange rate (equivalent to a weakening of the Indonesian currency). Notable trends include the significant capital outflows that occurred during the Asian Financial Crisis leading to the rupiah sliding from Rp 3,000 to Rp 10,000 per US dollar (per FRED data), as well as the significant but more gradual 70% depreciation between 2011 and 2022 due to factors such as US interest rate hikes and global

40 We include a more detailed discussion on model diagnostics in the technical appendix, however in the context of this research, the adjusted R-squared value of 0.78 is strong.

turmoil combining with Indonesian current account deficits and exports that are not stimulated by currency depreciations.

On top of this, we include a dummy variable for the inflation rate in Indonesia. Between 1994 and 2019, the average rate of inflation was 9.3% per annum. Despite being relatively high by developed-economy standards, it is clear from Figure 13 below that the one notable deviation from this mean rate occurred during the Asian Financial Crisis of 1997–1998. Due to this period of uncharacteristic volatility, we include an inflation dummy variable with the threshold set at twice the average inflation rate across the observation period. By controlling for any years where the rate of inflation was above 18.7%, we can isolate more effectively any outlying changes in the trend for productivity which would otherwise obfuscate the true effect of standards on productivity that we are attempting to identify.

Figure 13: Rate of inflation for Indonesia, % per annum, 1994–2019



Source: FRED and Cebr analysis

5.2 Findings

5.1.1. Quantitative results

The analysis reveals a strong and significant relationship between standards and labour productivity. Our regression result for Indonesia tells us that **a one percent increase in the net stock of standards is associated with a 0.156 percent increase in labour productivity**, where labour productivity is measured as real GDP per worker. To arrive at this headline figure, we combine the key coefficients from Table 15 and Table 16 below. These two tables present results, following the modelling specification outlines in Equation 10 and Equation 11, above.

The key quantitative results, utilising these equations can be seen below.

Table 15: Summary results for Equation 10, 1994–2019

Term	Coefficient	Standard Error	t-statistic	p-value	Significance
Ln TFP	**0.549**	0.221	2.479	0.021	**
Ln K/L	0.849	0.001	660.046	0.000	***

Source: Penn World Tables, World Bank, IMF, and Cebr analysis

Table 16: Summary results for Equation 11, 1994–2019

Term	Coefficient	Standard Error	t-statistic	p-value	Significance
Intercept	-1.433	0.497	-2.885	0.009	***
ln Standards	**0.284**	0.060	4.732	0.000	***
ln US$ Ex. Rate	-0.122	0.022	-5.569	0.000	***
Inflation (Dummy)	-0.036	0.018	-1.977	0.061	*

Source: BSN, FRED, Penn World Tables, and Cebr analysis

Note: Asterisks *, **, and *** are added to denote a significant relationship at the 10%, 5%, and 1% levels, respectively.

Within the first stage of the analysis, Equation 10 reveals that both TFP and the capital-to-labour ratio are positively related to labour productivity. Crucially, the coefficient β_1 suggests that **a one percent change in TFP is associated with a 0.549 percent change in labour productivity**.

Then, within the second stage of the analysis, Equation 11 reveals that standards and patents also both have a positive relationship with TFP. The coefficient γ_1 suggests that **a one percent change in the net stock of standards in Indonesia is associated with a 0.284 percent change in TFP**. The product of β_1 and γ_1 is then used to deduce the indirect impact of standards on labour productivity, thus generating the 0.156 result.

For completeness, both highlighted coefficients in the below summary tables are significant at the 5% level or higher. Table 15 **above provides summary results for the log-linearised**[41] **Cobb-Douglas equation, while** Table 16 **shows the regression results for the effect of standards on total factor productivity.** For more detailed statistical information regarding the two Tables below, please see the Technical Appendix in Section 5.4.

5.2.2 Discussion

Contribution of standards to economic growth

The findings presented above posit that a one percent growth of the stock of standards is associated with an increase in labour productivity of 0.156 percent across Indonesia. In terms of economic growth this has the following implications:

- Between 1994 and 2019, the net stock of standards in Indonesia grew by an average of 6.1% year-on-year, while the average year-on-year growth of labour productivity was 4.5%. Applying the elasticity of standards with respect to labour productivity (0.156) means that standards are associated with approximately 0.95 percentage points of the average labour productivity growth of 4.5% a year.

41 Log-linearisation here means converting the Cobb-Douglas production function (a nonlinear equation) into a new, linear equation expressed in logarithms, or logs.

- The result suggests that standardisation is associated with 21.2% of the growth in labour productivity and 14.5% of GDP growth in Indonesia during the period 1994 to 2019.
- For the purposes of expressing the findings in monetary terms, if it is assumed that the estimated impact is constant over time, standardisation at the national level would be associated with approximately Rp85.4 trillion of the Rp590.3 trillion of GDP growth recorded in 2019 (World Bank, 2019 prices).[42]

Table 17: Comparison of relevant summary results of national studies[43]

Country	Indonesia	Canada	France	Germany	Nordic	UK	UK
Publication year	**2023**	2007	2009	2000	2018	2005	2015
Analysis period	**1994-2019**	1981-2004	1950-2007	1961-1990	1976-2016	1948-2002	1921-2013
Estimated function[44]	**LP**	LP	GDP	GDP	LP	LP	LP
Elasticity of stock of standards	**0.16**	0.36	0.12	0.07	0.11	0.05	0.11
Share of labour productivity growth	**21.2%**	17.0%	27.1%	30.1%	39.5%	13.0%	37.4%
Growth rate of GDP, % p.a.	**6.5%**	2.7%	3.4%	3.3%	2.5%	2.5%	2.4%
Share of GDP growth	**14.5%**	9.2%	23.5%	27.4%	28.0%	11.0%	28.4%
Contribution of standards to GDP growth, % points	**0.9%**	0.3%	0.8%	0.9%	0.7%	0.3%	0.7%

Source: Standards Council of Canada (2007), AFNOR (2009), DIN (2000), Menon (2018), DTI (2005), and Cebr analysis

Standards can enhance labour productivity by increasing output per employee at individual firms. This can be achieved through various mechanisms such as improving production activity and efficiency, ensuring quality and precision, and spreading technical information and best practices. These improvements in organisational performance lead to cost savings, enabling firms to achieve higher output per worker. Additionally, standards allow firms to build on their strengths and specialise, leading to better division of labour, economies of scale, and increased output per staff member.

However, caution should be taken when interpreting these estimates as standards have an interdependent role in driving labour productivity along with other knowledge factors such as higher levels of education and training, advances in technology and increased innovative efforts. This means that standards play a mutually dependent and complementary role alongside other factors, such as those mentioned above, in facilitating productivity growth. Beyond standards having a direct impact on labour productivity, they are also associated with driving these other knowledge factors, and these then result in an increased value of standards.

42 As a point of reference, this figure converts to approximately $6.2 billion out of $43.1 billion in GDP growth in 2019, based on the 2019 US dollar exchange rate.

43 Note that not all the studies from Table 3 are presented here; only those that estimated the share of labour productivity of GDP growth associated with standardisation are included in this table. For a similar comparison with the other developing countries assessed within this study, see Section 9.1.

44 LP = Labour Productivity. GDP = Gross Domestic Product.

Equally, an improvement in the other knowledge factors leads to standards playing a more efficient role in boosting labour productivity.

On the whole, the results are positive. The Rp85.4 trillion contribution of standards to the Indonesian economy is a sizeable figure in absolute terms. However, the *relative* impact of standards on GDP growth is towards the middle-to-lower end of the range, in comparison to results from national studies conducted in developed countries. To a certain extent, there is a limit to the comparability of such results due to the difference between the driving forces of economic growth in the developing versus the developed contexts. Table 17 above presents a summary of results for other countries compared in the literature. This is not an exhaustive list of studies but a selection of those that provide details on the contribution of standards to economic growth.

Observing the penultimate row of the table, we can see that the relative contribution of standards to GDP growth in Indonesia is sometimes half that of the contribution observed elsewhere. For example, standards are associated with approximately 14.5% of GDP growth in Indonesia, while this figure reaches as high as 28.4% in the most recent UK study. A similar trend is also observed for the contribution of standards to labour productivity.

One explanation for this may be that Indonesia is at a different stage of its economic development process, and its economy is growing at a faster rate than that of more developed nations. The simple average of GDP growth rates across the other countries within Table 17 is 2.8%. In comparison, Indonesia observed an average growth rate of 6.5% across the observation period, more than 2.3x that of the average of the other countries. As a result, for a given percentage point contribution of standards to GDP growth, the relative share attributable to standards in Indonesia will be lower. In other words, compared to highly advanced economies, the share of Indonesian GDP growth attributable to standards will be lower due to other factors such as advances in technology, which help the Indonesian economy grow faster and catch up, or converge, with highly advanced economies.

While full exploration of these factors is beyond the scope of this research report, some of the contributors to Indonesia's high observed average annual GDP growth rate since the turn of the millennium include its favourable demographics of a large, young, and growing population; its relative abundance of natural resources; its relative political stability since the end of the authoritarian Suharto regime in 1998; and its robust export performance. By comparison, the service-led economies of the more developed Western hemisphere do not share these trends.

This additional context demonstrates that despite their mid-range share of GDP growth, their percentage point contribution to GDP growth is amongst the highest. It can be concluded that standards do have a crucial role to play in the economic prosperity of Indonesia.

Limitations and Caveats

For reasons of transparency and accountability, as well as to avoid any inappropriate conclusions being made, it is important to highlight some of the key limitations of this research.

First and foremost, our **analysis is exclusively focused on the assessment of the correlation between standards and productivity, rather than causality**. Correlation between variables simply means that they are related, and that as one variable changes the other does as well, but it does not mean that the change in one of the variables (e.g. productivity) is *caused* by the change in the other variable (e.g. standards). Causality, or causation, is when there is a causal relationship between two variables, i.e. that the change in one variable is caused by a change in the other. Further research would be valuable to be able to establish a *causal* relationship between the standards and productivity. That is, the identification of a direct cause-and-effect relationship between the two variables in Indonesia.

We have also not considered the direction of causality between the variables and cannot pass comment on the potential for endogeneity for the stock of standards in the context of Indonesia In other words, this study doesn't attempt to investigate which of standards or growth drives the other, merely that they are connected and, when one changes, so does the other.[45] An example of the two-way relationship between standards and growth is highlighted by a logic model produced by Zhang *et al.* (2019). They suggest that additional growth and technological progress brings about changes in environment and resources, which in turn leads to the emergence and application of new goods and services. The resulting lack of standards for new products forces the evolution of standards, while more firms lead to more enterprise and enterprise-dominated standards. Ultimately, there is potential for a virtuous cycle between standards and economic growth, but the applied framework does not account for this two-way relationship. Further research is required here.

Furthermore, **the analysis period of 1994 to 2019 is relatively short, covering only 26 periods** of continuous data. According to the methodological guidance document produced by ISO, the very lower bound (or minimum recommended amount) for the number of observations is likely to be somewhere around 15, and it is preferable to have at least 30 periods of data such that the Central Limit Theorem applies.[46]

While we have continuous data for standards between 1994 and 2022, we only have TFP data up until 2019, so there is a constraining factor on the period of analysis due to the availability of TFP data from the Penn World Tables. To an extent, this is not a critical issue, as data for 2020 onwards will have Covid-19 related challenges anyway. However, it does place a limit on the period of analysis, with the most recent year being 2019. The average number of observations in the other studies referenced in Table 17 is 50. Since this study has an observation period of 26 years, this analysis is on the threshold of what can be considered statistically robust.

Cebr is also keen to urge a degree of caution when interpreting these findings. Crucially, **the relationship between standards and productivity is somewhat of a 'black box'** and we have not attempted to incorporate a quantitative assessment of the mechanisms through which standards generate increased productivity. In other words, while we have determined that standards increase productivity, we have not determined *how* or *why* they do so. It is beyond the scope of this report to develop a richer understanding of these mechanisms and

45 Moreover, endogeneity is simply a term in econometrics which describes when a variable of interest (such as standards) is affected by other variables in the analysis. This can be problematic as it may lead to biased and unreliable estimates of the effect of standards (with endogeneity we can't be sure whether our model is saying that standards have a positive effect on growth, or if it's some other explanatory variable).

46 For datasets with less than 15 observations, it is harder to estimate the coefficients that describe the relationship between our variables of interest, and it can also lead to wider confidence intervals around the estimated coefficients (confidence intervals five us a range within which we are reasonably confident that the true value lies).

their effects, but studies at the company level, using firm-level data derived from surveys or case studies, have been conducted in the past and can assist here.[47]

Lastly, it should be recognised that that standards alone do not drive productivity. Rather, they play a mutually dependent and complementary role in facilitating the growth of productivity, along with other types of knowledge such as enhancements in education and progressions in technology. While we have attempted to control for key other potential explanatory factors, the model does not explicitly control for **all other** potential components of TFP. The model is instead an attempt to disentangle the effects of standards from other complementary factors that drive productivity, recognising also the constraints of the available country-level data.

5.3 Review of ISO Methodological Framework

5.3.1. Applicability and Effectiveness

To evaluate the applicability and effectiveness of the prescribed methodological framework, we first consider the key assumptions that are made to apply this two-stage least-squares approach[48] and discuss whether these assumptions are appropriate in this context. Then secondly, we consider whether we have been able to follow the same system of equations to estimate the indirect effect of standards on labour productivity.

The six explicit assumptions made by the methodology are as follows:

- Assumption 1: A stock of standards is a credible proxy for the extent to which standards are effectively utilised in the country.
- Assumption 2: The Cobb-Douglas production function is appropriate as an approximate model.
- Assumption 3: There is a one-way relationship between standards and economic growth.
- Assumption 4: The appropriate transmission mechanism from standards to economic growth resides in an increase in total factor productivity.
- Assumption 5: Data on standards, labour, capital, productivity, and any other variables is available.
- Assumption 6: The economy exhibits constant returns to scale.

Assumption 1: Stock of standards as a credible proxy

The assumption that the stock of standards is a credible proxy for the extent to which standards are effectively utilised is borne out of pragmatism. Across the literature, this is the accepted approach despite its limitations. For example, while it is true that a significant number

47 These include DIN (2000), Conference Board of Canada for the Standards Council of Canada (2007), AFNOR (2009), BERL Economics for The Standards Council of New Zealand (2011) and Menon Economics (2018).

48 Two-stage least-squares (or 2SLS) is a common regression analysis technique which is used when the dependent variable’s error terms are correlated with the independent variables. By using a two-step approach, 2SLS helps us isolate the true effect of standards on productivity by effectively removing the influence of other variables.

of standards may indicate that a country is committed to promoting and maintaining standards, it does not guarantee that these standards are effective.

Beyond simply the quantity of standards, effective standards concern the quality, relevance, implementation, and enforcement of standards in an economy. On one level, a large stock of standards may generate a degree of confusion among stakeholders, making it difficult for organisations to determine which standards are relevant to their needs. Furthermore, the standards may not be effective in achieving their intended goals if they are poorly written, outdated, or not based on the best available science or research.

In addition, the introduction of each new standard may not produce a proportional economic benefit. The assumption that the stock of standards is a robust representation of how standards contribute to the economy is equivalent to the assumption that each standard contributes an equivalent benefit to the economy. This assumption is unlikely to fully hold because newer standards are expected to offer greater benefits than older standards in the national catalogue. Furthermore, the impact of standards on the economy is also generated by the breadth of their use, and thus, some standards are more widely used, and thus more impactful.

Ultimately, while there are limitations to Assumption 1, these are not unique to the Indonesian context and the stock of standards is the best available option for our research.

Assumption 2: Cobb-Douglas production function is appropriate as a model

Economists use production functions to describe what can be produced given a set of inputs, which are typically simplified into capital and labour. Different combinations of capital and labour can be used to produce the same output. The example given by the ISO guidance document suggests that to make a hole in the ground, one can use a person and a spade, two people and two smaller spades, or one person and an excavator. This reflects a microeconomic phenomenon where capital and labour are substitutable. Any macroeconomic model must be consistent with this, and the Cobb-Douglas form is one of the most widely used and practical models within the field.

The use of the Cobb-Douglas production function as an approximate model is a pragmatic middle ground between an ideal world where economic models perfectly describe reality, and the real world where the model must be workable (i.e., linear, in this case).

The major strength of the Cobb-Douglas production function is its ease of use. However, there is a great deal of contradiction within the academic literature with respect to the empirical validity of the Cobb-Douglas functional form. On one hand, Miller (2008), Abidemi (2010), Adetunji *et al.* (2012), and Husain (2016) provide some support evidence for the specification of the model. While on the other hand, papers such as Fraser (2002), and Gechert *et al.* (2019) cast some doubt on the appropriateness of the Cobb-Douglas production function.

In the specific context of a developing economy, there may be some issues that are not present in other contexts, e.g., limited factor mobility (i.e. factor inputs such as labour, capital, or land cannot easily switch between alternative uses without a loss of efficiency). The Cobb-Douglas model assumes a high level of capital and labour mobility, which may not be present in a developing economy. For example, labour may be immobile due to limited access to education and training or a poor infrastructure system, while capital may be concentrated in a few large firms or industries.

While the Cobb-Douglas model can still provide insights into the relationship between inputs and outputs in a developing economy, it cannot fully capture the unique characteristics and challenges of all economies. Other models that allow for decreasing returns to scale or limited mobility of labour and capital may be more appropriate in this context, but further research is needed.

On balance, Assumption 2 may be slightly weaker in the developing context, however it is our view that it is a reasonable approach, and the above weaknesses should not categorically prevent the application of this methodology in any given country. The Cobb-Douglas production function is also effective given that it has allowed Cebr to expand the academic evidence base by conducting this analysis across 6 developing economies.

Assumption 3: There is a one-way relationship between standards and growth

We have already discussed Assumption 3 in the section above and concede that while this assumption has its limitations, it is made because it allows the presented methodology to be simple enough for most countries to adopt, given capacity and capability constraints.

Therefore, this is a limitation of the framework more broadly, but it has no consequences for the applicability and effectiveness of the framework in the developing context specifically.

Assumption 4: Standards impact economic growth through an increase in TFP

Within ISO R&I's methodological guidance document, a logic model is presented that describes the theory behind the effects of standards on an economy, ultimately linking the development of standards with economic growth. It highlights the main mechanism through which standards improve economic growth: unity, compatibility, compliance, and security.

Then, through factors such as product and market uniformity, knowledge and technology diffusion, reduced technical barriers to trade, easier market access, enhanced consumer rights, economic growth is driven by four key channels: trade growth, innovation ability, business environment, plus safety and environmental protection. Zhang *et al.*'s logic model was in fact developed as part of a study into the effects of standards development on economic growth in China. The linkages presented are universal and there is no evidence to suggest that they break down in the Indonesian context. Based upon a review of the academic literature and our economic expertise, we see no compelling argument to dispute this assumption in the Indonesian (or developing) context.

It is also worth noting that there may be some drags to economic growth through the application of standards. For example, overly burdensome standards could lock in old technologies or lead to premature selection of technologies, which would be an inefficient allocation of resources. On top of this, standards have the potential to restrict choice and increase market concentration, especially if dominant players can wield excessive influence on regulatory agencies. While these linkages are a possibility, on a net basis, there is compelling evidence to suggest that standards have a positive impact on productivity and growth.

As mentioned, there is an argument to suggest that in the developing context, there are greater frictions to overcome across the transmission mechanism compared to a more advanced economy. However, the critical point is that the *intuition* behind the linkages considered by Zhang *et al*. appears appropriate. Unless we directly test these linkages, we cannot say with certainty whether this hypothesis is correct. Within our study, the intuition of the TFP variable is to capture many of these complex and competing effects. Therefore, the assumption that the transmission mechanism from standards to economic growth resides in an increase in total factor productivity is sound.

Assumption 5: Data on the relevant variables is available

The fifth assumption of the framework is that data on standards, labour, capital, productivity, and any other required variables is available for the country in question.

We did not encounter issues with the breadth of data sets that were available for Indonesia. Data sources such as the World Bank, IMF, FRED, and the Penn World Tables provide comprehensive coverage for the country, however the main issue was with the length of the time series that were available. Crucially, we were only able to obtain reliable TFP data up to 2019, while patents data did not extend to periods before 2004.

Therefore, we could not incorporate all relevant variables into our models across the full period of analysis. In the case of patents specifically, including it in our models limited the analysis we could carry out since the data only goes back to 2004, meaning that our time series would be cut relatively short. Consequently, we were presented with a trade-off between including all relevant variables as outlined in the ISO methodology guidance or having a longer time series. After robustly testing the available options, the most favourable approach was to drop patents as a control variable in order to substantially increase the length of the data series.

Overall, despite the data limitations mentioned here and discussed in more detail elsewhere, the prescribed ISO methodological approach could be followed in the case of Indonesia as there were enough alternative options.

Assumption 6: The economy exhibits constant returns to scale

Lastly, the Cobb-Douglas model assumes a constant returns to scale (CRS), which means that increasing inputs will result in a proportional increase in output. While this assumption may be defensible at the global level (as it assumes that at any one time, many firms will be enjoying increasing returns to scale, while others will be experiencing decreasing returns to scale), it may not hold for all countries, especially in the developing context.

For example, in a developing economy, there may be infrastructure constraints, limited labour mobility, inadequate education and training, weak regulatory frameworks, or the inability to efficiently use additional inputs which could create pressures that generate decreasing returns to scale.

On the other hand, developing economies may exhibit increasing returns to scale through high labour mobility,[49] through lower per-unit production costs and high international competitiveness, through increasing marginal returns to investment in factors such as education, health, and welfare while the economy is still ‘young’, or through relatively high returns to capital which make developing economies attractive to foreign investors.

We discuss this topic in more detail within the Technical Appendix for Indonesia (Section 5.4). The limitations of the CRS assumption discussed in the appendix are generally accepted across the literature and on balance, we recommend that this assumption is sufficiently robust and defensible in the context of Indonesia.

Summary

49 Depending on the country, labour mobility may be a strength or a weakness. On one hand, a country with a large, young population will have a sizeable pool of workers to deploy in the regions or industries where they can be the most productively efficient. On the other hand, capacity constraints such as lack of housing stock, lack of education and training, or an inadequate rail and road infrastructure may limit the ability of this labour to be efficient.

Overall, the framework has been very successful in providing evidence of the impact of standards on productivity in Indonesia. We have been able to exactly follow the steps suggested within the guidance document and produce robust and significant estimates for the impact of standards on TFP and labour productivity, using the two-system of equations approach.

We have presented a review of the key assumptions made by the framework in the context of Indonesia and find that alongside the strong applicability of the framework, the effectiveness of the results is also relatively high given the quality of the model in explaining movements in total factor productivity.

There are some limitations present such as poor data availability, however these limitations are not a consequence of the prescribed framework, nor is the data sufficiently sparse that a sufficiently robust model cannot be produced. Overall, whilst we are confident in the robustness of the results presented within this study, caution as well as a sound understanding of the relevant limitations, is advised.

5.3.2. Recommendations for Future Research

Our recommendations for future research centre around addressing the limitations of this study and overcoming the gaps in data availability.

Uncovering ‘black box’ variables

One important criticism of generalised macroeconomic models such as the one used in this study – and by most of the other national level studies in this space – is that **the relationship between standards and productivity is treated as something of a ‘black box’**. The academic literature shows compelling evidence to suggest that standards enhance productivity and economic growth at the national level. In practice, this means that standards will help drive companies and their associated supply chains to operate more efficiently, thus reducing costs, expanding revenue opportunities, and ultimately allowing companies and sectors to become more productive and profitable.

On one hand, we can use our economic intuition and critically assess the credibility of the linkages suggested within Zhang *et al.*’s logic model in the context of Indonesia. However, on the other hand, we do not quantitatively assess the mechanisms by which standards generate increased productivity within this study. Other studies in the space have been conducted at the company level using sector- or firm-level data derived from secondary sources, primary surveys, or case studies.[50]

Since 2018, the Indonesian **National Standardisation Body (BSN) began to publish monthly data that incorporates statistics on standards by sector. As this data repository grows, the potential to conduct more granular analyses grows with it.** To maximise policy impact, identifying the key channels in which standards manifest and ultimately drive productivity and growth in the country is vital.

In Spring 2023, the IMF published its Article IV Mission to Indonesia statement. One of the preliminary recommendations for 2023 is that promoting an “enabling business environment” is important to “raise long term growth and make [the economy] more sustainable”. This is an

50 These include DIN (2000), Conference Board of Canada for the Standards Council of Canada (2007), AFNOR (2009), BERL Economics for The Standards Council of New Zealand (2011) and Menon Economics (2018).

area where standards can have a significant positive impact. In future research, it would be valuable to explore this further within Indonesia.

Identifying the direction of causality between standards and productivity

Secondly, **an assessment of the direction of the relationship between standards and productivity** would be an insightful avenue for further research. There is a virtuous cycle between standards and economic growth – whereby standards drive growth which subsequently drives standards which drives further growth, and so on – however, we have not tested this relationship as part of this study.

The prescribed framework does not account for this two-way relationship for reasons of methodological simplicity. While the quality of results may not be affected by the choice to model the relationship between standards and economic growth as one-way, there is still additional insight that could be gained from future research.

For example, one common option is to find a 'cointegrating' relationship between the key variables whereby there exists a stable long-run statistical relationship. Statistical tests can confirm if this relationship is non-spurious and whether it exists between standards and productivity. A similar approach was applied by Cebr in a 2015 study assessing the contribution of standards to UK productivity.

Other options are to use methods such as a Granger causality test which assesses whether one time series is an effective forecaster of another. This test is somewhat of a misnomer as it does not provide insight into a true cause-and-effect relationship. Rather, if standards were found to Granger-cause productivity, then this would demonstrate that historic increases in standards are related to increases in productivity today.

This is by no means an exhaustive list of econometric methods that could be used to extend beyond correlation analysis, but these more advanced techniques would require expansions to the prescribed methodological approach. Given that one of ISO's core aims is to expand the evidence base across developing economies, we would recommend that the prescribed framework is applied as an initial starting point due to its relative simplicity, while the more advanced techniques are applied in further studies.

Reducing data deprivation

Lastly, one of the key limiting factors of this research was data deprivation. As highlighted by ISO, statistical models are only as good as the data that goes into them. In this instance, we were unable to include patents as a control variable due insufficient historic data, despite it being a potentially important regressor to assess. Even if it was dropped from the final model, the fact that we could not comprehensively test whether patents are a statistically significant variable in determining productivity alongside standards is a notable shortcoming of the research. Therefore, we see it as important to use this report as a call-to-action for data collection agencies – both national and supranational bodies alike – to continue their work to expand data libraries, with a particular focus on developing economies.

The concept of data deprivation is not new. Data serves as the foundation for meaningful policymaking, efficient resource allocation, and effective public service delivery. By improving the statistical coverage of the developing world, there will be more opportunities for robust economic analyses to contribute to the literature and advance society's collective knowledge base.

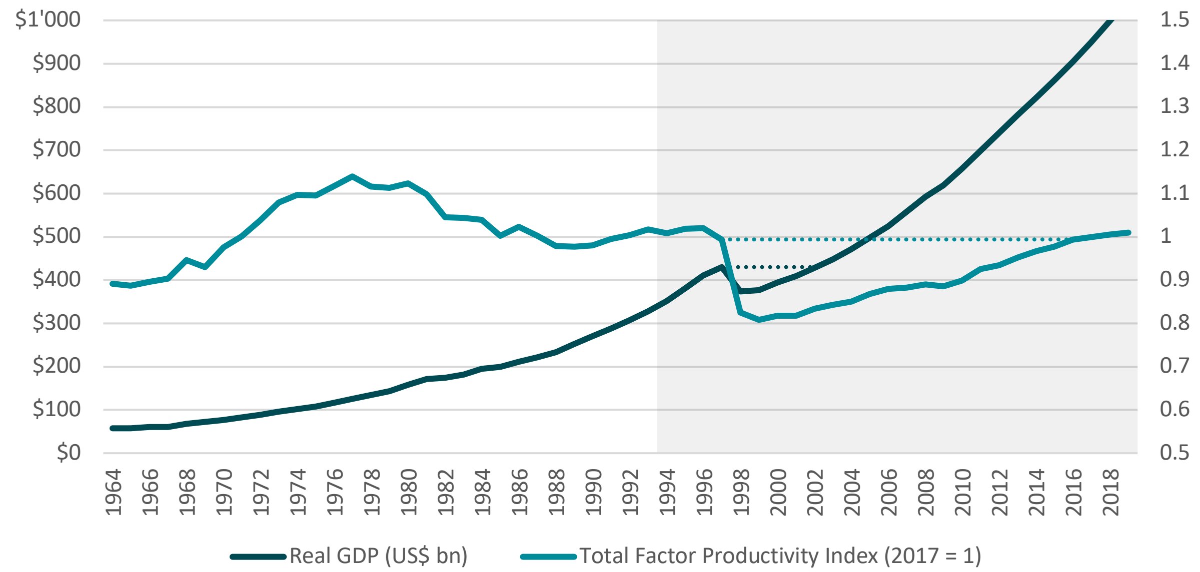
In general terms, a good example of this point is via the informal (or shadow) economy. The International Monetary Fund defines the 'shadow economy' to represent "illegal activities and unreported income from the production of legal goods and services, either from monetary or barter transactions, that would be taxable were they reported to the tax authorities." The livelihoods of individuals in developing economies often depends on these informal economic transactions.

In 2021, Elgin *et al*. introduced a comprehensive dataset of informal economic activity across more than 160 economies for the period 1990-2018. For Indonesia, they estimate that in 2018, the size of the informal economy represented 15.3% of official Indonesian GDP.

The implication of this phenomenon is that official statistics are not able to accurately account for the large swathes of economic activity occurring within the informal sector. This means that empirical studies such as this may not be reflective of the "true" state of the economy because they are entirely reliant upon these official statistics such as GDP, capital stock, and labour force participation. Therefore, the relationships between key variables that are established in the model – in this case, standards, TFP, and labour productivity – may behave differently or break down altogether in the real world.

In the context of this study, improved data availability would be very useful, especially because the Indonesian economy suffered a significant structural shock in the late 1990s due to the Asian Financial Crisis. TFP data in this study was taken from the Penn World Tables and Figure 14 presents the full time series for total factor productivity in Indonesia, with the crisis period in 1997 clearly observable. The grey shading indicates the period that is covered within our analysis, 1994–2019.

Figure 14: Real GDP (constant US$) and total factor productivity index for Indonesia (2017 = 1), 1964–2019



Sources: Penn World Tables, World Banks, and Cebr analysis

Two clear trends are observable following the Crisis. Firstly, in terms of real GDP, the recovery was very swift and pre-crisis levels were achieved by 2002. Then secondly, there are long lasting scars are observed in terms of total factor productivity, with pre-crisis levels achieved after two decades, in 2017.

Optically, there are also notable differences for TFP and GDP trends between the pre- and post-crisis periods. Using some very basic analysis techniques, we can compare the correlation coefficient between real GDP and TFP for the periods 1984–1997 and 1999–2019, as well as for the period 1994–2019, for reference. The results from Table 18 below demonstrate the stark differences between the periods.

Table 18: Pearson correlation coefficient for real GDP and total factor productivity

Period	Person Correlation Coefficient[51]
1984 – 1997 *(pre-crisis)*	0.309
1999 – 2019 *(post-crisis)*	0.991
1994 – 2019 *(reference)*	0.626

Source: Penn World Tables, World Bank, and Cebr analysis

As discussed in Section 0, 1984 was the year that the National Board of Standards was officially founded within Indonesia, hence this is chosen as the start of the relevant period for analysis. The correlation between TFP and GDP is positive in all three periods, but the strength of the relationship is noticeably stronger in the post-crisis period. Given that TFP is the channel through which standards affect economic output and there is a positive relationship between standards and TFP, we would expect this trend to be reflected for standards and output too.

Due to limited data availability in Indonesia for the required variables, we cannot comprehensively assess the pre- and post-crisis periods in a robust way using regression analysis. We recommend that as the statistical capacity of Indonesia is gradually improved, the analysis should be re-conducted with this context in mind and test how the role of standards has changed through recent Indonesian history.

5.4 Technical Appendix: Indonesia

5.4.1. Detailed methodology and results

In this sub-section, we present detailed results of the regression analysis, with accompanying explanation of the specific techniques used. These results are included for reasons of accountability and transparency. All technical shortcomings and limitations are made clear to help ensure that the results of this study are used appropriately.

As explained in Section 5.1, our goal is to estimate the impact of increasing the stock of standards on economic growth in Indonesia using a two-equation system. Table 19 presents the full results for the first of these equations.

51 The range of possible values for this coefficient are -1 to +1. As a rule of thumb, a coefficient of 0 to ±0.3 indicates a weak relationship between the two variables; a coefficient of ±0.4 to ±0.6 indicates a moderate relationship between the two variables; and a coefficient of ±0.7 to ±1 indicates a strong relationship between the two variables.

Rearranging the Cobb-Douglas production function

Below we show in five steps how the Cobb-Douglas production function can be transformed and rearranged to produce the key regressor equations used in the first- and second-stage models:

$$Y_t = A_t L_t^{1-\alpha} K_t^{\alpha}$$

Step 1 – linearise the Cobb-Douglas above by taking natural logarithms:

$$ln(Y_t) = ln(A_t L_t^{\alpha} K_t^{1-\alpha}) = ln(A_t) + (1-\alpha)\, ln(L_t) + \alpha\, ln(K_t) + \epsilon_t$$

Step 2 – rearrange as a function of labour productivity:

$$ln(Y_t) - ln(L_t) \; = ln(A_t) + \alpha\,[ln(K_t) - ln(L_t)] + \epsilon_t$$

Step 3 – as above but expressed in used form:

$$ln\left(\frac{Y_t}{L_t}\right) = ln(Labour\ Productivity_t) = \beta_1 ln\,(A_t) + \beta_2 ln\left(\frac{K_t}{L_t}\right) + \epsilon_t$$

Step 4 – TFP variable isolated and expressed as a function of standards plus other necessary control variables:

$$\ln(A_t) = \gamma_0 + \gamma_1 \ln\,(Standards_t) + \gamma_2 \ln(Patents_t) + \cdots + \gamma_n \ln(n_t) + \mu_t$$

Step 5 – augmented specification to sidestep the 2SLS framework:

$$ln\left(\frac{Y_t}{L_t}\right) = \gamma_0 + \gamma_1 ln\,(Standards_t) + \gamma_n ln(n_t) + \beta_2 ln\left(\frac{K_t}{L_t}\right) + \epsilon_t$$

First-stage model

Equation 10: The log-linearised Cobb-Douglas production function, rearranged as a function of labour productivity.

$$ln(Labour\ Productivity_t) \;=\; \beta_1 ln\,(A_t) + \beta_2 ln\left(\frac{K_t}{L_t}\right) + \epsilon_t$$

Table 19: Full regression results for Equation 10

Dependent Variable:	ln Labour Productivity
Method:	Ordinary Least Squares, HC4 standard errors
Date:	1994-2019
Observations:	26

Overall Fit			
Multiple R	0.99999	AIC	-130.6
R Square	0.99998	AICc	-129.6
Adjusted R Square	0.99998	SBC	-128.1
Standard Error	0.07813		

ANOVA	df	SS	MS	F	p-value
Regression	2	8,402.2	4,201.1	688,238.3	0.000
Residual	24	0.146	0.006		

Total	26	8,402.3			
Term	**Coefficient**	**Std. Error**	**t-statistic**	**p-value**	**VIF**
ln_TFP	0.549	0.221	2.479	0.021**	1.087
ln_K/L	0.849	0.001	660.046	0.000***	1.087

Source: Penn World Tables, World Bank, IMF, and Cebr analysis

Note: Asterisks *, **, and *** are added to denote a significant relationship at the 10%, 5%, and 1% levels, respectively.

This model specification performs well and is effective at describing the relationship between total factor productivity and labour productivity. The adjusted R-squared value and the highly significant F-statistic demonstrate the strength of the model. On top of this, there is no evidence of multicollinearity as the VIF score is close to 1.

The Gauss-Markov theorem shows that when certain conditions are satisfied, OLS coefficients will be the Best Linear Unbiased Estimates; hence, BLUE. When the assumption for homogeneity of variance is violated within the ordinary least squares regression method, the regression coefficients will not be BLUE. While they do remain unbiased, i.e., they will be correct on average, but they will not be efficient since they no longer have minimum variance, i.e., they will not be the 'best'. Therefore, it is important to test for heterogeneity of variance, commonly known as heteroscedasticity within statistics, to ensure that the model coefficients are the 'best'.

To do this we performed the Breusch-Pagan test to determine if heteroscedasticity was present in our model. The p-value for this test was 0.03, which is below the threshold of 0.05, suggesting that there was evidence of heteroscedasticity within our data and that the OLS coefficients will not be BLUE. We also note that this test should only be used when the residuals are normally distributed. We applied the Shapiro-Wilk test and the D'Agostino-Pearson test to assess the normality of the data but found that the residuals were not normally distrusted. Therefore, the results of the Breusch-Pagan test should be treated with a significant degree of caution.[52]

Ultimately, we could not rule out the potential for heteroscedasticity within our model. As a precautionary measure, we used Huber-White's robust standard errors approach which are also known as heteroscedasticity-consistent (HC) standard errors.[53] Therefore, the coefficients in the summary results in Table 15 and the full results in Table 19, are both produced using the most restrictive version of the approach; HC4 estimators.

This gives some degree of comfort with regards to the validity of the results, however we recommend that it may be more appropriate to use an alternative regression approach, such as Weighted Least Squares, to comprehensively address potential issues with heteroscedasticity within the data.

Second-stage model

52 For completeness, we also applied White's test for heteroscedastic errors which produced a result to suggest that the variances for the errors are in fact equal. However, the validity of this result is also highly dubious given that this test should only be used on large samples, where ours is not.

53 Hayes, A., and Cai, L. (2007). 'Using heteroskedasticity-consistent standard error estimators in OLS regression: An introduction and software implementation.'

Moving on to the second of the two equations, we use the US dollar spot exchange rate for Indonesia and a dummy for the rate of inflation as the control variables alongside the stock of standards to represent technological progress and explain movements in total factor productivity in Indonesia. As previously mentioned, this combination was found the be the best performing model to describe the evolution of Indonesian TFP with an adjusted R-squared of 0.78 and an F-stat of 30.0.

Full regression results for this Equation are presented in Table 20 below. Crucially, note that we did not use an OLS regression here, and instead used the Cochrane-Orcutt procedure.

Equation 11: Used specification to isolate the effect of increasing standards on total factor productivity in Indonesia.

$$ln(A_t) \; = \; \gamma_0 + \gamma_1 ln\,(Standards_t) + \; \gamma_2\, ln(US\$\; Exchange\; Rate_t) + \; \gamma_3 Inflation\; Dummy_t + \mu_t$$

Table 20: Full regression results for Equation 11

Dependent Variable:	ln TFP
Method:	Cochrane-Orcutt procedure
Date:	1994-2019
Observations:	25

Overall Fit			
Multiple R	0.90042	AIC	-196.2
R Square	0.81075	AICc	-193.0
Adjusted R Square	0.78371	SBC	-191.3
Standard Error	0.01839		

ANOVA	df	SS	MS	F	p-value
Regression	3	0.030	0.010	30.0	0.000
Residual	21	0.007	0.000		
Total	24	0.038			

Term	Coefficient	Std. Error	t-Statistic	p-Value	VIF
Intercept	-1.433	0.497	-2.885	0.009***	
ln Standards	0.284	0.060	4.732	0.000***	1.130
ln US$ Ex. Rate	-0.122	0.022	-5.569	0.000***	1.781
Inflation (Dummy)	-0.036	0.018	-1.977	0.061*	1.654

Source: BSN, FRED, Penn World Tables, and Cebr analysis

Note: Asterisks *, **, and *** are added to denote a significant relationship at the 10%, 5%, and 1% levels, respectively.

We use a Cochrane-Orcutt regression procedure to address the problems of autocorrelation that were detected within the data using a Durbin-Watson test.

Autocorrelation is the degree of correlation of the same variables between two successive time intervals. It measures how the lagged version of the value of a variable is related to the original version of it in a time series. Autocorrelation is a problem because it leads to inefficient estimates (i.e., they do not have minimum variance) hence our confidence in the result is lowered if autocorrelation is present. The Cochrane-Orcutt regression procedure is a technique that takes serial correlation into account within the error term, hence solving for autocorrelation within the regression model.

One downside with this approach is that the transformation applied by the technique removes the first observation from the time series. Given that our sample is relatively small to start with, this is not optimal. However, the trade-off is worthwhile to obtain robust results that do not suffer from autocorrelation issues.

5.4.2. Limitations and Caveats

Although there are no major limitations or weaknesses with our model as discussed above, there are nonetheless some caveats, both conceptual and practical, that need to be discussed.

The main limitation of this analysis is the small number of observations driven by the lack of historical data for most of the variables of interest. While this is not a significant issue in and of itself – the number of observations is still over 25 – it makes the model weaker and can make inference harder if it is not optimally specified.

Moreover, there is some multicollinearity present in the data, meaning that some of the control variables are correlated with each other. In some cases where the degree of multicollinearity is high enough, this can cause problems when interpreting the results. However, this was resolved during the preliminary testing stage and, after having chosen the most appropriate control variables, the final model presented in the previous sections does not suffer from a degree of multicollinearity which would be expected to cause any issues (as evidenced by the low Variance Inflation Factor values, or VIFs, in Table 19 and Table 20).

As part of the preliminary testing stage, we carried out several checks to get a sense of the data and make sure we were correctly specifying our model. One of the more simple but effective tools at an early stage is to plot the data (such as by looking at correlograms and plots of the residuals) to get a better understanding of any trends present in the data, as well as any outliers which might affect our results. Beyond this, we used tools such as the Durbin-Watson test, the Augmented Dickey-Fuller (ADF) test, or the Breusch-Pagan and White tests to test for autocorrelation, stationarity, and heteroscedasticity, respectively.

The assumption about constant returns to scale, or CRS, (see Section 5.3) is worth discussing in more detail. The empirical literature on the extent to which CRS is a realistic characteristic that countries exhibit is relatively sparse and slightly ambiguous. McCombie and Roberts (2007) showed that the values for returns to scale depend on how these are estimated and that these often yield significantly different results. In the case of Indonesia, a 2016 study published in the Jurnal Ekonomi Pembangunan (Journal of Development Economics) analysed the technical efficiency and returns to scale of the Indonesian economy during the years 1967 to 2013. The analysis evaluated returns to scale based on the Indonesian economy's business cycle across this period, producing estimates for returns to scale in each. CRS is implied when the sum of the output elasticities on labour and capital equal one. If their sum is less than one, then decreasing returns to scale are present, and vice versa for a sum of more than one.

The author finds that over the period average the economy typically exhibits a degree of decreasing returns to scale, with the sum of the output elasticities at approximately 0.8. This implies that doubling the inputs of labour and capital would lead to a less than proportional increase in final output. This result also provides Indonesia-specific support for the initial expectation for the weakness of the CRS assumption in the developing context more broadly.

However, we also see evidence of other macroeconomic academic studies of Indonesia that do credibly impose the constant returns to scale condition when conduction the analysis. Other studies, such as Harris and Liu (1999), estimate increasing returns to scale for most countries around the world, including several in southeast Asia. Furthermore, many other countries to which this ISO standards framework has been applied have been found to exhibit lower returns to scale than the 0.8 found for Indonesia by Muchdie (2016). For example, Golany and Thore

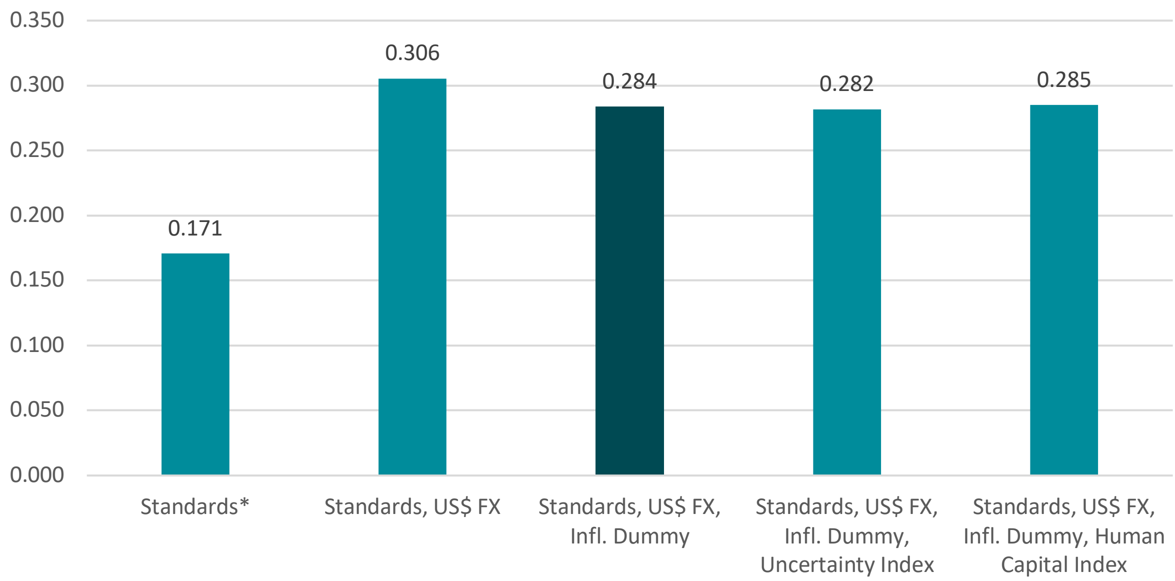
(1997) present an empirical evaluation of the returns to scale across 72 developed and developing countries between 1970 and 1985 – a period covered by many of the other studies assessing the economic impact of standards. [54] They conclude that the United Kingdom, the Scandinavian countries, Australia, and New Zealand all exhibit decreasing returns to scale, while many less advanced economies exhibit increasing returns to scale.

5.4.3. Sensitivity Testing

In this subsection, we highlight the consistency of estimator for standards depending on control variables. We gradually add new variables and change the structural specification of the regression model. We can see that the model is relatively settled.

We chose the highlighted equation because this performs the best – the adjusted R-squared is the highest while the F-statistic is significant.[55] There is also a degree of economic intuition here, and it is our view that controlling for the significant shock to the Indonesian economy from the AFC is important, hence the inclusion of this dummy variable.

Figure 15: Coefficients for standards from different models for Equation 11*



Source: Cebr analysis

*Note: This equation was not found to be significant.

We first used patents as a control variable as this was one of the key regressors mentioned in the ISO guidance document. However, due to limitations on availability of historical data for patents in Indonesia, the period covered in this alternative analysis only covered 2004 to 2019, despite continuous standards data for the period 1994 to 2019. Therefore, as analysis would based upon just 16 observations, it was our view that dropping patents as a control variable and extending the time period was the most robust approach in this case.

54 See Section 1.5.

55 These models all also have AIC statistics within the same range (-190's), therefore the quality of the models is relatively even.

We cannot control for patents. This may not be too much of an issue because they were found to be an insignificant regressor for the period 2004 to 2019. But we have had to drop them due to data availability. We would expect that some of the effect of standards on TFP would be captured by patents. As a result, it is likely that our we are overestimating the effect of standards on TFP given the omission of patents.

Chapter 6: The Economic Impact of Standards in Jamaica

6.1 Summary of the Used Methodological Approach

Despite some heavily restrictive data-related limitations, we were able to apply the *theoretical* economic framework prescribed by the ISO methodological guidance note and produce a regression model for the impact of standards on labour productivity in Jamaica.

To address the data issues, and while staying within the wider Cobb-Douglas framework, we estimated the effect of standards *directly* on labour productivity by embedding Equation 3 into Equation 2. In other words, instead of employing a two-stage model whereby standards are assumed to indirectly impact labour productivity through an increase in TFP, we use a single-stage model where we explicitly estimate the direct impact of standards on labour productivity.

Although the step-by-step process may be different from the one set out by ISO, conceptually both are still attempting to do the same thing – they should be interpreted as different algebraic rearrangements of the same core model: the Cobb-Douglas production function. Whereas the two-stage approach leaves in terms for both capital and labour as well as TFP (A), with the single equation seen below, we maintain capital and labour within the model through the k term (which denotes the capital-employment ratio), and then we simply substitute TFP with our list of explanatory variables (including standards), which we explain further below.

One caveat to note about this altered model is that by removing the TFP term and substituting it with the explanatory variables discussed, we are in effect no longer directly quantifying the explicit role of TFP. As a reminder, TFP is essentially the "catch-all" term for everything that affects economic output that is not capital or labour. It will include the specific explanatory variables we use – such as standards – but it is likely to include many other external factors that are not estimated or accounted for in our model (these include poor competitiveness and low infrastructure quality, amongst others, which are harder to quantify). As such, although the single-stage model we have used is the best at estimating the isolated impact of standards on labour productivity, it is more limited when it comes to identifying the relationship between TFP and labour productivity.

Equation 12: Used log-linearised Cobb-Douglas production function, rearranged as a function of labour productivity.

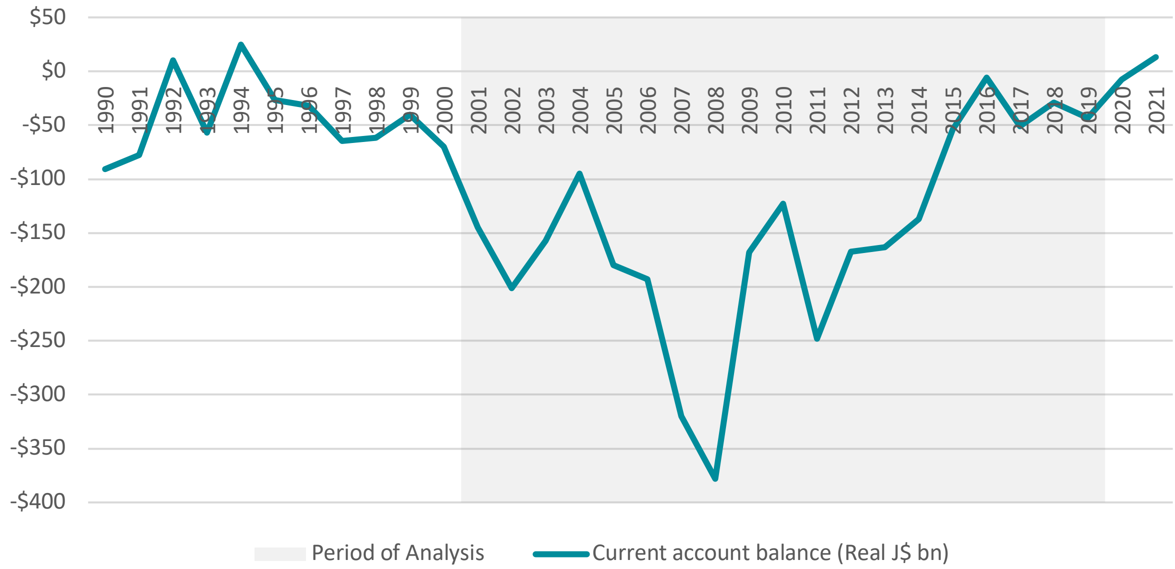
$$ln(Labour\ Productivity_t) = \gamma_0 + \gamma_1 ln\,(Sale\ of\ Standards_t) + \gamma_2 Current\ Account\ Balance_t + \gamma_3\, ln(Net\ Emigration_t) + \beta_2 ln\left(\frac{K_t}{L_t}\right) + \epsilon_t$$

In this single equation, we by-pass the two-stage least-squares approach and directly substitute standards plus all other control variables into the Cobb-Douglas function. Therefore, all the γ_n terms are used a proxy for TFP.

To represent technological progress and explain movements in total factor productivity in Jamaica, alongside the sale of standards we use the current account balance of Jamaica, plus the net emigration rate[56] – below we explain why we chose these as our control variables. This combination was found the be the best performing model to describe the evolution of Jamaican labour productivity with an adjusted R-squared of 0.99 and an F-statistic of 924,434 demonstrating that the model is highly significant.[57]

We have included the current account balance[58] as a regressor, while Figure 16 shows the current account balance for Jamaica since 1990 in real 2017 Jamaican dollars. According to World Bank data, Jamaica has historically been a significant net importer of goods with an overall trade deficit in each year across the observation period other than 1992, 1994, and 2021. Trade deficits occur when a country's imports exceed its exports.

Figure 16: Current account balance for Jamaica, Jamaican dollars (2017 real), 1990–2021.



Source: World Bank and Cebr analysis

Through the specific period of analysis in this study – 2001 to 2019 – we see that there was a sharp V-shaped path between 2001 to 2004 followed by a larger decline in the current account balance to the period low in 2008. Specifically, Jamaica's current account balance fell from -J$95.1 billion in 2004 to a low of -J$378.1 billion in 2008, followed by broad improvements across the remainder of the period. Ultimately, Jamaica's current account balance reached -J$43.4 billion in 2019, with a peak of -J$5.7 billion in 2016.

Crucially, therefore, our study controls for the impact on labour productivity of a current account deficit that is (on average) declining. An improving current account balance that is still negative, meaning that the deficit is narrowing but still exists, can have both positive and negative impacts on labour productivity and GDP:

56 Net emigration is the net total of emigrants during the period, that is, the number of emigrants minus the number of immigrants, including both citizens and non-citizens.

57 We include a more detailed discussion on model diagnostics in the technical appendix.

58 Current account balance of a country is a measure of its net transactions with the rest of the world, including trade in goods and services, income from investments, and unilateral transfers.

- An improving current account balance, even if it remains negative, can signal a more stable economic environment. It can instil confidence among investors, both domestic and foreign, which can lead to increased investment and economic activity. Similarly, a narrowing current account deficit indicates that a country is becoming less reliant on external financing. It can reduce external vulnerabilities and the risk of sudden capital outflows. This enhanced stability and confidence could provide a conducive environment for economic growth and investment, which can have positive spillover effects on labour productivity and contribute to GDP growth.
- Conversely, declining current account deficits due to reduced imports of crucial inputs and raw materials for domestic industries may negatively affect labour productivity. If businesses rely heavily on imported inputs for production, a decline in imports can lead to supply chain disruptions and increased costs. This can hinder production processes and limit the availability of necessary resources, with industries that heavily rely on imported intermediate goods or technology facing challenges in maintaining their productivity levels.

On top of this, we have also included net emigration within the model. In the context of Jamaica in the 21st Century, net emigration is likely to have had both positive and negative implications for labour productivity growth. For example, Jamaica experienced a significant brain drain during this period, with many skilled and educated individuals leaving the country in search of better opportunities abroad. The loss of highly skilled workers can have a detrimental effect on labour productivity as it reduces the pool of talent available domestically. The departure of skilled individuals can result in a skills gap and a lack of expertise in key sectors, hindering overall productivity growth.

While net emigration can result in a loss of skilled workers, there is also the potential for Jamaican emigrants who gained valuable knowledge and skills abroad to return to Jamaica as experienced workers and bring back expertise and technological know-how. This can potentially have a positive impact on labour productivity through the promotion of more advanced practices and technologies. Again, on the positive side, Jamaica has been one of the largest recipients of remittances as a percentage of its GDP over recent years. The remittances sent back by Jamaican emigrants have contributed to domestic consumer spending, increased investment, and economic development. This infusion of funds has the potential to stimulate productivity growth indirectly by creating business opportunities, supporting entrepreneurship, and improving access to capital for domestic industries.

As a result, the overall impact of net emigration on labour productivity in Jamaica over the last two decades is difficult to predict and will be a function of the various competing factors above.

6.2 Findings

6.2.1 Quantitative results

The analysis reveals a positive and significant relationship between standards and labour productivity. Our regression result for Jamaica tells us that **a one percent increase in the net sale of standards is associated with a 0.018 percent increase in labour productivity**, where labour productivity is measured as real GDP per worker.

The key quantitative results, utilising the key equation, can be seen in Table 21 below.

Table 21: Summary results for Equation 12, 2001–2019

Term	Coefficient	Standard Error	t-statistic	p-value	Significance
Ln K/L	0.750	0.040	18.767	0.000	***
Ln Sale of Standards	0.018	0.010	1.765	0.098	*
Current Account Balance (Real J$tr)	-0.0001	0.001	-0.092	0.928	Insignificant
Ln Net Emigration	0.182	0.062	2.927	0.010	**

Source: BSJ, World Bank, Penn World Tables, and Cebr analysis

Note: Asterisks *, **, and *** are added to denote a significant relationship at the 10%, 5%, and 1% levels, respectively.

Within the regression analysis, Equation 12 reveals that standards, net emigration and the capital-to-labour ratio are positively related to labour productivity, while the current account balance is negatively related to labour productivity.

The coefficient γ_1 suggests that a one percent change in the cumulative sale of standards is associated with a 0.018 percent change in labour productivity. **Crucially, the p-value for this coefficient is 0.098 showing that the result is significant at the 10% level, meaning that the observed effect or relationship is positive and statistically different from zero.**

We discuss the implications and limitations of this result in the following subsection. As an example, since we could not control for patents due to data limitations, it is likely that we are overestimating the effect of standards on labour productivity given the omission of patents. However, for more detailed statistical information regarding the results table, please see the Technical Appendix.

6.2.2 Discussion

Contribution of standards to economic growth

The findings in Section 6.2.1 above posit that a one percent growth of the cumulative sale of standards across Jamaica is associated with an increase in labour productivity of 0.018 percent.

In the case of Jamaica, we cannot provide any estimates for the contribution of standards to economic growth because we do not have any visibility of the number of standards that were sold prior to 2001. Therefore, we do not have a reliable baseline to robustly calculate the average year-on-year growth rate of the cumulative sale of standards for the period 2001 to 2019. Any current calculations would drastically overstate the average annual percentage increase in the sale of standards as we would be starting from 0 rather than the number of standards sold between 1969 and 2000, for example (i.e., since the inception of BSJ). Therefore, without this data, the analysis would otherwise produce gross overestimates for the relative contribution of standards to economic growth.

For completeness, we show Table 22 below that includes the full suite of results for other national studies. We see that the elasticity for the sale of standards in Jamaica is lower than the elasticity for the stock of standards estimated in the other studies. Comparisons here can only be limited because the variables are not consistent with one another.

Table 22: Comparison of relevant summary results of national studies[59]

Country	Jamaica	Canada	France	Germany	Nordic	UK	UK
Publication year	**2023**	2007	2009	2000	2018	2005	2015
Analysis period	**2001-2019**	1981-2004	1950-2007	1961-1990	1976-2016	1948-2002	1921-2013
Estimated function[60]	**LP**	LP	GDP	GDP	LP	LP	LP
Elasticity of stock of standards	**0.02***	0.36	0.12	0.07	0.11	0.05	0.11
Share of labour productivity growth	-	17.0%	27.1%	30.1%	39.5%	13.0%	37.4%
Growth rate of GDP, % p.a.	***0.6%***	2.7%	3.4%	3.3%	2.5%	2.5%	2.4%
Share of GDP growth	-	9.2%	23.5%	27.4%	28.0%	11.0%	28.4%
Contribution of standards to GDP growth, % points	-	0.3%	0.8%	0.9%	0.7%	0.3%	0.7%

Source: Standards Council of Canada (2007), AFNOR (2009), DIN (2000), Menon (2018), DTI (2005), and Cebr analysis

*Note: The coefficient for Jamaica refers to the **cumulative sale of standards** rather than the stock of standards due to data availability issues.

Standards can enhance labour productivity by increasing output per employee at individual firms. This can be achieved through various mechanisms such as improving production activity and efficiency, ensuring quality and precision, and spreading technical information and best practices. These improvements in organisational performance lead to cost savings, enabling firms to achieve higher output per worker. Additionally, standards allow firms to build on their strengths and specialise, leading to better division of labour, economies of scale, and increased output per staff member.

That being said, caution should be taken when interpreting these estimates as standards have an interdependent role in driving labour productivity along with other knowledge factors such as higher levels of education and training, advances in technology and increased innovative efforts. This means that standards play a mutually dependent and complementary role alongside other factors, such as those mentioned above, in facilitating productivity growth. Beyond standards having a direct impact on labour productivity, they are also associated with driving these other knowledge factors, and these then result in an increased value of standards. Equally, an improvement in the other knowledge factors leads to standards playing a more efficient role in boosting labour productivity.

Limitations and Caveats

For reasons of transparency and accountability, as well as to avoid any inappropriate conclusions being made, it is important to highlight some of the key limitations of this research.

Firstly, the analysis period of 2001 to 2019 is short, covering only 19 periods of continuous data. According to the methodological guidance document produced by ISO, the

59 Note that not all the studies from Table 3 are presented here; only those that estimated the share of labour productivity of GDP growth associated with standardisation are included in this table. For a similar comparison with the other developing countries assessed within this study, see Section 9.1.

60 LP = Labour Productivity. GDP = Gross Domestic Product.

very lower bound (or minimum recommended amount) on the number of observations is likely to be somewhere around 15, and it is preferable to have at least 30 periods of data such that the Central Limit Theorem applies.[61]

Therefore, the constraining factor on the period of analysis is due to the availability of the standards data. While we have continuous data for TFP between 1990 and 2019, we only have sale of standards data back to 2001. The average number of observations in the other studies referenced in Table 22 is 50. Since this study has an observation period of 19 years, this analysis is can, at best, only be considered to be indicative rather than statistically robust.

Secondly, **our analysis is exclusively focused on the assessment of the correlation between standards and productivity, rather than causality**. Correlation between variables simply means that they are related, and that as one variable changes the other does as well, but it does not mean that the change in one of the variables (e.g. productivity) is *caused* by the change in the other variable (e.g. standards). Causality, or causation, is when there is a causal relationship between two variables, i.e. that the change in one variable is caused by a change in the other. Further research would be valuable to be able to establish a *causal* relationship between the standards and productivity. That is, the identification of a direct cause-and-effect relationship between the two variables in Jamaica.

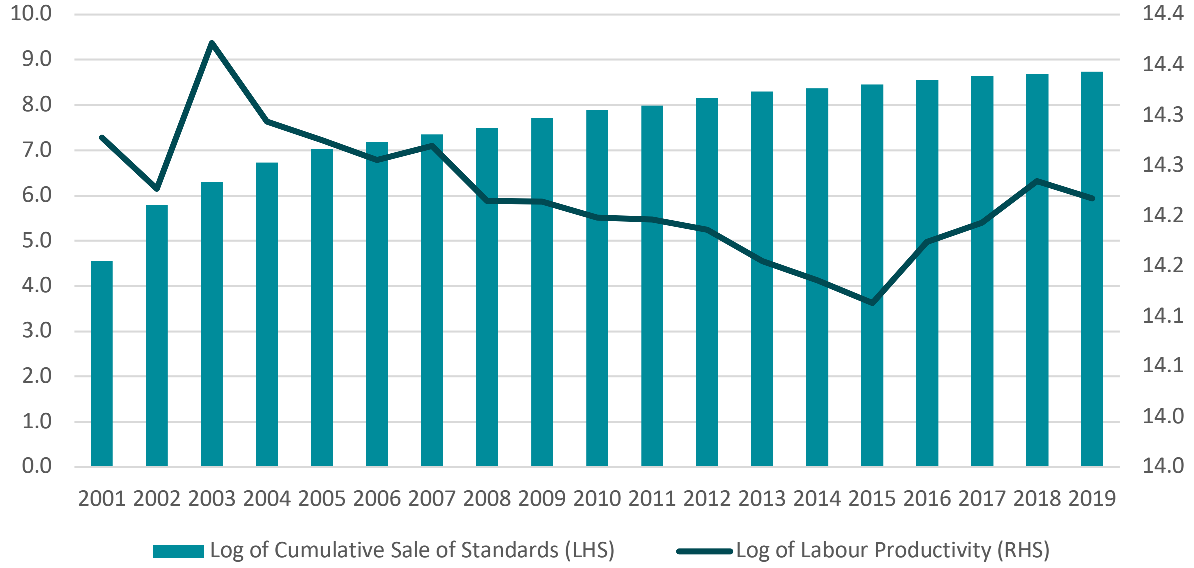
The above is a more general approach, with regards to Jamaica specifically, throughout this report we have used the variable 'cumulative sale of standards' rather than the stock of standards. The ISO methodological guidance document suggests that the stock of standards is used, however, as shown in Figure 4 in Section 1.2, this data is incomplete and did not lead to conclusive results when used in the model. As a result, the final specification of the model has had to be constructed using second-choice variables meaning that the specific relationship being assessed is not consistent with others in the literature.

The sale of standards is a valid alternative and is explicitly referenced within the guidance document, and accordingly it provides results that are comparable to similar studies that have relied on the stock of standards as the variable. In fact, the sale of standards is sometimes considered a better measure of the use of standards than the stock of active standards because it reflects the current usage and demand for standards. Sales indicate the number of standards being actively sought and implemented by businesses and organisations, providing a more accurate representation of the level of use and adherence to specific standards. On the other hand, the stock of active standards may include standards that are no longer in widespread use, potentially leading to an overestimation of the actual use level. Despite this context, it does not diminish the fact that this is a second-choice model.

Figure 17 shows the movement of the two key variables across the observation period, with a clear negative relationship between them, on average.

61 For datasets with less than 15 observations, it is harder to estimate the coefficients that describe the relationship between our variables of interest, and it can also lead to wider confidence intervals around the estimated coefficients (confidence intervals give us a range within which we are reasonably confident that the true value lies).

Figure 17: Logged cumulative sale of standards against logged labour productivity, 2001–2019



Source: BSJ, Penn World Tables and Cebr analysis

As explained in the methodological guidance document, subjective judgement is often required within the field of economics. Given the strong quantitative literature base from studies across other countries, we would expect that standards have a positive effect on labour productivity in Jamaica. Furthermore, given the inverse relationship observed in Figure 17, to elicit a positive relationship between the two variables, all relevant control variables must be included within the regression model. However, **the relationship between standards and productivity is somewhat of a 'black box'** and we have not attempted to incorporate a quantitative assessment of the mechanisms through which standards generate increased productivity. In other words, while we have determined that standards increase productivity, we have not determined *how* or *why* they do so. It is beyond the scope of this report to develop a richer understanding of these mechanisms and their effects, but studies at the company level, using firm-level data derived from surveys or case studies, have been conducted in the past and can assist here.[62] If this further research were to be conducted, this may allow for an improved selection of control variables to be used alongside standards.

It should also be recognised that standards alone do not drive productivity. Rather, they play a mutually dependent and complementary role in facilitating the growth of productivity, along with other types of knowledge such as enhancements in education and progressions in technology. While we have attempted to control for key other potential explanatory factors, the model does not explicitly control for **all other** potential components of TFP. The model is instead an attempt to disentangle the effects of standards from other complementary factors that drive productivity, recognising also the constraints of the available country-level data.

We have also not considered the direction of causality between the variables and cannot pass comment on the potential for endogeneity for the stock of standards in the context of Jamaica. Simply, endogeneity occurs when a variable of interest (such as standards) is affected by other variables in the analysis, leading to biased and unreliable estimates. An example of the

62 These include DIN (2000), Conference Board of Canada for the Standards Council of Canada (2007), AFNOR (2009), BERL Economics for The Standards Council of New Zealand (2011) and Menon Economics (2018).

two-way relationship between standards and growth is highlighted by a logic model produced by Zhang *et al.* (2019). They suggest that additional growth and technological progress brings about changes in environment and resources, which in turn leads to the emergence and application of new goods and services. The resulting lack of standards for new products forces the evolution of standards, while more firms lead to more enterprise and enterprise-dominated standards. Ultimately, there is potential for a virtuous cycle between standards and economic growth, but the applied framework does not account for this two-way relationship. Further research is required here.

6.3 Review of ISO Methodological Framework

6.3.1 Applicability and Effectiveness

To evaluate the applicability and effectiveness of the prescribed methodological framework, we first consider the key assumptions that are made to apply this single-stage least-squares approach and discuss whether these assumptions are appropriate in this context. The six explicit assumptions made by the methodology are as follows:

- Assumption 1: A stock of standards is a credible proxy for the extent to which standards are effectively utilised in the country.
- Assumption 2: The Cobb-Douglas production function is appropriate as an approximate model.
- Assumption 3: There is a one-way relationship between standards and economic growth.
- Assumption 4: The appropriate transmission mechanism from standards to economic growth resides in an increase in total factor productivity.
- Assumption 5: Data on standards, labour, capital, productivity, and any other variables is available.
- Assumption 6: The economy exhibits constant returns to scale.

Assumption 1: Stock of standards as a credible proxy

The assumption that the stock of standards is a credible proxy for the extent to which standards are effectively utilised is borne out of pragmatism. Across the literature, this is the accepted approach despite its limitations. For example, while it is true that a significant number of standards may indicate that a country is committed to promoting and maintaining standards, it does not guarantee that these standards are effective.

In the context of this study, we have been required to use the sale of standards as our proxy for the extent to which standards are effectively utilised because we do not have sufficient data for the stock of standards. In some ways, this is a more appropriate variable for the *effective* stock of standards because the number of standards that are sold is directly associated with the breadth of their use, whereas the stock of standards does not give any direct indication of the level of use of standards in a country.

In addition, the introduction of each new standard may not produce a proportional economic benefit. The assumption that the sale (or stock) of standards is a robust representation of how standards contribute to the economy is equivalent to the assumption that each standard purchased contributes an equivalent benefit to the economy. This assumption is unlikely to fully hold because newer standards are expected to offer greater benefits than older standards in the national catalogue. Furthermore, the standards may not be effective in achieving their intended goals if they are poorly written, have not been recently updated, or not based on the best available science or research.

Ultimately, while there are limitations to Assumption 1, these are not unique to the Jamaican context and the sale of standards is the best available option for our research and is a reasonable proxy for the extent to which standards are effectively utilised in Jamaica.

Assumption 2: Cobb-Douglas production function is appropriate as a model

Economists use production functions to describe what can be produced given a set of inputs, which are typically simplified into capital and labour. Different combinations of capital and labour can be used to produce the same output. The example given by the ISO guidance document suggests that to make a hole in the ground, one can use a person and a spade, two people and two smaller spades, or one person and an excavator. This reflects a microeconomic phenomenon where capital and labour are substitutable. Any macroeconomic model must be consistent with this, and the Cobb-Douglas form is one of the most widely used and practical models within the field.

The use of the Cobb-Douglas production function as an approximate model is a pragmatic middle ground between an ideal world where economic models perfectly describe reality, and the real world where the model must be workable (i.e., linear, in this case).

The major strength of the Cobb-Douglas production function is its ease of use. However, there is a great deal of contradiction within the academic literature with respect to the empirical validity of the Cobb-Douglas functional form. On one hand, Miller (2008), Abidemi (2010), Adetunji *et al.* (2012) and Husain (2016) provide some support evidence for the specification of the model. While on the other hand, papers such as Fraser (2002), and Gechert *et al.* (2019) cast some doubt on the appropriateness of the Cobb-Douglas production function.

In the specific context of a developing economy, there may be some issues that are not present in other contexts, e.g., limited factor mobility (i.e., factor inputs such as labour, capital, or land cannot easily switch between alternative uses without a loss of efficiency). The Cobb-Douglas model assumes a high level of capital and labour mobility, which may not be present in a developing economy. For example, labour may be immobile due to limited access to education and training or a poor infrastructure system, while capital may be concentrated in a few large firms or industries.

For this particular report on the economic impact of standards on productivity in Jamaica, we have employed a Cobb-Douglas production function for our model, though it has been rearranged into a different set-up from the one in the prescribed within the ISO methodological guidance note (see Section 6.1 for more information).

Therefore, although we have a slightly altered Cobb-Douglas production function as our model (relative to the algebraic manipulation in the ISO methodological guidance note), we were able to use the recommended underlying economic framework. As such we find that Assumption 2 is sensible, even if it may be a slightly weaker assumption in the developing context given the general challenges discussed above. The weaknesses outlined above should not categorically prevent the application of this methodology in any given country.

Assumption 3: There is a one-way relationship between standards and growth

We have already discussed Assumption 3 in the section above and concede that while this assumption has its limitations, it is made because it allows the presented methodology to be simple enough for most countries to adopt, given capacity and capability constraints.

Therefore, this is a limitation of the framework more broadly, but it has no consequences for the applicability and effectiveness of the framework in the developing context specifically.

Assumption 4: Standards impact economic growth through an increase in TFP

Within ISO R&I's methodological guidance document, a logic model is presented that describes the theory behind the effects of standards on an economy, ultimately linking the development of standards with economic growth. It highlights the main mechanism through which standards improve economic growth: unity, compatibility, compliance, and security.

Then, through factors such as product and market uniformity, knowledge and technology diffusion, reduced technical barriers to trade, easier market access, enhanced consumer rights, economic growth is driven by four key channels: trade growth, innovation ability, business environment, plus safety and environmental protection. Zhang *et al.*'s logic model was in fact developed as part of a study into the effects of standards development on economic growth in China. The linkages presented are universal and there is no evidence to suggest that they break down in the Jamaican context. Based upon a review of the academic literature and our economic expertise, we see no compelling argument to dispute this assumption in the Jamaican (or developing) context.

It is also worth noting that there may be some drags to economic growth through the application of standards. For example, overly burdensome standards could lock in old technologies or lead to premature selection of technologies, which would be an inefficient allocation of resources. On top of this, standards have the potential to restrict choice and increase market concentration, especially if dominant players can wield excessive influence on regulatory agencies. While these linkages are a possibility, on a net basis, there is compelling evidence to suggest that standards have a positive impact on productivity and growth.

As mentioned, there is an argument to suggest that in the developing context, there are greater frictions to overcome across the transmission mechanism compared to a more advanced economy. However, the critical point is that the *intuition* behind the linkages considered by Zhang *et al*. appears appropriate. Unless we directly test these linkages, we cannot say with certainty whether this hypothesis is correct. Within our study, the intuition of the TFP variable is to capture many of these complex and competing effects. Therefore, the assumption that the transmission mechanism from standards to economic growth resides in an increase in total factor productivity is sound.

Nonetheless and as discussed, because we have decided not to use the two-stage approach for our analysis of Jamaica, there is no explicit role for TFP within our model. Therefore, we cannot know whether our estimated impact of standards on economic growth occurs through an increase in TFP. As we have calculated this through a rearranged Cobb-Douglas model, with the sole change being the replacing of the TFP term with further explanatory variables (such as standards), implicitly the only mechanism through which standards impacts growth logically is via an increase in TFP. As such, while this assumption about standards positively impacting growth through TFP seems like a reasonable hypothesis, we cannot definitively prove whether this assertion is true.

Assumption 5: Data on the relevant variables is available

The fifth assumption of the framework is that data on standards, labour, capital, productivity, and any other required variables is available for the country in question.

Overall, it is our view that the data limitations faced when conducting this research were highly restrictive and although we were able to produce a well performing Cobb-Douglas model, we were unable to elicit a statistically significant relationship between standards and labour productivity (or standards and TFP).

Namely, continuous data for the stock of standards was not available. Despite this, there was a reasonable breadth of data sets that were available for Jamaica. For example, data sources such as the World Bank, IMF, FRED, and the Penn World Tables provided sufficient data to produce a well performing model, however the main issue was with the length of the time series that were available. For example, we were only able to obtain reliable capital stock data up to 2019, while sale of standards data did not extend to periods before 2001. This meant that the maximum period of analysis was 19 years, below the threshold of 30 observations required for a statistically reliable result.

In a number of the other country-level studies conducted by Cebr as part of this wider pilot study, we were presented with a trade-off between including all relevant variables as outlined in the ISO methodology guidance or having a longer time series. As an example, data for stock of patents – one of the key variables as highlighted by ISO – did not extend before 2004 for Jamaica. As a result, we dropped patents from the model in order to increase the length of the time series by three periods despite the stock of patents in Jamaica being an important control variable.

In summary, whilst there was sufficient breadth of data to produce an indicative model for the impact of standards on labour productivity in Jamaica, Assumption 5 is relatively weak as the length of available data for the key variables was not sufficient. **Overall, with the use of a second-choice standards variable and an observation period of 19 years, we recommend that the results from this study are treated with a high degree of caution.**

The success of future research into the impact of standards on productivity in Jamaica will depend on how the quality of the available data improves over time.

Assumption 6: The economy exhibits constant returns to scale

Lastly, the Cobb-Douglas model assumes a constant returns to scale (CRS), which means that increasing inputs will result in a proportional increase in output. While this assumption may be defensible at the global level (as it assumes that at any one time, many firms will be enjoying increasing returns to scale, while others will be experiencing decreasing returns to scale), it may not hold for all countries, especially in the developing context.

For example, in a developing economy, there may be infrastructure constraints, limited labour mobility, inadequate education and training, weak regulatory frameworks, or the inability to efficiently use additional inputs which could create pressures that generate decreasing returns to scale.

On the other hand, developing economies may exhibit increasing returns to scale through high labour mobility, [63] through lower per-unit production costs and high international

63 Depending on the country, labour mobility may be a strength or a weakness. On one hand, a country with a large, young population will have a sizeable pool of workers to deploy in the regions or industries where they can be the most productively efficient. On the other hand, capacity constraints such as lack of housing stock,

competitiveness, through increasing marginal returns to investment in factors such as education, health, and welfare while the economy is still ‘young’, or through relatively high returns to capital which make developing economies attractive to foreign investors.

We discuss this topic in more detail within the Technical Appendix for Jamaica in Section 6.4. The limitations of the CRS assumption discussed in the appendix are generally accepted across the literature and on balance, we recommend that this assumption is sufficiently robust and defensible in the context of Jamaica.

Summary

Overall, the framework has had limited success in providing evidence of the impact of standards on productivity in Jamaica. We have not been able to exactly follow the exact steps suggested within the guidance document. Specifically, we have only been able to produce a model at the very lower bound on the number of observations using the same theoretical economic framework,[64] while applying this through an augmented single-stage Cobb-Douglas approach[65] due to data-related limitations.

We have presented a review of the key assumptions made by the framework in the context of Jamaica and find that **Assumption 5 is weak**, i.e., we are constrained by data availability. As a result, the effectiveness of the results is limited because we only have 19 periods of analysis and cannot be certain that our results are robust. Therefore, even though we find that there is a positive and statistically significant relationship between standards and labour productivity, we cannot be certain about this result due to the short period of 2001–2019.

It is worth highlighting that the limitations are not a consequence of the prescribed framework, rather it is external factors such as sparse data availability that have led to an insufficiently robust model being produced. As a result, a sound understanding of the relevant limitations is critical while the results of this study must be interpreted with a high degree of caution and considered indicative only.

6.3.2 Recommendations for Future Research

Our recommendations for future research centre around addressing the limitations of this study and overcoming the gaps in data availability.

Reducing data deprivation

First and foremost, the key limiting factor of this research was data deprivation. As highlighted by ISO, statistical models are only as good as the data that goes into them. In this instance, we did not have data for the stock of standards, data on patents only covered the period 2004 to 2019, and the maximum possible period of analysis was 2001 to 2019 – just 19 observations. Therefore, we see it as important to use this report as a call-to-action for data collection

lack of education and training, or an inadequate rail and road infrastructure may limit the ability of this labour to be efficient.

64 i.e., the Cobb-Douglas model.

65 As opposed to the two-stage least-squares approach that is recommended within the methodological guidance document whereby the impact of standards on labour productivity is indirectly calculated by first estimating the effect of standards on TFP, and then the effect of TFP on labour productivity. In this paper, we regress standards directly against labour productivity.

agencies – both national and supranational bodies alike – to continue their work to expand data libraries, with a particular focus on developing economies.

The concept of data deprivation is not new. Data serves as the foundation for meaningful policymaking, efficient resource allocation, and effective public service delivery. By improving the statistical coverage of the developing world, there will be more opportunities for robust economic analyses to contribute to the literature and advance society's collective knowledge base.

In general terms, a good example of this point is via the informal (or shadow) economy. The International Monetary Fund defines the 'shadow economy' to represent "illegal activities and unreported income from the production of legal goods and services, either from monetary or barter transactions, that would be taxable were they reported to the tax authorities." The livelihoods of individuals in developing economies often depends on these informal economic transactions.

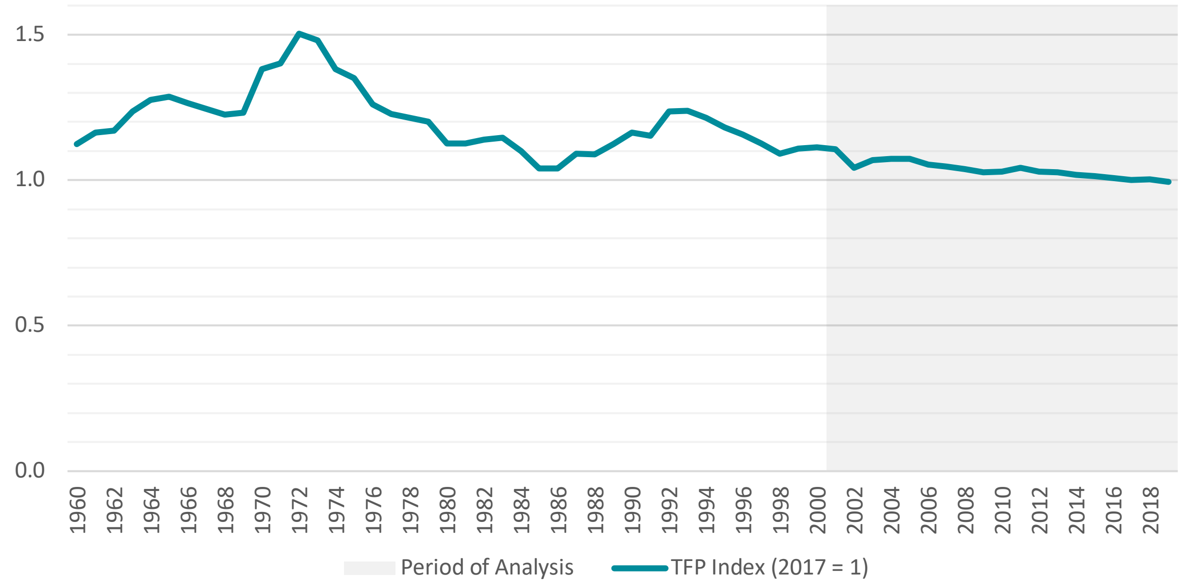
In 2021, Elgin *et al*. introduced a comprehensive dataset of informal economic activity across more than 160 economies for the period 1990-2018. For Jamaica, they estimate that **in 2018, the size of the informal economy represented 33.2% of official GDP**. The implication of this phenomenon is that official statistics are not able to accurately account for the large swathes of economic activity occurring beyond the view of the formal sector and formal statistics.

This means that empirical studies such as this may not reflect the "true" state of the economy because they are entirely reliant upon these official statistics such as GDP, capital stock, and labour force participation. Therefore, the relationships between key variables that are established in the model – in this case, standards and labour productivity – may behave differently or break down altogether in the real world.

In the context of this study, improved data availability would be very beneficial, especially because over the last three decades, the Jamaica economy has been suffering from declining total factor productivity and labour productivity, heightening the importance of the use of relevant control variables to elucidate the expected positive relationship between standards and productivity.

To this point, in his 2011 address to the Jamaica Chamber of Commerce, Brian Wynter, former Governor of the Bank of Jamaica, highlighted that over the period 1990 to 2010, total factor productivity declined at an average rate of 2.1 per cent every year. Furthermore, labour productivity contracted at an average rate of 0.5 per cent per year over the same period according to Bank of Jamaica sources. Figure 18 below shows the trend of TFP from 1960 to 2019, demonstrating the decline since the early 1990s and that the trend observed by the BOJ in 2011 has broadly been maintained. Other than a brief period of growth between the mid-1980s and the early 1990s, TFP in Jamaica has been on a steadily declining path since the early 1970s.

Figure 18: Total factor productivity Index for Jamaica, 2017 = 1, 1960–2019



Sources: Penn World Tables and Cebr analysis

Within the Bank of Jamaica address, the proposed causes of the declining productivity levels included deficiencies in human capital, high levels of crime, and fiscal distortions. Then, more than a decade later in the 2022 Article IV report by the IMF, boosting total factor productivity was still on the policy agenda, and still the same deficiencies were responsible. While these factors are certainly measurable and could be incorporated into a regression analysis, they were not able to adequately control for the negative trend.

Rather, a separate phenomenon related to a generally low work ethic is also suggested to have contributed to Jamaica's low productivity and economic growth. In fact, this was the fourth topic highlighted by the Bank of Jamaica in 2011, who reference a 1996 World Bank study looking into the same issue. This is a longstanding concern for the country, however the causes are to do with workplace attitudes, bad worker-management relations, and a generally poor work ethic. These are particularly difficult themes to accurately and consistently value, measure, and track over time. Therefore, this has limited our ability to control for the negative trend in productivity in order to demonstrate the anticipated positive effect that standards exhibit on Jamaican productivity.

Finally, it is noteworthy that **we are only able to capture a snapshot of the relationship between standards and productivity as highlighted by the short period of analysis in Figure 18.** By reducing the degree of data deprivation through an expansion of the time series data on standards in Jamaica (amongst other things), a greater observation period would be unlocked, in which the prescribed two-stage approach would have potentially been successful.

In summary, due to limited data availability in Jamaica for all of the required variables, we have not been able to comprehensively assess the relationship between standards and productivity in a robust way using regression analysis. We recommend that as the statistical capacity of Jamaica is gradually improved, the analysis should be re-conducted with this context in mind and test how the role of standards has changed through recent Jamaican history.

Uncovering 'black box' variables

One important criticism of generalised macroeconomic models such as the one used in this study – and by most of the other national level studies in this space – is that **the relationship between standards and productivity is treated as something of a 'black box'**.

There is one notable difference between our model and the original one prescribed by ISO in its methodological guidance note: by substituting in our explanatory variables into the TFP term (A) we are altering our model from estimating the indirect impact of standards on labour productivity (though an increase in TFP) to being an estimate of the direct impact of standards on productivity. Although we know the magnitude of this impact, we still definitively do not know the underlying mechanisms through which this occurs.

The academic literature shows compelling evidence to suggest that standards enhance productivity and economic growth at the national level. In practice, this means that standards will help drive companies and their associated supply chains to operate more efficiently, thus reducing costs, expanding revenue opportunities, and ultimately allowing companies and sectors to become more productive and profitable.

On one hand, we can use our economic intuition and critically assess the credibility of the linkages suggested within Zhang *et al.*'s logic model in the context of Jamaica. However, on the other hand, we do not quantitatively assess the mechanisms by which standards generate increased productivity within this study. Other studies in the space have been conducted at the company level using sector- or firm-level data derived from secondary sources, primary surveys, or case studies.[66]

Some national standards bodies publish standards data at the sectoral level. Parallel to the recommendation to reduce data deprivation, any additional granularity for the stock of standards data will likely be beneficial in allowing practitioners to conduct more in-depth research. In turn, this will help to maximise policy impact by identifying the key channels in which standards manifest and ultimately drive productivity and growth in the country.

Identifying the direction of causality between standards and productivity

Finally, **an assessment of the direction of the relationship between standards and productivity** would be an insightful avenue for further research. There is a virtuous cycle between standards and economic growth – whereby standards drive growth which subsequently drives standards which drives further growth, and so on – however, we have not tested this relationship as part of this study.

The prescribed framework does not account for this two-way relationship for reasons of methodological simplicity. While the quality of results may not be affected by the choice to model the relationship between standards and economic growth as one-way, there is still additional insight that could be gained from future research.

For example, one common option is to find a 'cointegrating' relationship between the key variables whereby there exists a stable long-run statistical relationship. Statistical tests can confirm if this relationship is non-spurious and whether it exists between standards and productivity. A similar approach was applied by Cebr in a 2015 study assessing the contribution of standards to UK productivity.

Other options are to use methods such as a Granger causality test which assesses whether one time series is an effective forecaster of another. This test is somewhat of a misnomer as it does not provide insight into a true cause-and-effect relationship. Rather, if standards were

66 These include DIN (2000), Conference Board of Canada for the Standards Council of Canada (2007), AFNOR (2009), BERL Economics for The Standards Council of New Zealand (2011) and Menon Economics (2018).

found to Granger-cause productivity, then this would demonstrate that historic increases in standards are related to increases in productivity today.

This is by no means an exhaustive list of econometric methods that could be used to extend beyond correlation analysis, but these more advanced techniques would require expansions to the prescribed methodological approach. Given that one of ISO's core aims is to expand the evidence base across developing economies, we would recommend that the prescribed framework is applied as an initial starting point due to its relative simplicity, while the more advanced techniques are applied in further studies.

6.4 Technical Appendix: Jamaica

6.4.1 Detailed methodology and results

In this sub-section, we present detailed results of the regression analysis, with accompanying explanation of the specific techniques used. These results are included for reasons of accountability and transparency. All technical shortcomings and limitations are made clear to help ensure that the results of this study are used appropriately.

As explained in Section 6.1, our initial goal was to estimate the impact of increasing the stock of standards on economic growth in Jamaica using a two-equation system, as prescribed by the ISO methodological guidance. However, due to data deprivation this was not feasible, so we opted for a single-stage regression approach using the sale of standards data.

Below we present how the Cobb-Douglas production function can be rearranged to produce the key regressor equations for the first- and second-stage models, and the final step ultimately utilised to derive the used one-stage equation.

Table 23 presents the full results for the first of these equations.

Rearranging the Cobb-Douglas production function

Below we show in five steps how the Cobb-Douglas production function can be transformed and rearranged to produce the key regressor equations used in the first- and second-stage models:

$$Y_t = A_t L_t^{1-\alpha} K_t^{\alpha}$$

Step 1 – linearise the Cobb-Douglas above by taking natural logarithms:

$$ln(Y_t) = ln(A_t L_t^{\alpha} K_t^{1-\alpha}) = ln(A_t) + (1-\alpha)\, ln(L_t) + \alpha\, ln(K_t) + \epsilon_t$$

Step 2 – rearrange as a function of labour productivity:

$$ln(Y_t) - ln(L_t) = ln(A_t) + \alpha\,[ln(K_t) - ln(L_t)] + \epsilon_t$$

Step 3 – as above but expressed in used form:

$$ln\left(\frac{Y_t}{L_t}\right) = ln(Labour\ Productivity_t) = \beta_1 ln\,(A_t) + \beta_2 ln\left(\frac{K_t}{L_t}\right) + \epsilon_t$$

Step 4 – TFP variable isolated and expressed as a function of standards plus other necessary control variables:

$$\ln(A_t) = \gamma_0 + \gamma_1 \ln\,(Standards_t) + \gamma_2 \ln(Patents_t) + \cdots + \gamma_n \ln(n_t) + \mu_t$$

Step 5 – augmented specification to sidestep the 2SLS framework:

$$ln\left(\frac{Y_t}{L_t}\right) = \gamma_0 + \gamma_1 ln\,(Standards_t) + \gamma_n ln(n_t) + \ \beta_2 ln\left(\frac{K_t}{L_t}\right) + \ \epsilon_t$$

For the Jamaican study, Step 5 is the key equation, whereby standards are directly regressed against labour productivity. This augmented specification sidesteps the indirect approach using Step 3 and 4 above. Practically, this means that we do not estimate the impact of standards on TFP, nor the impact of TFP on labour productivity (as we otherwise would do in the two-equation system).

Single-stage model

Equation 12: The log-linearised Cobb-Douglas production function, rearranged as a function of labour productivity.

$$ln(Labour\ Productivity_t)\ =\ \gamma_0 +$$
$$\gamma_1 ln\,(Sale\ of\ Standards_t) +\ \gamma_2 Current\ Account\ Balance_t +\ \gamma_3\ ln(Net\ Emigration_t) +\ \beta_2 ln\left(\frac{K_t}{L_t}\right) +\ \epsilon_t$$

Table 23: Full regression results for Equation 12

Dependent Variable:	ln Labour Productivity
Method:	Ordinary Least Squares
Date:	2001-2019
Observations:	19

Overall Fit			
Multiple R	0.999998	AIC	-127.0
R Square	0.999996	AICc	-122.4
Adjusted R Square	0.999995	SBC	-123.2
Standard Error	0.032236		

ANOVA	df	SS	MS	F	p-value
Regression	4	3,842.6	960.6	924,433.9	0.000***
Residual	15	0.0	0.0		
Total	19	3,842.6			

Term	Coefficient	Std. Error	t-statistic	p-value	VIF
Ln K/L	0.750	0.040	18.767	0.000***	1.63
Ln Sale of Standards	0.018	0.010	1.765	0.098*	3.27
Current Account Balance (Real J$tr)	-0.0001	0.001	-0.092	0.928	1.66
Ln Net Emigration	0.182	0.062	2.927	0.010**	3.36

Source: Penn World Tables, World Bank, IMF, and Cebr analysis

Note: Asterisks *, **, and *** are added to denote a significant relationship at the 10%, 5%, and 1% levels, respectively.

As demonstrated by the F-statistic and the adjusted R squared statistic, respectively, this overall model specification is both highly significant and effective at explaining movements in the dependent variable.

The Gauss-Markov theorem shows that when certain conditions are satisfied, OLS coefficients will be the Best Linear Unbiased Estimates; hence, BLUE. When the assumption for homogeneity of variance is violated within the ordinary least squares regression method, the regression coefficients will not be BLUE. While they do remain unbiased, i.e., they will be correct on average, but they will not be efficient since they no longer have minimum variance, i.e., they will not be the 'best'. Therefore, it is important to test for heterogeneity of variance, commonly known as heteroscedasticity within statistics, to ensure that the model coefficients are the 'best'.

To do this we performed the Breusch-Pagan test to determine if heteroscedasticity was present in our model. The p-value for this test was 0.85, which is below the threshold of 0.05, suggesting that there was no evidence of heteroscedasticity within our data. We also note that this test should only be used when the residuals are normally distributed. We applied the Shapiro-Wilk test and the D'Agostino-Pearson test to assess the normality of the data and found that the residuals were normally distrusted and therefore we can be confident in the results of the Breusch-Pagan test.[67]

We also test for autocorrelation within the model. Autocorrelation is the degree of correlation of the same variables between two successive time intervals. It measures how the lagged version of the value of a variable is related to the original version of it in a time series. Autocorrelation is a problem because it leads to inefficient estimates (i.e., they do not have minimum variance) hence our confidence in the result is lowered if autocorrelation is present. Using a Durbin-Watson test, we find that the test statistic (1.72) is between the upper (1.85) and lower (0.86) values and is closer to the upper value. Therefore, while the result is inconclusive, there is no direct evidence of autocorrelation present.

Finally, we also note the variance inflation factor (VIF) score for each term in the regression model. The VIF score of an independent variable represents how well each variable in the equation is explained by other the other independent variables, in other words, the correlation of each predictor with the other predictors. This is known as multicollinearity.

As a general rule of thumb, a VIF score of less than 1 shows that the variables are not correlated, between 1 and 5 shows that there is moderate correlation, and above 10 indicates that the results from the regression model will become unreliable. Although there is some multicollinearity present in the data, our final model does not show cause for concern: the highest VIF is less than 5, so there is no strong evidence that multicollinearity persists in our chosen econometric specification.

6.4.2 Limitations and Caveats

Aside from the conceptual discussion about different methodological approaches to estimate the impact of standards on labour productivity through a single-equation approach or a two-stage approach via TFP, **the critical limitation of this analysis is that the analysis period**

67 For completeness, we also applied White's test for heteroscedastic errors which produced a result to suggest that the variances for the errors are in fact equal. However, the validity of this result is also highly dubious given that this test should only be used on large samples, where ours is not.

is just 19 years. This means that the results can only be considered indicative, rather than statistically robust.

Beyond this, the assumption about constant returns to scale, or CRS, (see Assumption 6 under Section 6.3) is worth discussing in more detail. CRS is implied when the sum of the output elasticities on labour and capital equal one. If their sum is less than one, then decreasing returns to scale are present, and vice versa for a sum of more than one. The empirical literature on the extent to which CRS is a realistic characteristic that countries exhibit is relatively sparse and slightly ambiguous.

In the case of Jamaica, a 2021 working paper by the Bank of Jamaica determined that Jamaica's production function exhibits constant returns to scale at the 1 per cent level of significance. This provides strong evidence to support the applicability of the CRS assumption in the context of this study given that the BOJ paper covers the same observation period as this research.

On the other hand, studies such as Harris and Liu (1999), estimate increasing returns to scale for most countries around the world, including several in Latin America. Their result for Jamaica between 1965 and 1990 finds the long-run estimation of returns to scale as 1.2. Given the observation period does not overlap with this study, while insightful, the applicability is weaker than the BOJ paper.

Accurately and consistently calculating estimates for returns to scale is difficult. McCombie and Roberts (2007) showed that the values for returns to scale depend on how these are estimated and that these often yield significantly different results. Despite this, the use of the CRS assumption is widely accepted across the economic literature.

Many other countries to which this ISO standards framework has been applied have been found to exhibit returns to scale that are not equal to one. For example, Golany and Thore (1997) present an empirical evaluation of the returns to scale across 72 developed and developing countries between 1970 and 1985 – a period covered by many of the other studies assessing the economic impact of standards.[68] They conclude that the United Kingdom, the Scandinavian countries, Australia, and New Zealand all exhibit decreasing returns to scale, while many less advanced economies exhibit increasing returns to scale.

Ultimately, the strong evidence from the Bank of Jamaica is sufficient for us to be confident about the application of the CRS assumption in this study.

6.4.3 Sensitivity Testing

In this subsection, the aim is to highlight the consistency of the estimator for standards depending on control variables by gradually adding new variables and changing the structural specification of the regression model to demonstrate stability.

In the case of Jamaica, we have not been able to construct a suite of results that are not only robust but that also show the impact of standards to be significant. Combinations of other variables yielded unsatisfactory models that we had to discard as they tended to be mis-specified, overfitted, or suffered from unacceptably high levels of multicollinearity. This is the reason why we could not shortlist a few suitable models to assess the consistency of the estimator for standards.

68 See Section 1.5.

Finally, since we could not control for patents due to data limitations, it is likely that we are overestimating the effect of standards on labour productivity given the omission of patents.

Chapter 7: The Economic Impact of Standards in Senegal

7.1 Summary of the Used Methodological Approach

Due to the lack of data on TFP in Senegal, we were unable to follow the two-stage process as outlined above. In other words, it was not possible to estimate the effect of standards on TFP (Equation 3) and the effect of TFP on labour productivity (Equation 2).

In the ISO methodological note, it is suggested that, in the absence of official TFP data, it is possible to multiply the measure of the volume of labour and the measure of the volume of capital and then take real GDP divided by this number to yield a very approximate measure of TFP. However, in our view, the calculation described above yields the ratio of real GDP to the combined labour and capital input, which is known as labour and capital productivity, but it does not isolate the TFP component. TFP represents the portion of output growth that cannot be attributed to changes in labour and capital inputs alone. It captures the efficiency, technological progress, and other factors that impact output beyond the measured inputs. Calculating TFP requires a more comprehensive approach that explicitly accounts for labour and capital inputs separately. To estimate TFP, we typically employ econometric techniques and production function estimation and analyse the unexplained residual in the relationship between output and labour and capital inputs, considering the effects of factors other than labour and capital. This, however, goes beyond the scope of this report.

To address this issue, and while staying within the wider Cobb-Douglas framework, we estimated the effect of standards directly on labour productivity by embedding Equation 3 into Equation 2. In other words, instead of employing a two-stage model whereby standards are assumed to indirectly impact labour productivity through an increase in TFP, we use a single-stage model where we explicitly estimate the direct impact of standards on labour productivity.

Although the step-by-step process may be different from the one set out by ISO, conceptually both are still attempting to do the same thing – they should be interpreted as different algebraic rearrangements of the same core model: the Cobb-Douglas production function. Whereas the two-stage approach leaves in terms for both capital and labour as well as TFP (A), with the single equation seen below, we maintain capital and labour within the model through the k term (which denotes the capital-employment ratio), and then we simply substitute TFP with our list of explanatory variables (including standards), which we explain further below.

The one caveat to note about this altered model is that by removing the TFP term and substituting it with the explanatory variables discussed, we are in effect no longer directly quantifying the explicit role of TFP. As a reminder, TFP is essentially the "catch-all" term for everything that affects economic output that's not capital or labour. It will include the specific explanatory variables we use – such as standards – but it is likely to include many other external factors that are not estimated or accounted for in our model (these include poor competitiveness and low infrastructure quality, amongst others, which are harder to quantify). As such, although the single-stage model we have used is the best at estimating the isolated impact of standards on labour productivity, it is more limited when it comes to identifying the relationship between TFP and labour productivity.

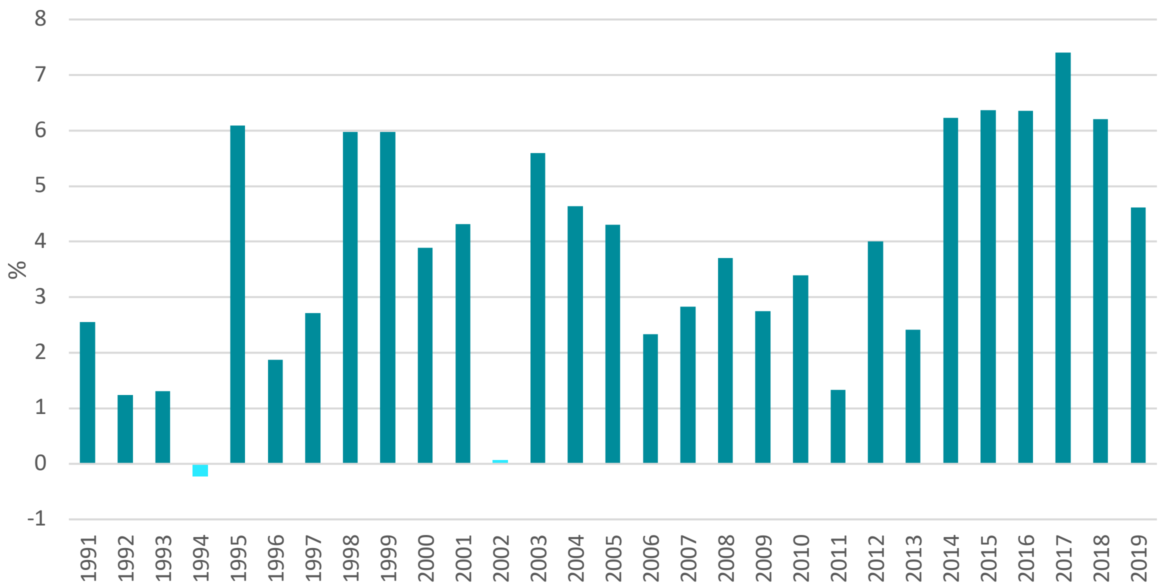
Equation 13: The augmented log-linearised Cobb-Douglas production function, embedding the determinants of TFP.

$$ln(Labour\ Productivity_t) = \underbrace{\gamma_0 + \gamma_1 ln\ (Standards_t) + \gamma_2 Recession_t}_{\textbf{TFP}} + \beta_2 ln\left(\frac{K_t}{L_t}\right) + \epsilon_t$$

In this equation, to represent technological progress and explain movements in total factor productivity in Senegal, alongside the stock of standards, we use a dummy variable representing years where there has been a recession or an abnormal decrease in real GDP growth as a control variable. We could not include patents in the model as the availability of data on patents in Senegal is limited.

We include a dummy variable for periods of economic recessions or crises to improve the accuracy of the model by accounting for important structural breaks or shifts in the relationship between standards and labour productivity. These exceptional periods may exhibit different dynamics and relationships compared to normal periods, and incorporating a dummy variable allows the model to capture and reflect these changes more accurately. Figure 19 below shows real GDP growth in Senegal between 1991 and 2019. During this period, the average GDP growth rate was 3.8%. Two notable deviations from this mean rate occurred in 1994 where GDP growth was negative and in 2002 where the economy grew by only 0.07%. This was the result of severe drought conditions in 1994, for instance, resulting in poor harvests and a decline in agricultural production coupled with fiscal austerity measures which resulted in short-term economic hardships. We hence include a dummy variable to these two years of uncharacteristic volatility to control for their influence in the analysis and isolate more effectively any outlying changes in the trend for productivity, which would otherwise obfuscate the true effect of standards on productivity that we are attempting to identify. This helps to ensure that the estimated coefficient for standards is not biased by the presence of outliers.

Figure 19: Real GDP growth, 1991–2019



Source: IMF WEO

7.2 Findings

7.2.1 Quantitative results

The analysis reveals a weak but significant relationship between standards and labour productivity. Our regression result for Senegal tells us that **a one percent increase in the net stock of standards is associated with a 0.078 percent increase in labour productivity**, where labour productivity is measured as real GDP per worker.

The key quantitative results can be seen below.

Table 24: Summary results for Equation 13, 1994–2019

Term	Coefficient	Standard Error	t-statistic	p-value	Significance
Intercept	6.875	0.108	63.903	0.000	***
ln (K/L)	0.066	0.025	2.630	0.015	**
ln Standards	**0.078**	0.033	2.336	0.028	**
Recession dummy	-0.038	0.018	-2.074	0.049	**

Source: ILO, ASN, IMF, and Cebr analysis

Note: Asterisks *, **, and *** are added to denote a significant relationship at the 10%, 5%, and 1% levels, respectively.

Our model reveals that both standards and the capital-to-labour ratio are positively related to labour productivity while the dummy variable for economic recession has a significant and negative impact on labour productivity. All variables in the above summary table are statistically significant at the 5% level or higher. For more detailed statistical information regarding the model, please see the Technical Appendix.

7.2.2 Discussion

Contribution of standards to economic growth

The findings above posit that a one percent growth of the stock of standards is associated with an increase in labour productivity of 0.078 percent across Senegal. In terms of economic growth this has the following implications:

- Between 1991 and 2019, the net stock of standards in Senegal grew by an average of 8.4% year-on-year, while the average year-on-year growth of labour productivity was 0.84%. Applying the elasticity of standards with respect to labour productivity (0.078) to the average growth in the stock of standards, we find that standards are associated with 78.0% of the growth in labour productivity and 17.1% of GDP growth in Senegal during the period 1991 to 2019.
- If we unpack this finding, we find that standards are associated with, on average, 0.65 percentage points of growth in labour productivity during the period. But, as mentioned above, labour productivity only grew by 0.84% per year on average. What this means is that while standards contributed 0.65 percentage point to labour productivity growth, other external factors that are not estimated or accounted for in our model were bringing down labour productivity growth such that its net growth was only 0.84%
- As we explain below, this is in large part due to the shorter time frame due to data limitations, which makes these estimates much more sensitive to outliers and disturbances during the time period we are considering.
- For the purposes of expressing the findings in monetary terms, if it is assumed that the estimated impact is constant over time, standardisation at the national level would be

associated with approximately 103.3 billion CFA Francs of the 604.8 billion CFA Francs of GDP growth recorded in 2019 (IMF, 2019 prices).[69]

Table 25 below presents a summary of results for other countries compared in the literature. This is not an exhaustive list of studies but a selection of those that provide details on the contribution of standards to economic growth.

Table 25: Comparison of relevant summary results of national studies[70]

Country	Senegal	Canada	France	Germany	Nordic	UK	UK
Publication year	**2023**	2007	2009	2000	2018	2005	2015
Analysis period	**1991-2019**	1981-2004	1950-2007	1961-1990	1976-2016	1948-2002	1921-2013
Estimated function[71]	**LP**	LP	GDP	GDP	LP	LP	LP
Elasticity of stock of standards	**0.078**	0.36	0.12	0.07	0.11	0.05	0.11
Share of labour productivity growth	**78.0%**	17.0%	27.1%	30.1%	39.5%	13.0%	37.4%
Growth rate of GDP, % p.a.	**3.8%**	2.7%	3.4%	3.3%	2.5%	2.5%	2.4%
Share of GDP growth	**17.1%**	9.2%	23.5%	27.4%	28.0%	11.0%	28.4%
Contribution of standards to GDP growth, % points	**0.7%**	0.3%	0.8%	0.9%	0.7%	0.3%	0.7%

Source: Standards Council of Canada (2007), AFNOR (2009), DIN (2000), Menon (2018), DTI (2005), and Cebr analysis

Standards can enhance labour productivity by increasing output per employee at individual firms. This can be achieved through various mechanisms such as improving production activity and efficiency, ensuring quality and precision, and spreading technical information and best practices. These improvements in organisational performance lead to cost savings, enabling firms to achieve higher output per worker. Additionally, standards allow firms to build on their strengths and specialise, leading to better division of labour, economies of scale, and increased output per staff member.

However, in the case of Senegal, the figures derived above should be treated with caution. The extrapolation to estimate the share of labour productivity growth and GDP growth attributable to the increase in standards is based on a point-to-point analysis between 1991 and 2019 where we assume a constant growth rate of these variables between these years; notably a 0.84% annual growth in productivity. In reality, labour productivity growth has been more volatile. Anchoring the analysis in 2019 (which can be considered as an outlier due to a sharp fall in productivity that year) results in the low average productivity growth of 0.84%. This has the effect of overestimating the share of productivity growth attributed to standards,

69 As a point of reference, this figure converts to approximately $176.5 million out of $1 billion in GDP growth in 2019, based on the 2019 US dollar exchange rate.

70 Note that not all the studies from Table 3 are presented here; only those that estimated the share of labour productivity of GDP growth associated with standardisation are included in this table. For a similar comparison with the other developing countries assessed within this study, see Section 9.1.

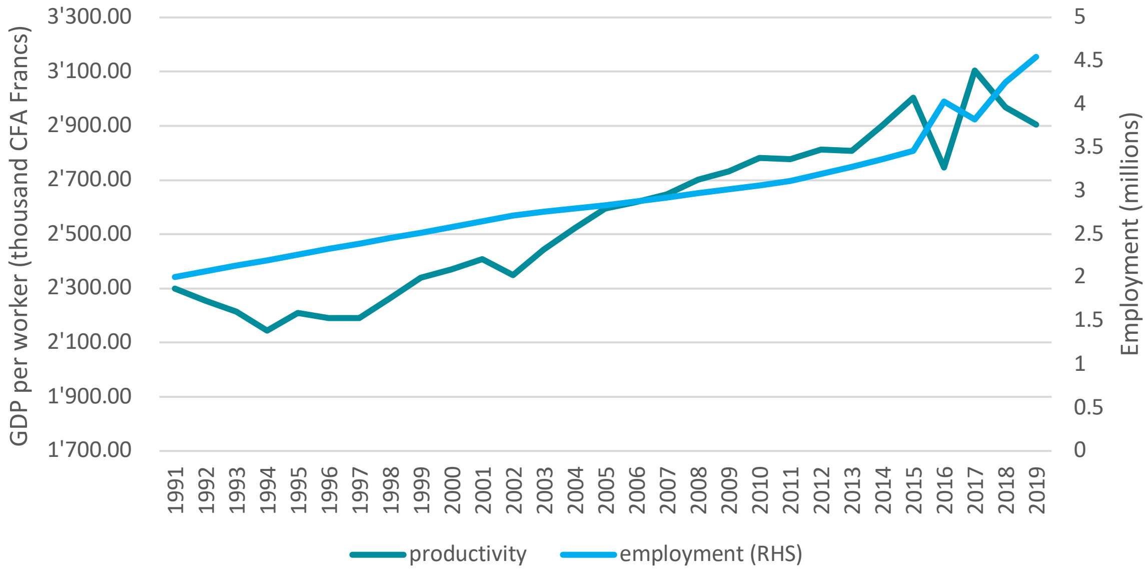
71 LP = Labour Productivity. GDP = Gross Domestic Product.

as we see in Table 25 above with the estimated share of 78%, compared to 58%, for instance, if we anchored the analysis between 1991 and 2015. The reason for having some outliers and disturbances in labour productivity can be traced to the source data on the number of persons in employment, which is the indicator that underpins labour productivity.

For this analysis, we resorted to the International Labour Organization's modelled estimates for employed population in Senegal due to the scarcity of regular and robust labour market data from national official sources. As shown in Figure 20 below, the modelled estimates for employment have been increasing steadily until 2015, after which some unusual volatility is observed, with a sudden jump of 16% in the number of employed persons in 2016. For comparison, the annual average growth in employment between 1991 and 2015 was 2.3%. This resulted in an abrupt fall in estimated labour productivity, dragging down its average growth over the whole period. Moreover, given the shorter time series for Senegal compared to the other country studies – except Canada and Germany, all have at least 50 years' worth of data – the results above are not directly comparable because the average growth in labour productivity in Senegal is much more sensitive to outliers and disturbances during the time period we are considering.

That said, while the interpretation of the above extrapolated estimates should be made with caution, the underlying elasticity of standards on labour productivity derived from our model remains a reliable and robust estimate. Our model uses a robust estimation method that is designed to be more resilient to outliers and data irregularities. For more detailed information on the regression method used in our model, please see the relevant Technical Appendix (Section 7.4).

Figure 20: Evolution of employment and labour productivity, 1991–2019



Source: ILO, IMF, and Cebr analysis

More generally, caution should be taken when interpreting these estimates as standards have an interdependent role in driving labour productivity along with other knowledge factors such as higher levels of education and training, advances in technology and increased innovative efforts. This means that standards play a mutually dependent and complementary role alongside other factors, such as those mentioned above, in facilitating productivity growth. Beyond standards having a direct impact on labour productivity, they are also associated with driving these other knowledge factors, and these then result in an increased value of standards. Equally, an improvement in the other knowledge factors leads to standards playing a more efficient role in boosting labour productivity.

Limitations and Caveats

For reasons of transparency and accountability, as well as to avoid any inappropriate conclusions being made, it is important to highlight some of the key limitations of this research.

First and foremost, our **analysis is exclusively focused on the assessment of the correlation between standards and productivity, rather than causality**. Correlation between variables simply means that they are related, and that as one variable changes, the other does as well, but it does not mean that the change in one of the variables (e.g. productivity) is *caused* by the change in the other variable (e.g. standards). Causality, or causation, is when there is a causal relationship between two variables, i.e. that the change in one variable is caused by a change in the other. Further research would be valuable to be able to establish a *causal* relationship between the standards and productivity. That is, the identification of a direct cause-and-effect relationship between the two variables in Senegal.

We have also not considered the direction of causality between the variables and cannot pass comment on the potential for endogeneity for the stock of standards in the context of Senegal In other words, this study does not attempt to investigate which of standards or growth drives the other, merely that they are connected and, when one changes, so does the other.[72] An example of the two-way relationship between standards and growth is highlighted by a logic model produced by Zhang *et al.* (2019). They suggest that additional growth and technological progress brings about changes in environment and resources, which in turn leads to the emergence and application of new goods and services. The resulting lack of standards for new products forces the evolution of standards, while more firms lead to more enterprise and enterprise-dominated standards. Ultimately, there is potential for a virtuous cycle between standards and economic growth, but the applied framework does not account for this two-way relationship. Further research is required here.

Furthermore, **the analysis period of 1991 to 2019 is relatively short, covering only 29 periods** of continuous data. According to the methodological guidance document produced by ISO, the very lower bound (or minimum recommended amount) for the number of observations is likely to be somewhere around 15, and it is preferable to have at least 30 periods of data such that the Central Limit Theorem applies.[73] That said, in the case of Senegal, a larger time frame would be even more optimal as additional observations would enable us to capture underlying dynamics more accurately, in view of the high volatility and irregular patterns that have been observed and discussed above. While we have continuous data for standards between 1983 and 2022, employment data is only available from 1991 to 2019, so there is a constraining factor on the period of analysis due to the availability of

72 Moreover, endogeneity is simply a term in econometrics which describes when a variable of interest (such as standards) is affected by other variables in the analysis. This can be problematic as it may lead to biased and unreliable estimates of the effect of standards (with endogeneity we cannot be sure whether our model is saying that standards have a positive effect on growth, or if it's some other explanatory variable).

73 For datasets with less than 15 observations, it is harder to estimate the coefficients that describe the relationship between our variables of interest, and it can also lead to wider confidence intervals around the estimated coefficients (confidence intervals five us a range within which we are reasonably confident that the true value lies).

employment data from the ILO. The average number of observations in the other studies referenced in Table 25

is around 50. Since this study has an observation period of 29 years, this analysis is on the threshold of what can be considered statistically robust.

Cebr are also keen to urge a degree of caution when interpreting these findings. Crucially, **the relationship between standards and productivity is somewhat of a 'black box'** and we have not attempted to incorporate a quantitative assessment of the mechanisms through which standards generate increased productivity. In other words, while we have determined that standards increase productivity, we have not determined *how* or *why* they do so. It is beyond the scope of this report to develop a richer understanding of these mechanisms and their effects, but studies at the company level, using firm-level data derived from surveys or case studies, have been conducted in the past and can assist here.[74]

Lastly, it should be recognised that standards alone do not drive productivity. Rather, they play a mutually dependent and complementary role in facilitating the growth of productivity, along with other types of knowledge such as enhancements in education and progressions in technology. While we have attempted to control for key other potential explanatory factors, the model does not explicitly control for **all other** potential components of TFP. The model is instead an attempt to disentangle the effects of standards from other complementary factors that drive productivity, recognising also the constraints of the available country-level data.

7.3 Review of ISO Methodological Framework

7.3.1 Applicability and Effectiveness

To evaluate the applicability and effectiveness of the prescribed methodological framework, we first consider the key assumptions that are made to apply the two-stage least-squares approach[75] and discuss whether these assumptions are appropriate in this context. Then secondly, we consider whether we have been able to follow the same system of equations to estimate the indirect effect of standards on labour productivity.

The six explicit assumptions made by the methodology are as follows:

- Assumption 1: A stock of standards is a credible proxy for the extent to which standards are effectively utilised in the country.
- Assumption 2: The Cobb-Douglas production function is appropriate as an approximate model.
- Assumption 3: There is a one-way relationship between standards and economic growth.

74 These include DIN (2000), Conference Board of Canada for the Standards Council of Canada (2007), AFNOR (2009), BERL Economics for The Standards Council of New Zealand (2011) and Menon Economics (2018).

75 Two-stage least-squares (or 2SLS) is a common regression analysis technique which is used when the dependent variable's error terms are correlated with the independent variables. By using a two-step approach, 2SLS helps us isolate the true effect of standards on productivity by effectively removing the influence of other variables.

- Assumption 4: The appropriate transmission mechanism from standards to economic growth resides in an increase in total factor productivity.
- Assumption 5: Data on standards, labour, capital, productivity, and any other variables is available.
- Assumption 6: The economy exhibits constant returns to scale.

Assumption 1: Stock of standards as a credible proxy

The assumption that the stock of standards is a credible proxy for the extent to which standards are effectively utilised is borne out of pragmatism. Across the literature, this is the accepted approach despite its limitations. For example, while it is true that a significant number of standards may indicate that a country is committed to promoting and maintaining standards, it does not guarantee that these standards are effective.

Beyond simply the quantity of standards, effective standards concern the quality, relevance, implementation, and enforcement of standards in an economy. On one level, a large stock of standards may generate a degree of confusion among stakeholders, making it difficult for organisations to determine which standards are relevant to their needs. Furthermore, the standards may not be effective in achieving their intended goals if they are poorly written, outdated, or not based on the best available science or research.

In addition, the introduction of each new standard may not produce a proportional economic benefit. The assumption that the stock of standards is a robust representation of how standards contribute to the economy is equivalent to the assumption that each standard contributes an equivalent benefit to the economy. This assumption is unlikely to fully hold because newer standards are expected to offer greater benefits than older standards in the national catalogue. Furthermore, the impact of standards on the economy is also generated by the breadth of their use, and thus, some standards are more widely used, and thus more impactful.

Ultimately, while there are limitations to Assumption 1, these are not unique to the Senegalese context and the stock of standards is the best available option for our research.

Assumption 2: Cobb-Douglas production function is appropriate as a model

Economists use production functions to describe what can be produced given a set of inputs, which are typically simplified into capital and labour. Different combinations of capital and labour can be used to produce the same output. The example given by the ISO guidance document suggests that to make a hole in the ground, one can use a person and a spade, two people and two smaller spades, or one person and an excavator. This reflects a microeconomic phenomenon where capital and labour are substitutable. Any macroeconomic model must be consistent with this, and the Cobb-Douglas form is one of the most widely used and practical models within the field.

The use of the Cobb-Douglas production function as an approximate model is a pragmatic middle ground between an ideal world where economic models perfectly describe reality, and the real world where the model must be workable (i.e., linear, in this case).

The major strength of the Cobb-Douglas production function is its ease of use. However, there is a great deal of contradiction within the academic literature with respect to the empirical validity of the Cobb-Douglas functional form. On one hand, Miller (2008), Abidemi (2010), Adetunji *et al.* (2012) and Husain (2016) provide some support evidence for the specification of the model. While on the other hand, papers such as Fraser (2002), and Gechert *et al.* (2019) cast some doubt on the appropriateness of the Cobb-Douglas production function.

In the specific context of a developing economy, there may be some issues that are not present in other contexts, e.g., limited factor mobility (i.e. factor inputs such as labour, capital, or land cannot easily switch between alternative uses without a loss of efficiency). The Cobb-Douglas model assumes a high level of capital and labour mobility, which may not be present in a developing economy. For example, labour may be immobile due to limited access to education and training or a poor infrastructure system, while capital may be concentrated in a few large firms or industries.

For this particular report on the economic impact of standards on productivity in Senegal, we have employed a Cobb-Douglas production function for our model, though it has been rearranged into a different set-up from the one in the prescribed within the ISO methodological guidance note (see Section 7.1 for more information).

Therefore, although we have a slightly altered Cobb-Douglas production function as our model (relative to the algebraic manipulation in the ISO methodological guidance note), we were able to use the recommended underlying economic framework. As such we find that Assumption 2 is sensible, even if it may be a slightly weaker assumption in the developing context given the general challenges discussed above. The weaknesses outlined above should not categorically prevent the application of this methodology in any given country.

Assumption 3: There is a one-way relationship between standards and growth

We have already discussed Assumption 3 in the section above and concede that while this assumption has its limitations, it is made because it allows the presented methodology to be simple enough for most countries to adopt, given capacity and capability constraints.

Therefore, this is a limitation of the framework more broadly, but it has no consequences for the applicability and effectiveness of the framework in the developing context specifically.

Assumption 4: Standards impact economic growth through an increase in TFP

Within ISO R&I's methodological guidance document, a logic model is presented that describes the theory behind the effects of standards on an economy, ultimately linking the development of standards with economic growth. It highlights the main mechanism through which standards improve economic growth: unity, compatibility, compliance, and security.

Then, through factors such as product and market uniformity, knowledge and technology diffusion, reduced technical barriers to trade, easier market access, enhanced consumer rights, economic growth is driven by four key channels: trade growth, innovation ability, business environment, plus safety and environmental protection. Zhang *et al.*'s logic model was in fact developed as part of a study into the effects of standards development on economic growth in China. The linkages presented are universal and there is no evidence to suggest that they break down in the Senegalese context. Based upon a review of the academic literature and our economic expertise, we see no compelling argument to dispute this assumption in the Senegalese (or developing) context.

It is also worth noting that there may be some drags to economic growth through the application of standards. For example, overly burdensome standards could lock in old technologies or lead to premature selection of technologies, which would be an inefficient allocation of resources. On top of this, standards have the potential to restrict choice and increase market concentration, especially if dominant players can wield excessive influence on regulatory agencies. While these linkages are a possibility, on a net basis, there is compelling evidence to suggest that standards have a positive impact on productivity and growth.

As mentioned, there is an argument to suggest that in the developing context, there are greater frictions to overcome across the transmission mechanism compared to a more advanced economy. However, the critical point is that the *intuition* behind the linkages considered by Zhang *et al*. appears appropriate. Unless we directly test these linkages, we cannot say with certainty whether this hypothesis is correct. Within our study, the intuition of the TFP variable is to capture many of these complex and competing effects. Therefore, the assumption that the transmission mechanism from standards to economic growth resides in an increase in total factor productivity is sound.

Nonetheless and as discussed, because we have decided not to use the two-stage approach for our analysis of Senegal, there is no explicit role for TFP within our model. So we cannot know whether our estimated impact of standards on economic growth occurs through an increase in TFP. As we have calculated this through a rearranged Cobb-Douglas model, with the sole change being the replacing of the TFP term with further explanatory variables (such as standards), implicitly the only mechanism through which standards impacts growth logically is via an increase in TFP. As such, while this assumption about standards positively impacting growth through TFP seems like a reasonable hypothesis, we cannot definitely prove whether this assertion is true.

Assumption 5: Data on the relevant variables is available

The fifth assumption of the framework is that data on standards, labour, capital, productivity, and any other required variables is available for the country in question.

Firstly, as per the original ISO methodological guidance note, to estimate the effect of standards on labour productivity via the TFP channel using the Cobb-Douglas framework, annual data on TFP over the whole period of analysis is required. Unfortunately, data on TFP for Senegal is not readily available in a comprehensive and standardised form It can be challenging to obtain such information in a consistent and reliable manner especially in the context of developing countries. TFP estimation requires comprehensive data on inputs (labour and capital) and outputs (GDP) over time and some developing countries like Senegal may have weak statistical systems and limited resources, capacity, or infrastructure to consistently collect and report such data.

It is suggested in the ISO methodological note that, in the absence of official TFP data, it is possible to divide real GDP by the product of labour inputs and capital inputs to yield a very approximate measure of TFP. We, however, chose not to do so as this calculation yields the ratio of real GDP to the combined labour and capital input, which is known as 'labour and capital productivity', but it does not isolate the TFP component. Labour and capital productivity are often analysed together to gain a more comprehensive understanding of how efficiently both labour and capital inputs are being utilised in the production process and their combined impact on output. By examining both aspects, it becomes possible to assess the overall efficiency and effectiveness of resource allocation and utilisation within an economy. TFP, on the other hand, represents the portion of output growth that cannot be attributed to changes in labour and capital inputs alone. It captures the efficiency, technological progress, and other factors that impact output beyond the measured inputs.

Calculating TFP requires a more comprehensive approach that explicitly accounts for labour and capital inputs separately. To estimate TFP, we typically employ econometric techniques and production function estimation and analyse the unexplained residual in the relationship between output and labour and capital inputs, considering the effects of factors other than labour and capital. This, however, goes beyond the scope of this report.

Due to the lack of data on TFP in Senegal, we were unable to follow the two-stage least squares approach, i.e. we could not estimate the effect of standards on TFP and the effect of TFP on labour productivity. Instead, we estimated the effect of standards directly on labour productivity through one single equation.

Furthermore, to measure the impact of standards on labour productivity accurately, data on labour productivity itself should be consistent and reliable, and this, in turn, largely rests on the availability of robust data on GDP and employment. While GDP figures were sourced reliably from the IMF, employment statistics were, however, not directly available. Labour market indicators have not been published for long enough and as consistently by the relevant official bodies in Senegal as they usually are in developed countries through household or labour force surveys. As an alternative, we sourced employment figures for Senegal from the International Labour Organization (ILO), which produces modelled estimates of labour market indicators using a series of econometric models. These estimates are generally designed to provide a view of labour market trends, in the countries and years for which country-reported data are unavailable. The ILO advises that estimates for countries with very limited labour market information have a high degree of uncertainty and hence should not be considered as "observed" data, and great care needs to be applied when using these data for analysis, especially at the country level.

Lastly, we were unable to control for patents in our model as there is no data on patents granted in Senegal prior to 2014.

Overall, despite the data limitations mentioned here and discussed in more detail elsewhere, the prescribed ISO methodological approach could be followed in the case of Senegal as there were enough alternative options.

Assumption 6: The economy exhibits constant returns to scale

Lastly, the Cobb-Douglas model assumes a constant returns to scale (CRS), which means that increasing inputs will result in a proportional increase in output. While this assumption may be defensible at the global level (as it assumes that at any one time, many firms will be enjoying increasing returns to scale, while others will be experiencing decreasing returns to scale), it may not hold for all countries, especially in the developing context.

For example, in a developing economy, there may be infrastructure constraints, limited labour mobility, inadequate education and training, weak regulatory frameworks, or the inability to efficiently use additional inputs which could create pressures that generate decreasing returns to scale.

On the other hand, developing economies may exhibit increasing returns to scale through high labour mobility, [76] through lower per-unit production costs and high international competitiveness, through increasing marginal returns to investment in factors such as

76 Depending on the country, labour mobility may be a strength or a weakness. On one hand, a country with a large, young population will have a sizeable pool of workers to deploy in the regions or industries where they can be the most productively efficient. On the other hand, capacity constraints such as lack of housing stock, lack of education and training, or an inadequate rail and road infrastructure may limit the ability of this labour to be efficient.

education, health, and welfare while the economy is still 'young', or through relatively high returns to capital which make developing economies attractive to foreign investors.

That said, the Cobb-Douglas framework with CRS remains commonly employed as it has a simple and well-defined mathematical form, making it easier to work with analytically and computationally. It is characterised by a linear relationship in logarithmic form, which simplifies calculations and allows for straightforward interpretation of the coefficients.

We discuss this topic in more detail within the Technical Appendix for Senegal at the end of this chapter (see Section 7.4). The limitations of the CRS assumption discussed in the appendix are generally accepted across the literature and on balance, we recommend that this assumption is defensible in the context of Senegal.

Summary

Overall, despite some limitations, the framework has been successful in providing evidence of the impact of standards on productivity in Senegal. Although we had to depart slightly from the exact steps suggested within the guidance document, we stayed within the wider Cobb-Douglas framework and succeeded in producing robust and significant estimates for the impact of standards on labour productivity.

We have presented a review of the key assumptions made by the framework in the context of Senegal and find that alongside the applicability of the framework, the effectiveness of the results is also relatively high given the quality of the model in explaining movements in labour productivity.

There are some limitations present such as poor data availability, however these limitations are not a consequence of the prescribed framework, nor is the data so sparse that a sufficiently robust model cannot be produced. Overall, whilst we are confident in the robustness of the results presented within this study, caution as well as a sound understanding of the relevant limitations, is advised.

7.3.2 Recommendations for Future Research

Our recommendations for future research centre around addressing the limitations of this study and overcoming the gaps in data availability.

Uncovering 'black box' variables

One important criticism of generalised macroeconomic models such as the one used in this study – and by most of the other national level studies in this space – is that **the relationship between standards and productivity is treated as something of a 'black box'**.

There is one notable difference between our model and the original one prescribed by ISO in its methodological guidance note: by substituting in our explanatory variables into the TFP term (A) we are altering our model from estimating the indirect impact of standards on labour productivity (through an increase in TFP) to being an estimate of the direct impact of standards on productivity. Although we know the magnitude of this impact, we still do not definitively know the underlying mechanisms through which this occurs.

The academic literature shows compelling evidence to suggest that standards enhance productivity and economic growth at the national level. In practice, this means that standards will help drive companies and their associated supply chains to operate more efficiently, thus reducing costs, expanding revenue opportunities, and ultimately allowing companies and sectors to become more productive and profitable.

On one hand, we can use our economic intuition and critically assess the credibility of the linkages suggested within Zhang *et al.*'s logic model in the context of Senegal. However, on the other hand, we do not quantitatively assess the mechanisms by which standards generate increased productivity within this study. Other studies in the space have been conducted at the company level using sector- or firm-level data derived from secondary sources, primary surveys, or case studies.[77]

Identifying the direction of causality between standards and productivity

Secondly, **an assessment of the direction of the relationship between standards and productivity** would be an insightful avenue for further research. There is a virtuous cycle between standards and economic growth – whereby standards drive growth which subsequently drives standards which drives further growth, and so on – however, we have not tested this relationship as part of this study.

The prescribed framework does not account for this two-way relationship for reasons of methodological simplicity. While the quality of results may not be affected by the choice to model the relationship between standards and economic growth as one-way, there is still additional insight that could be gained from future research.

For example, one common option is to find a 'cointegrating' relationship between the key variables whereby there exists a stable long-run statistical relationship. Statistical tests can confirm if this relationship is non-spurious and whether it exists between standards and productivity. A similar approach was applied by Cebr in a 2015 study assessing the contribution of standards to UK productivity.

Other options are to use methods such as a Granger causality test which assesses whether one time series is an effective forecaster of another. This test is somewhat of a misnomer as it does not provide insight into a true cause-and-effect relationship. Rather, if standards were found to Granger-cause productivity, then this would demonstrate that historic increases in standards are related to increases in productivity today.

This is by no means an exhaustive list of econometric methods that could be used to extend beyond correlation analysis, but these more advanced techniques would require expansions to the prescribed methodological approach. Given that one of ISO's core aims is to expand the evidence base across developing economies, we would recommend that the prescribed framework is applied as an initial starting point due to its relative simplicity, while the more advanced techniques are applied in further studies.

Reducing data deprivation

Lastly, one of the key limiting factors of this research was data deprivation. As highlighted by ISO, statistical models are only as good as the data that goes into them. In this instance, we were unable to follow the two-stage approach due to the lack of data on TFP. Furthermore, even the dependent variable, i.e. labour productivity, was affected by the lack of consistent and reliable employment data. Labour market indicators have not been published for long enough and as consistently in Senegal through household or labour force surveys. Employment figures were instead sourced from the International Labour Organization (ILO), which were in fact modelled estimates using econometric models. The

77 These include DIN (2000), Conference Board of Canada for the Standards Council of Canada (2007), AFNOR (2009), BERL Economics for The Standards Council of New Zealand (2011) and Menon Economics (2018).

ILO warns that these estimates have a high degree of uncertainty and hence should not be considered as "observed" data, and great care needs to be applied when using these data for analysis, especially at the country level.

Furthermore, we could not include patents as a control variable due insufficient historic data, despite it being a potentially important regressor to assess. Even if it was dropped from the final model, the fact that we could not comprehensively test whether patents are a statistically significant variable in determining productivity alongside standards is a notable shortcoming of the research. Therefore, we see it as important to use this report as a call-to-action for data collection agencies – both national and supranational bodies alike – to continue their work to expand data libraries, with a particular focus on developing economies.

The concept of data deprivation is not new. Data serves as the foundation for meaningful policymaking, efficient resource allocation, and effective public service delivery. By improving the statistical coverage of the developing world, there will be more opportunities for robust economic analyses to contribute to the literature and advance society's collective knowledge base.

In general terms, a good example of this point is via the informal (or shadow) economy. The International Monetary Fund defines the 'shadow economy' to represent "illegal activities and unreported income from the production of legal goods and services, either from monetary or barter transactions, that would be taxable were they reported to the tax authorities." The livelihoods of individuals in developing economies often depends on these informal economic transactions.

In 2021, Elgin *et al*. introduced a comprehensive dataset of informal economic activity across more than 160 economies for the period 1990-2018. For Senegal, they estimate that in 2018, the size of the informal economy represented 37.9% of official Senegalese GDP, a slight decrease from 44.7% in 1990.

The implication of this phenomenon is that official statistics are not able to accurately account for the large swathes of economic activity occurring within the informal sector. This means that empirical studies such as this may not be reflective of the "true" state of the economy because they are entirely reliant upon these official statistics such as GDP, capital stock, and labour force participation. Therefore, the relationships between key variables that are established in the model – in this case, standards, TFP, and labour productivity – may behave differently or break down altogether in the real world.

7.4 Technical Appendix: Senegal

7.4.1 Detailed methodology and results

In this sub-section, we present detailed results of the regression analysis, with accompanying explanation of the specific techniques used. These results are included for reasons of accountability and transparency. All technical shortcomings and limitations are made clear to help ensure that the results of this study are used appropriately.

As explained in Section 7.1, our initial goal was to estimate the impact of increasing the stock of standards on economic growth in Senegal using a two-equation system, as prescribed by the ISO methodological guidance. However, due to data deprivation this was not feasible, so we opted for a single-stage regression approach. Below we present how the Cobb-Douglas production function can be rearranged to produce the key regressor equations for the first- and second-stage models, and the final step ultimately utilised to derive the used one-stage equation.

Rearranging the Cobb-Douglas production function

Below we show in five steps how the Cobb-Douglas production function can be transformed and rearranged to produce the key regressor equations used in the first- and second-stage models:

$$Y_t = A_t L_t^{1-\alpha} K_t^{\alpha}$$

Step 1 – linearise the Cobb-Douglas above by taking natural logarithms:

$$ln(Y_t) = ln(A_t L_t^{\alpha} K_t^{1-\alpha}) = ln(A_t) + (1-\alpha)\,ln(L_t) + \alpha\,ln(K_t) + \epsilon_t$$

Step 2 – rearrange as a function of labour productivity:

$$ln(Y_t) - ln(L_t) = ln(A_t) + \alpha\,[ln(K_t) - ln(L_t)] + \epsilon_t$$

Step 3 – as above but expressed in used form:

$$ln\left(\frac{Y_t}{L_t}\right) = ln(Labour\ Productivity_t) = \beta_1 ln\,(A_t) + \beta_2 ln\left(\frac{K_t}{L_t}\right) + \epsilon_t$$

Step 4 – TFP variable isolated and expressed as a function of standards plus other necessary control variables:

$$\ln(A_t) = \gamma_0 + \gamma_1 \ln\,(Standards_t) + \gamma_2 \ln(Patents_t) + \cdots + \gamma_n \ln(n_t) + \mu_t$$

Step 5 – augmented specification to sidestep the 2SLS framework:

$$ln\left(\frac{Y_t}{L_t}\right) = \gamma_0 + \gamma_1 ln\,(Standards_t) + \gamma_n ln(n_t) + \beta_2 ln\left(\frac{K_t}{L_t}\right) + \epsilon_t$$

Model equation

Equation 13: The augmented log-linearised Cobb-Douglas production function, embedding the determinants of TFP.

$$ln(Labour\ Productivity_t) = \gamma_0 + \gamma_1 ln\,(Standards_t) + \gamma_2 Recession_t + \beta_2 ln\left(\frac{K_t}{L_t}\right) + \epsilon_t$$

Table 26: Full regression results for Equation 13

Dependent Variable:	ln Labour Productivity
Method:	Cochrane-Orcutt procedure
Date:	1991-2019
Observations:	28

Overall Fit			
Multiple R	0.9004	AIC	-195.37
R Square	0.8108	AICc	-192.65
Adjusted R Square	0.7871	SBC	-190.05
Standard Error	0.0286		

ANOVA	df	SS	MS	F	p-value
Regression	3	0.084	0.028	34.276	0.000

Residual	24	0.020	0.001		
Total	27	0.104			

Term	Coefficient	Std. Error	t-statistic	p-value	VIF
Intercept	6.875	0.108	63.903	0.000***	
Ln (K/L)	0.066	0.025	2.630	0.015 **	4.134
Ln Standards	0.078	0.033	2.336	0.028 **	4.108
Recession dummy	-0.038	0.018	-2.074	0.049 **	1.013

Source: ASN, ILO, IMF, and Cebr analysis

Note: Asterisks *, **, and *** are added to denote a significant relationship at the 10%, 5%, and 1% levels, respectively.

This model specification performs well and is effective at describing the relationship between standards and labour productivity. The R-squared value and the highly significant F-statistic demonstrate the strength of the model. The R-squared suggests that 90% of the variation in the labour productivity is explained by the independent variables in the model. On top of this, there is no evidence of high multicollinearity as shown by the VIF score. As a rule of thumb, VIF values below 5 are often considered acceptable, indicating that the level of multicollinearity is relatively low.

We use a Cochrane-Orcutt regression procedure to address the problems of autocorrelation that were detected within the data using a Durbin-Watson test. Autocorrelation is the degree of correlation of the same variables between two successive time intervals. It measures how the lagged version of the value of a variable is related to the original version of it in a time series. Autocorrelation is a problem because it leads to inefficient estimates (i.e., they do not have minimum variance) hence our confidence in the result is lowered if autocorrelation is present. The Cochrane-Orcutt regression procedure is a technique that takes serial correlation into account within the error term, hence solving for autocorrelation within the regression model.

One downside with this approach is that the transformation applied by the technique removes the first observation from the time series. Given that our sample is relatively small to start with, this is not optimal. However, the trade-off is worthwhile to obtain robust results that do not suffer from autocorrelation issues.

The Gauss-Markov theorem shows that when certain conditions are satisfied, OLS coefficients will be the Best Linear Unbiased Estimates (BLUE). When the assumption for homogeneity of variance is violated within the ordinary least squares regression method, the regression coefficients will not be BLUE. While they do remain unbiased, i.e., they will be correct on average, but they will not be efficient since they no longer have minimum variance, i.e., they will not be the ‘best’. Therefore, it is important to test for heterogeneity of variance, commonly known as heteroscedasticity, to ensure that the model coefficients are the ‘best’.

To do this we performed the Breusch-Pagan test to determine if heteroscedasticity was present in our model. The p-value for this test was 0.02, which is below the threshold of 0.05, suggesting that there was evidence of heteroscedasticity within our data and that the coefficients will not be BLUE.

Ultimately, we could not rule out the potential for heteroscedasticity within our model. As a precautionary measure, we tested the validity of the model using Huber-White’s robust standard errors approach, which are also known as heteroscedasticity-consistent (HC) standard errors and found that standards is still a statistically significant variable using the most restrictive version of the approach; HC4 estimators.

This gives some degree of comfort with regards to the validity of the results, however we recommend that it may be more appropriate to use an alternative regression approach, such as Weighted Least Squares, to comprehensively address potential issues with heteroscedasticity within the data.

7.4.2 Limitations and Caveats

Aside from the conceptual discussion about different methodological approaches to estimate the impact of standards on labour productivity through a single-equation approach or a two-stage approach via TFP, there are no major practical limitations or weaknesses with our analysis as it relates to Senegal. Nonetheless, there are some caveats which we discuss below.

The main limitation of this analysis is the small number of observations driven by the lack of historical data for most of the variables of interest. While this is not a significant issue in and of itself – the number of observations is still over 25 – it makes the model weaker and can make inference harder if it is not optimally specified.

As part of the preliminary testing stage, we carried out several checks to get a sense of the data and make sure we were correctly specifying our model. One of the more simple but effective tools at an early stage is to plot the data (such as by looking at correlograms and plots of the residuals) to get a better understanding of any trends present in the data, as well as any outliers which might affect our results. Beyond this, we used tools such as the Durbin-Watson test, the Augmented Dickey-Fuller (ADF) test, or the Breusch-Pagan and White tests to test for autocorrelation, stationarity, and heteroscedasticity, respectively.

Although there is some multicollinearity present in the data – meaning that some of the control variables are correlated with each other – our final model does not show cause for concern: its highest VIF is less than 5, so there is no strong evidence that multicollinearity persists in our chosen econometric specification.

The assumption about constant returns to scale, or CRS, (see Section 7.3) is worth discussing in more detail. While the Cobb-Douglas framework with CRS remains commonly employed due to its ease of use and interpretation, the empirical literature on the extent to which CRS is a realistic characteristic that countries exhibit is relatively sparse and slightly ambiguous. McCombie and Roberts (2007) showed that the values for returns to scale depend on how these are estimated and that these often yield significantly different results. In the case of Senegal, Diagne & Demont (2007) found evidence of increasing returns to scale in agricultural production, indicating that a proportional increase in inputs leads to a greater than proportional increase in output. The study examined the returns to scale and technical efficiency in Senegalese agriculture using a stochastic frontier production function approach. Furthermore, many other countries to which this ISO standards framework has been applied have been found to exhibit lower returns to scale. For example, Golany and Thore (1997) present an empirical evaluation of the returns to scale across 72 developed and developing countries between 1970 and 1985 – a period covered by many of the other studies assessing the economic impact of standards.[78] They conclude that the United Kingdom, the Scandinavian countries, Australia, and New Zealand all exhibit decreasing returns to scale, while many less advanced economies exhibit increasing returns to scale.

78 See Section 1.5.

Lastly, it has been touched upon in the discussion around Assumption 4 in Section 7.3, but it deserves further discussion here. The main weakness in switching from a two-stage model to a single-stage model is that we are no longer explicitly estimating the role of TFP as it relates to standards and labour productivity. While our estimate for the direct impact of standards on labour productivity is robust and comes from a strong model, we lose some useful context – we cannot prove that the positive impact of standards on labour productivity growth occurs through an increase in TFP.

7.4.3 Sensitivity Testing

We could not successfully gauge the consistency of the estimator for standards. We gradually added new variables and changed the structural specification of the regression model until we found a suitable model that satisfied the conditions required to use the Ordinary Least Squares (OLS) regression method. These conditions are assumptions that, when met, allow for accurate and reliable estimation of the regression model. We chose our ultimate model, i.e. Equation 13 because this was the only model that performed well without violating the assumptions that may affect the validity of the OLS results.

It performed well in terms of goodness of fit, measured by the R^2, and explains around 90% of the variation in the labour productivity observed during the period. Furthermore, while all the variables we chose in the model turned out to be statistically significant, the signs of their respective coefficients also align with general economic intuition.

Combinations of other variables yielded unsatisfactory models that we had to discard as they tended to be mis specified, overfitted, or suffered from unacceptably high levels of multicollinearity. This is the reason why we could not shortlist a few suitable models to assess the consistency of the estimator for standards.

Finally, since we could not control for patents due to data limitations, it is likely that we are overestimating the effect of standards on TFP given the omission of patents.

Chapter 8: The Economic Impact of Standards in Uganda

8.1 Summary of the Used Methodological Approach

Due to the lack of data on TFP in Uganda, we were unable to follow the two-stage process as outlined above. In other words, it was not possible to estimate the effect of standards on TFP (Equation 3) and the effect of TFP on labour productivity (Equation 2).

In the ISO methodological note, it is suggested that, in the absence of official TFP data, it is possible to multiply the measure of the volume of labour and the measure of the volume of capital and then take real GDP divided by this number to yield a very approximate measure of TFP. However, we are of the view that the calculation described above yields the ratio of real GDP to the combined labour and capital input, which is known as labour and capital productivity, but it does not isolate the TFP component. TFP represents the portion of output growth that cannot be attributed to changes in labour and capital inputs alone. It captures the efficiency, technological progress, and other factors that impact output beyond the measured inputs. Calculating TFP requires a more comprehensive approach that explicitly accounts for labour and capital inputs separately. To estimate TFP, we typically employ econometric techniques and production function estimation and analyse the unexplained residual in the relationship between output and labour and capital inputs, considering the effects of factors other than labour and capital. This, however, goes beyond the scope of this report.

To address this issue, and while staying within the wider Cobb-Douglas framework, we estimated the effect of standards directly on labour productivity by embedding Equation 3 into Equation 2. In other words, instead of employing a two-stage model whereby standards are assumed to indirectly impact labour productivity through an increase in TFP, we use a single-stage model where we explicitly estimate the direct impact of standards on labour productivity. Our final model is specified by Equation 14 below.

Although the step-by-step process may be different from the one set out by ISO, conceptually both are still attempting to do the same thing – they should be interpreted as different algebraic rearrangements of the same core model: the Cobb-Douglas production function. Whereas the two-stage approach leaves in terms for both capital and labour as well as TFP (A), with the single equation seen below, we maintain capital and labour within the model through the k term (which denotes the capital-employment ratio), and then we simply substitute TFP with our list of explanatory variables (including standards), which we explain further below.

The one caveat to note about this altered model is that by removing the TFP term and substituting it with the explanatory variables discussed, we are in effect no longer directly quantifying the explicit role of TFP. As a reminder, TFP is essentially the "catch-all" term for everything that affects economic output that is not capital or labour. It will include the specific explanatory variables we use – such as standards – but it is likely to include many other external factors that are not estimated or accounted for in our model (these include poor competitiveness and low infrastructure quality, amongst others, which are harder to quantify). As such, although the single-stage model we have used is the best at estimating the isolated impact of standards on labour productivity, it is more limited when it comes to identifying the relationship between TFP and labour productivity.

Equation 14: The augmented log-linearised Cobb-Douglas production function, embedding the determinants of TFP.

$$ln(Labour\ Productivity_t) = \underbrace{\gamma_0 + \gamma_1 ln\,(Standards_t) + \gamma_2 t}_{\textbf{TFP}} + \beta_2 ln\left(\frac{K_t}{L_t}\right) + \epsilon_t$$

In this equation, $Standards$ denotes the net stock of standards, t is a linear time trend variable and K/L is the capital-employment ratio. We could not include patents in the model as the availability of data on patents in Uganda is limited.

If we fail to capture the drivers of TFP in the model as control variables, the model could possibly suggest a negative relationship between standards and productivity. The growth of TFP is linked to several interconnected factors that cannot be measured due to data limitations or sometimes the unquantifiable nature of these factors. These can include quality of institutions and governance, innovation and knowledge spillover effects, infrastructure quality, cost of doing business, efficiency of the financial sector and trade openness. Due to limitations in measuring these factors, we included a linear time variable, denoted by t, to attempt to capture any general increasing or declining trend in TFP as a result of these unquantifiable factors.

8.2 Findings

8.2.1 Quantitative results

The analysis reveals a positive and significant relationship between standards and labour productivity. Our regression result for Uganda tells us that **a one percent increase in the net stock of standards is associated with a 0.096 percent increase in labour productivity**, where labour productivity is measured as real GDP per worker.

The key quantitative results can be seen below in Table 27.

Table 27: Summary results for Equation 14, 2001–2019

Term	Coefficient	Standard Error	t-statistic	p-value	Significance
Intercept	6.893	0.238	29.020	0.000	***
ln (K/L)	1.013	0.142	7.138	0.000	***
ln Standards	0.096	0.048	2.005	0.063	*
Time trend	-0.034	0.008	-4.295	0.001	***

Source: UNBS, IMF, and Cebr analysis

Note: Asterisks *, **, and *** are added to denote a significant relationship at the 10%, 5%, and 1% levels, respectively.

Our model reveals that both standards and the capital-to-labour ratio are positively related to labour productivity while the time trend has a significant and negative impact on labour productivity. This indicates a general declining trend in drivers of TFP other than standards. All variables in the above summary table are statistically significant at the 10% level or higher. For more detailed statistical information regarding the model, please see the Technical Appendix.

8.2.2 Discussion

Contribution of standards to economic growth

The findings above posit that a one percent growth of the stock of standards is associated with an increase in labour productivity of 0.096 percent in Uganda. In terms of economic growth this has the following implications:

- Between 2001 and 2019, the net stock of standards in Uganda grew by an average of 16.2% year-on-year, while the average year-on-year growth of labour productivity was 3.0%. Applying the elasticity of standards with respect to labour productivity (0.096) to the average growth in the stock of standards, we find that standards are associated with 51.6% of the growth in labour productivity and 23.7% of GDP growth in Uganda during the period 2001 to 2019.
- As we explain below, these figures should be interpreted with caution due to the shorter time frame, which makes these estimates much more sensitive to outliers and disturbances during the time period we are considering.

Table 28 below presents a summary of results for other countries compared in the literature. This is not an exhaustive list of studies but a selection of those that provide details on the contribution of standards to economic growth.

Table 28: Comparison of relevant summary results of national studies[79]

Country	Uganda	Canada	France	Germany	Nordic	UK	UK
Publication year	**2023**	2007	2009	2000	2018	2005	2015
Analysis period	**2001-2019**	1981-2004	1950-2007	1961-1990	1976-2016	1948-2002	1921-2013
Estimated function[80]	**LP**	LP	GDP	GDP	LP	LP	LP
Elasticity of stock of standards	**0.096**	0.36	0.12	0.07	0.11	0.05	0.11
Share of labour productivity growth	**51.6%**	17.0%	27.1%	30.1%	39.5%	13.0%	37.4%
Growth rate of GDP, % p.a.	**6.5%**	2.7%	3.4%	3.3%	2.5%	2.5%	2.4%
Share of GDP growth	**23.7%**	9.2%	23.5%	27.4%	28.0%	11.0%	28.4%
Contribution of standards to GDP growth, % points	**1.55%**	0.3%	0.8%	0.9%	0.7%	0.3%	0.7%

Source: Standards Council of Canada (2007), AFNOR (2009), DIN (2000), Menon (2018), DTI (2005), and Cebr analysis

Standards can enhance labour productivity by increasing output per employee at individual firms. This can be achieved through various mechanisms such as improving production activity and efficiency, ensuring quality and precision, and spreading technical information and best practices. These improvements in organisational performance lead to cost savings, enabling firms to achieve higher output per worker. Additionally, standards allow firms to build on their strengths and specialise, leading to better division of labour, economies of scale, and increased output per staff member.

However, in the case of Uganda, the figures derived above should be treated with caution. The extrapolation to estimate the share of labour productivity growth and GDP growth attributable to the increase in standards is based on a point-to-point analysis between 2001 and 2019 where we assume a constant growth rate of these variables between these years;

79 Note that not all the studies from Table 3 are presented here; only those that estimated the share of labour productivity of GDP growth associated with standardisation are included in this table. For a similar comparison with the other developing countries assessed within this study, see Section 9.1.

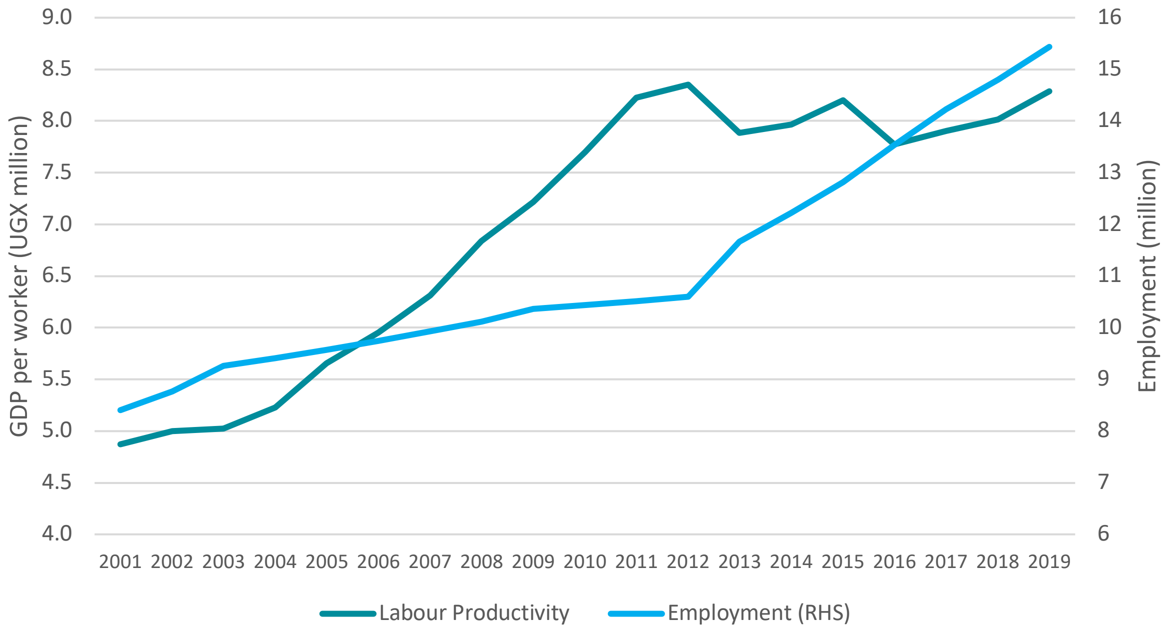
80 LP = Labour Productivity. GDP = Gross Domestic Product.

notably a 3% annual growth in productivity. In reality, labour productivity growth has been more volatile. Between 2001 and 2010, labour productivity has grown at 5.2% annually, while from 2011 onwards, growth was almost flat at 0.1% annually. One of the reasons for the disturbances in labour productivity can be traced to the source data on the number of persons in employment, which is the indicator that underpins labour productivity.

For this analysis, we used the International Labour Organization's modelled estimates for employed population in Uganda due to the scarcity of regular and robust labour market data from national official sources. As shown in Figure 21 below, the modelled estimates for employment have been increasing steadily until 2012, after which some unusual volatility is observed, with a sudden jump of 10% in the number of employed persons in 2013. For comparison, the annual average growth in employment between 1991 and 2012 was 2.1%. This resulted in an abrupt fall in estimated labour productivity. Moreover, given the shorter time series for Uganda compared to the other country studies – except Canada and Germany, all have at least 50 years' worth of data – the results above are not directly comparable because the average growth in labour productivity in Uganda is much more sensitive to outliers and disturbances during the time period we are considering.

That said, while the interpretation of the above extrapolated estimates should be made with caution, the underlying elasticity of standards on labour productivity derived from our model remains a robust estimate. Our model is designed to be more resilient to outliers and data irregularities. For more detailed information on the regression method used in our model, please see the relevant Technical Appendix.

Figure 21: Evolution of employment and labour productivity, 1991–2019



Source: ILO, IMF, and Cebr analysis

More generally, caution should be taken when interpreting these estimates as standards have an interdependent role in driving labour productivity along with other knowledge factors such as higher levels of education and training, advances in technology and increased innovative efforts. By interdependent we mean that standards play a mutually dependent and complementary role alongside other factors, such as those mentioned above, in facilitating productivity growth. Beyond standards having a direct impact on labour productivity, they are also associated with driving these other knowledge factors, and these then result in an increased value of standards. Equally, an improvement in the other knowledge factors leads to standards playing a more efficient role in boosting labour productivity.

Limitations and Caveats

For reasons of transparency and accountability, as well as to avoid any inappropriate conclusions being made, it is important to highlight some of the key limitations of this research.

First and foremost, **the analysis period of 2001 to 2019 is relatively short, covering only 19 periods** of continuous data. According to the methodological guidance document produced by ISO, the very lower bound (or minimum recommended amount) for the number of observations is likely to be somewhere around 15, and it is preferable to have at least 30 periods of data such that the Central Limit Theorem applies.[81] In the case of Uganda, a larger time frame would be even more optimal as additional observations would enable us to capture underlying dynamics more accurately, in view of the high volatility and irregular patterns that have been observed and discussed above. Data on stock of standards is only available as from 2001, so there is a constraining factor on the period of analysis. The average number of observations in the other studies referenced in Table 28 is around 50. Since this study has an observation period of 19 years, this analysis is on the threshold of what can be considered statistically robust.

Secondly, our **analysis is exclusively focused on the assessment of the correlation between standards and productivity, rather than causality**. Correlation between variables simply means that they are related, and that as one variable changes, the other does as well, but it does not mean that the change in one of the variables (e.g. productivity) is *caused* by the change in the other variable (e.g. standards). Causality, or causation, is when there is a causal relationship between two variables, i.e. that the change in one variable is caused by a change in the other. Further research would be valuable to be able to establish a *causal* relationship between the standards and productivity. That is, the identification of a direct cause-and-effect relationship between the two variables in Uganda.

We have also not considered the direction of causality between the variables and cannot pass comment on the potential for endogeneity for the stock of standards in the context of Uganda In other words, this study does not attempt to investigate which of standards or growth drives the other, merely that they are connected and, when one changes, so does the other.[82] An example of the two-way relationship between standards and growth is highlighted by a logic model produced by Zhang *et al.* (2019). They suggest that additional growth and technological progress brings about changes in environment and resources, which in turn leads to the emergence and application of new goods and services. The resulting lack of standards for new products forces the evolution of standards, while more firms lead to more enterprise and enterprise-dominated standards. Ultimately, there is potential for a virtuous cycle between

81 For datasets with less than 15 observations, it is more complicated to estimate the coefficients that describe the relationship between our variables of interest, and it can also lead to wider confidence intervals around the estimated coefficients (confidence intervals give us a range within which we are reasonably confident that the true value lies).

82 Moreover, endogeneity is simply a term in econometrics which describes when a variable of interest (such as standards) is affected by other variables in the analysis. This can be problematic as it may lead to biased and unreliable estimates of the effect of standards (with endogeneity we cannot be sure whether our model is saying that standards have a positive effect on growth, or if it's another explanatory variable).

standards and economic growth, but the applied framework does not account for this two-way relationship. Further research is required here.

Cebr is also keen to urge a degree of caution when interpreting these findings. Crucially, **the relationship between standards and productivity is somewhat of a 'black box'** and we have not attempted to incorporate a quantitative assessment of the mechanisms through which standards generate increased productivity. In other words, while we have determined that standards increase productivity, we have not determined *how* or *why* they do so. It is beyond the scope of this report to develop a richer understanding of these mechanisms and their effects, but studies at the company level, using firm-level data derived from surveys or case studies, have been conducted in the past and can assist here.[83]

Lastly, it should be recognised that standards alone do not drive productivity. Rather, they play a mutually dependent and complementary role in facilitating the growth of productivity, along with other types of knowledge such as enhancements in education and progressions in technology. While we have attempted to control for key other potential explanatory factors, the model does not explicitly control for **all other** potential components of TFP. The model is instead an attempt to disentangle the effects of standards from other complementary factors that drive productivity, recognising also the constraints of the available country-level data.

8.3 Review of ISO Methodological Framework

8.3.1 Applicability and Effectiveness

To evaluate the applicability and effectiveness of the prescribed methodological framework, we first consider the key assumptions that are made to apply the two-stage least-squares approach[84] and discuss whether these assumptions are appropriate in this context. Then secondly, we consider whether we have been able to follow the same system of equations to estimate the indirect effect of standards on labour productivity.

The six explicit assumptions made by the methodology are as follows:

- Assumption 1: A stock of standards is a credible proxy for the extent to which standards are effectively utilised in the country.
- Assumption 2: The Cobb-Douglas production function is appropriate as an approximate model.
- Assumption 3: There is a one-way relationship between standards and economic growth.
- Assumption 4: The appropriate transmission mechanism from standards to economic growth resides in an increase in total factor productivity.

83 These include DIN (2000), Conference Board of Canada for the Standards Council of Canada (2007), AFNOR (2009), BERL Economics for The Standards Council of New Zealand (2011) and Menon Economics (2018).

84 Two-stage least-squares (or 2SLS) is a common regression analysis technique which is used when the dependent variable's error terms are correlated with the independent variables. By using a two-step approach, 2SLS helps us isolate the true effect of standards on productivity by effectively removing the influence of other variables.

- Assumption 5: Data on standards, labour, capital, productivity, and any other variables is available.
- Assumption 6: The economy exhibits constant returns to scale.

Assumption 1: Stock of standards as a credible proxy

The assumption that the stock of standards is a credible proxy for the extent to which standards are effectively utilised is borne out of pragmatism. Across the literature, this is the accepted approach despite its limitations. For example, while it is true that a significant number of standards may indicate that a country is committed to promoting and maintaining standards, it does not guarantee that these standards are effective.

Beyond simply the quantity of standards, effective standards concern the quality, relevance, implementation, and enforcement of standards in an economy. On one level, a large stock of standards may generate a degree of confusion among stakeholders, making it difficult for organisations to determine which standards are relevant to their needs. Furthermore, the standards may not be effective in achieving their intended goals if they are poorly written, outdated, or not based on the best available science or research.

In addition, the introduction of each new standard may not produce a proportional economic benefit. The assumption that the stock of standards is a robust representation of how standards contribute to the economy is equivalent to the assumption that each standard contributes an equivalent benefit to the economy. This assumption is unlikely to fully hold because newer standards are expected to offer greater benefits than older standards in the national catalogue. Furthermore, the impact of standards on the economy is also generated by the breadth of their use, and thus, some standards are more widely used, and thus more impactful.

Ultimately, while there are limitations to Assumption 1, these are not unique to the Ugandan context and the stock of standards is the best available option for our research.

Assumption 2: Cobb-Douglas production function is appropriate as a model

Economists use production functions to describe what can be produced given a set of inputs, which are typically simplified into capital and labour. Different combinations of capital and labour can be used to produce the same output. The example given by the ISO guidance document suggests that to make a hole in the ground, one can use a person and a spade, two people and two smaller spades, or one person and an excavator. This reflects a microeconomic phenomenon where capital and labour are substitutable. Any macroeconomic model must be consistent with this, and the Cobb-Douglas form is one of the most widely used and practical models within the field.

The use of the Cobb-Douglas production function as an approximate model is a pragmatic middle ground between an ideal world where economic models perfectly describe reality, and the real world where the model must be workable (i.e., linear, in this case).

The major strength of the Cobb-Douglas production function is its ease of use. However, there is a great deal of contradiction within the academic literature with respect to the empirical validity of the Cobb-Douglas functional form. On one hand, Miller (2008), Abidemi (2010), Adetunji *et al.* (2012), and Husain (2016) provide some support evidence for the specification of the model. While on the other hand, papers such as Fraser (2002), and Gechert *et al.* (2019) cast some doubt on the appropriateness of the Cobb-Douglas production function.

In the specific context of a developing economy, there may be some issues that are not present in other contexts, e.g., limited factor mobility (i.e. factor inputs such as labour, capital, or land cannot easily switch between alternative uses without a loss of efficiency). The Cobb-

Douglas model assumes a high level of capital and labour mobility, which may not be present in a developing economy. For example, labour may be immobile due to limited access to education and training or a poor infrastructure system, while capital may be concentrated in a few large firms or industries.

For this particular report on the economic impact of standards on productivity in Uganda, we have employed a Cobb-Douglas production function for our model, though it has been rearranged into a different set-up from the one prescribed within the ISO methodological guidance note (see Section 8.1 for more information).

Therefore, although we have a slightly altered Cobb-Douglas production function as our model (relative to the algebraic manipulation in the ISO methodological guidance note), we were able to use the recommended underlying economic framework. As such we find that Assumption 2 is sensible, even if it may be a slightly weaker assumption in the developing context given the general challenges discussed above. The weaknesses outlined above should not categorically prevent the application of this methodology in any given country.

Assumption 3: There is a one-way relationship between standards and growth

We have already discussed Assumption 3 in the section above and concede that while this assumption has its limitations, it is made because it allows the presented methodology to be simple enough for most countries to adopt, given capacity and capability constraints.

Therefore, this is a limitation of the framework more broadly, but it has no consequences for the applicability and effectiveness of the framework in the developing context specifically.

Assumption 4: Standards impact economic growth through an increase in TFP

Within ISO R&I's methodological guidance document, a logic model is presented that describes the theory behind the effects of standards on an economy, ultimately linking the development of standards with economic growth. It highlights the main mechanism through which standards improve economic growth: unity, compatibility, compliance, and security.

Then, through factors such as product and market uniformity, knowledge and technology diffusion, reduced technical barriers to trade, easier market access, enhanced consumer rights, economic growth is driven by four key channels: trade growth, innovation ability, business environment, plus safety and environmental protection. Zhang *et al.*'s logic model was in fact developed as part of a study into the effects of standards development on economic growth in China. The linkages presented are universal and there is no evidence to suggest that they break down in the Ugandan context. Based upon a review of the academic literature and our economic expertise, we see no compelling argument to dispute this assumption in the Ugandan (or developing) context.

It is also worth noting that there may be some drags to economic growth through the application of standards. For example, overly burdensome standards could lock in old technologies or lead to premature selection of technologies, which would be an inefficient allocation of resources. On top of this, standards have the potential to restrict choice and increase market concentration, especially if dominant players can wield excessive influence on regulatory agencies. While these linkages are a possibility, on a net basis, there is compelling evidence to suggest that standards have a positive impact on productivity and growth.

As mentioned, there is an argument to suggest that in the developing context, there are greater frictions to overcome across the transmission mechanism compared to a more advanced economy. However, the critical point is that the *intuition* behind the linkages considered by Zhang *et al*. appears appropriate. Unless we directly test these linkages, we cannot say with certainty whether this hypothesis is correct. Within our study, the intuition of the TFP variable is to capture many of these complex and competing effects. Therefore, the assumption that the transmission mechanism from standards to economic growth resides in an increase in total factor productivity is sound.

Nonetheless and as discussed, because we have decided not to use the two-stage approach for our analysis of Uganda, there is no explicit role for TFP within our model. So we cannot know whether our estimated impact of standards on economic growth occurs through an increase in TFP. As we have calculated this through a rearranged Cobb-Douglas model, with the sole change being the replacing of the TFP term with further explanatory variables (such as standards), implicitly the only mechanism through which standards impacts growth logically is via an increase in TFP. As such, while this assumption about standards positively impacting growth through TFP seems like a reasonable hypothesis, we cannot definitely prove whether this assertion is true.

Assumption 5: Data on the relevant variables is available

The fifth assumption of the framework is that data on standards, labour, capital, productivity, and any other required variables is available for the country in question.

Firstly, as per the original ISO methodological guidance note, to estimate the effect of standards on labour productivity via the TFP channel using the Cobb-Douglas framework, annual data on TFP over the whole period of analysis is required. Unfortunately, data on TFP for Uganda is not readily available in a comprehensive and standardised form as it is for most developed economies. It can be challenging to obtain such information in a consistent and reliable manner especially in the context of developing countries. TFP estimation requires comprehensive data on inputs (labour and capital) and outputs (GDP) over time and some developing countries, such as Uganda, may have limited resources, capacity, or infrastructure to consistently collect and report such data.

It is suggested in the ISO methodological It is suggested in the ISO methodological note that, in the absence of official TFP data, it is possible to divide real GDP by the product of labour inputs and capital inputs to yield a very approximate measure of TFP. We, however, chose not to do so as this calculation yields the ratio of real GDP to the combined labour and capital input, which is known as 'labour and capital productivity', but it does not isolate the TFP component. Labour and capital productivity are often analysed together to gain a more comprehensive understanding of how efficiently both labour and capital inputs are being utilised in the production process and their combined impact on output. By examining both aspects, it becomes possible to assess the overall efficiency and effectiveness of resource allocation and utilisation within an economy. TFP, on the other hand, represents the portion of output growth that cannot be attributed to changes in labour and capital inputs alone. It captures the efficiency, technological progress, and other factors that impact output beyond the measured inputs.

Calculating TFP requires a more comprehensive approach that explicitly accounts for labour and capital inputs separately. To estimate TFP, we typically employ econometric techniques and production function estimation and analyse the unexplained residual in the relationship between output and labour and capital inputs, considering the effects of factors other than labour and capital. This, however, goes beyond the scope of this report.

Due to the lack of data on TFP in Uganda, we were unable to follow the two-stage least squares approach, i.e. we could not estimate the effect of standards on TFP and the effect of TFP on labour productivity. Instead, we estimated the effect of standards directly on labour productivity through one single equation.

Furthermore, to measure the impact of standards on labour productivity accurately, data on labour productivity itself should be consistent and reliable, and this, in turn, largely rests on the availability of robust data on GDP and employment. While GDP figures were sourced reliably from the IMF, employment statistics were, however, not directly available. Labour market indicators have not been published for long enough and as consistently by the relevant official bodies in Uganda as they usually are in developed countries through household or labour force surveys. As an alternative, we sourced employment figures for Uganda from the International Labour Organization (ILO), which produces modelled estimates of labour market indicators using a series of econometric models. These estimates are generally designed to provide a view of labour market trends, in the countries and years for which country-reported data are unavailable. The ILO advises that estimates for countries with very limited labour market information have a high degree of uncertainty and hence should not be considered as “observed” data, and great care needs to be applied when using these data for analysis, especially at the country level.

Overall, despite the data limitations mentioned here and discussed in more detail elsewhere, the prescribed ISO methodological approach could be followed in the case of Uganda as there were enough alternative options.

Assumption 6: The economy exhibits constant returns to scale

Lastly, the Cobb-Douglas model assumes a constant returns to scale (CRS), which means that increasing inputs will result in a proportional increase in output. While this assumption may be defensible at the global level (as it assumes that at any one time, many firms will be enjoying increasing returns to scale, while others will be experiencing decreasing returns to scale), it may not hold for all countries, especially in the developing context.

For example, in a developing economy, there may be infrastructure constraints, limited labour mobility, inadequate education and training, weak regulatory frameworks, or the inability to efficiently use additional inputs which could create pressures that generate decreasing returns to scale.

On the other hand, developing economies may exhibit increasing returns to scale through high labour mobility, [85] through lower per-unit production costs and high international competitiveness, through increasing marginal returns to investment in factors such as education, health, and welfare while the economy is still ‘young’, or through relatively high returns to capital which make developing economies attractive to foreign investors.

85 Depending on the country, labour mobility may be a strength or a weakness. On one hand, a country with a large, young population will have a sizeable pool of workers to deploy in the regions or industries where they can be the most productively efficient. On the other hand, capacity constraints such as lack of housing stock, lack of education and training, or an inadequate rail and road infrastructure may limit the ability of this labour to be efficient.

That said, the Cobb-Douglas framework with CRS remains commonly employed as it has a simple and well-defined mathematical form, making it easier to work with analytically and computationally. It is characterised by a linear relationship in logarithmic form, which simplifies calculations and allows for straightforward interpretation of the coefficients.

We discuss this topic in more detail within the Technical Appendix in Section 8.4. The limitations of the CRS assumption discussed in the appendix are generally accepted across the literature and on balance, we maintain that this assumption is defensible in the context of Uganda.

Summary

Overall, despite some limitations, the framework has been successful in providing evidence of the impact of standards on productivity in Uganda. Although we had to depart slightly from the exact steps suggested within the guidance document, we stayed within the wider Cobb-Douglas framework and succeeded in producing robust and significant estimates for the impact of standards on labour productivity.

We have presented a review of the key assumptions made by the framework in the context of Uganda and find that alongside the applicability of the framework, the effectiveness of the results is also relatively high given the quality of the model in explaining movements in labour productivity.

There are some limitations present such as low number of observations and poor data availability, however these limitations are not a consequence of the prescribed framework, nor is the data so sparse that a sufficiently robust model cannot be produced. Overall, whilst we are confident in the robustness of the results presented within this study, caution as well as a sound understanding of the relevant limitations, is advised.

8.3.2 Recommendations for Future Research

Our recommendations for future research centre around addressing the limitations of this study and overcoming the gaps in data availability.

Uncovering ‘black box’ variables

One important criticism of generalised macroeconomic models such as the one used in this study – and by most of the other national level studies in this space – is that **the relationship between standards and productivity is treated as something of a ‘black box’**.

There is one notable difference between our model and the original one prescribed by ISO in its methodological guidance note: by substituting our explanatory variables into the TFP term (A) we are altering our model from estimating the indirect impact of standards on labour productivity (though an increase in TFP) to being an estimate of the direct impact of standards on productivity. Although we know the magnitude of this impact, we still do not definitively know the underlying mechanisms through which this occurs.

The academic literature shows compelling evidence to suggest that standards enhance productivity and economic growth at the national level. In practice, this means that standards will help drive companies and their associated supply chains to operate more efficiently, thus reducing costs, expanding revenue opportunities, and ultimately allowing companies and sectors to become more productive and profitable.

On one hand, we can use our economic intuition and critically assess the credibility of the linkages suggested within Zhang *et al.*’s logic model in the context of Uganda. However, on the other hand, we do not quantitatively assess the mechanisms by which standards generate increased productivity within this study. Other studies in the space have been conducted at the company level using sector- or firm-level data derived from secondary sources, primary surveys, or case studies.[86]

Identifying the direction of causality between standards and productivity

Secondly, **an assessment of the direction of the relationship between standards and productivity** would be an insightful avenue for further research. There is a virtuous cycle between standards and economic growth – whereby standards drive growth which subsequently drives standards which drives further growth, and so on – however, we have not tested this relationship as part of this study.

The prescribed framework does not account for this two-way relationship for reasons of methodological simplicity. While the quality of results may not be affected by the choice to model the relationship between standards and economic growth as one-way, there is still additional insight that could be gained from future research.

For example, one common option is to find a 'cointegrating' relationship between the key variables whereby there exists a stable long-run statistical relationship. Statistical tests can confirm if this relationship is non-spurious and whether it exists between standards and productivity. A similar approach was applied by Cebr in a 2015 study assessing the contribution of standards to UK productivity.

Other options are to use methods such as a Granger causality test which assesses whether one time series is an effective forecaster of another. This test is somewhat of a misnomer as it does not provide insight into a true cause-and-effect relationship. Rather, if standards were found to Granger-cause productivity, then this would demonstrate that historic increases in standards are related to increases in productivity today.

This is by no means an exhaustive list of econometric methods that could be used to extend beyond correlation analysis, but these more advanced techniques would require expansions to the prescribed methodological approach. Given that one of ISO's core aims is to expand the evidence base across developing economies, we would recommend that the prescribed framework is applied as an initial starting point due to its relative simplicity, while the more advanced techniques are applied in further studies.

Reducing data deprivation

Lastly, one of the key limiting factors of this research was data deprivation. As highlighted by ISO, statistical models are only as good as the data that goes into them. In this instance, we were unable to follow the two-stage approach due to the lack of data on TFP. Furthermore, even the dependent variable, i.e. labour productivity, was affected by the lack of consistent and reliable employment data. Labour market indicators have not been published for long enough and as consistently in Uganda through household or labour force surveys. Employment figures were instead sourced from the ILO, which were in fact modelled estimates using econometric models. The ILO warns that these estimates have a high degree of uncertainty and hence should not be considered as "observed" data, and

86 These include DIN (2000), Conference Board of Canada for the Standards Council of Canada (2007), AFNOR (2009), BERL Economics for The Standards Council of New Zealand (2011) and Menon Economics (2018).

great care needs to be applied when using these data for analysis, especially at the country level.

Furthermore, we could not include patents as a control variable due significant gaps in patent data, despite it being a potentially important regressor to assess. Even if it was dropped from the final model, the fact that we could not comprehensively test whether patents are a statistically significant variable in determining productivity alongside standards is a notable shortcoming of the research. Therefore, we see it as important to use this report as a call-to-action for data collection agencies – both national and supranational bodies alike – to continue their work to expand data libraries, with a particular focus on developing economies.

The concept of data deprivation is not new. Data serves as the foundation for meaningful policymaking, efficient resource allocation, and effective public service delivery. By improving the statistical coverage of the developing world, there will be more opportunities for robust economic analyses to contribute to the literature and advance society's collective knowledge base.

In general terms, a good example of this point is via the informal (or shadow) economy. The International Monetary Fund defines the 'shadow economy' to represent "illegal activities and unreported income from the production of legal goods and services, either from monetary or barter transactions, that would be taxable were they reported to the tax authorities." The livelihoods of individuals in developing economies often depends on these informal economic transactions.

In 2021, Elgin *et al.* introduced a comprehensive dataset of informal economic activity across more than 160 economies for the period 1990-2018. For Uganda, they estimate that in 2018, the size of the informal economy represented 33.7% of official Ugandan GDP, compared to 44.9% in 1990.[87]

The implication of this phenomenon is that official statistics are not able to accurately account for the large swathes of economic activity occurring within the informal sector. This means that empirical studies such as this may not be reflective of the "true" state of the economy because they are entirely reliant upon these official statistics such as GDP, capital stock, and labour force participation. Therefore, the relationships between key variables that are established in the model – in this case, standards, TFP, and labour productivity – may behave differently or break down altogether in the real world.

8.4 Technical Appendix: Uganda

8.4.1 Detailed methodology and results

In this sub-section, we present detailed results of the regression analysis, with accompanying explanation of the specific techniques used. These results are included for

87 While the study does not mention the causes of this decline in informal activity in Uganda, a report by the World Bank has attributed the general decline in informality in developing countries to improvements in policy climates such as reduced tax burdens, enhanced access to finance, education, and public services; and improved governance and regulatory quality. Additionally, policies that seek to streamline tax regulation, strengthen tax administration, and improve public service delivery have been associated with declines in informality (Ohnsorge & Yu, 2022).

reasons of accountability and transparency. All technical shortcomings and limitations are made clear to help ensure that the results of this study are used appropriately.

As explained in Section 8.1, our initial goal was to estimate the impact of increasing the stock of standards on economic growth in Uganda using a two-equation system, as prescribed by the ISO methodological guidance. However, due to data deprivation this was not feasible, so we opted for a single-stage regression approach. Below we present how the Cobb-Douglas production function can be rearranged to produce the key regressor equations for the first- and second-stage models, and the final step ultimately utilised to derive the used one-stage equation.

Rearranging the Cobb-Douglas production function

Below we show in five steps how the Cobb-Douglas production function can be transformed and rearranged to produce the key regressor equations used in the first- and second-stage models:

$$Y_t = A_t L_t^{1-\alpha} K_t^{\alpha}$$

Step 1 – linearise the Cobb-Douglas above by taking natural logarithms:

$$ln(Y_t) = ln(A_t L_t^{\alpha} K_t^{1-\alpha}) = ln(A_t) + (1-\alpha)\, ln(L_t) + \alpha\, ln(K_t) + \epsilon_t$$

Step 2 – rearrange as a function of labour productivity:

$$ln(Y_t) - ln(L_t) = ln(A_t) + \alpha\, [ln(K_t) - ln(L_t)] + \epsilon_t$$

Step 3 – as above but expressed in used form:

$$ln\left(\frac{Y_t}{L_t}\right) = ln(Labour\ Productivity_t) = \beta_1 ln\,(A_t) + \beta_2 ln\left(\frac{K_t}{L_t}\right) + \epsilon_t$$

Step 4 – TFP variable isolated and expressed as a function of standards plus other necessary control variables:

$$\ln(A_t) = \gamma_0 + \gamma_1 \ln\,(Standards_t) + \gamma_2 \ln(Patents_t) + \cdots + \gamma_n \ln(n_t) + \mu_t$$

Step 5 – augmented specification to sidestep the 2SLS framework:

$$ln\left(\frac{Y_t}{L_t}\right) = \gamma_0 + \gamma_1 ln\,(Standards_t) + \gamma_n ln(n_t) + \beta_2 ln\left(\frac{K_t}{L_t}\right) + \epsilon_t$$

Model equation

Equation 14: The augmented log-linearised Cobb-Douglas production function, embedding the determinants of TFP.

$$ln(Labour\ Productivity_t) = \gamma_0 + \gamma_1 ln\,(Standards_t) + \gamma_2 t + \beta_2 ln\left(\frac{K_t}{L_t}\right) + \epsilon_t$$

Table 29: Full regression results for Equation 14

Dependent Variable:	ln Labour Productivity
Method:	OLS regression
Date:	2001-2019
Observations:	19

Overall Fit			
Multiple R	0.9870	AIC	-124.0
R Square	0.9742	AICc	-119.4
Adjusted R Square	0.9691	SBC	-120.2
Standard Error	0.0349		

ANOVA	df	SS	MS	F	p-value
Regression	3	0.690	0.230	188.877	0.000
Residual	15	0.018	0.001		
Total	18	0.709			

Term	Coefficient	Std. Error	t-statistic	p-value	VIF
Intercept	6.893	0.238	29.020	0.000	
Ln (K/L)	1.013	0.142	7.138	0.000	25.3
Ln Standards	0.096	0.048	2.005	0.063	27.1
Time trend	-0.034	0.008	-4.295	0.001	29.3

Source: UNBS, IMF, ILO, and Cebr analysis

Note: Asterisks *, **, and *** are added to denote a significant relationship at the 10%, 5%, and 1% levels, respectively.

This model specification performs well and is effective at describing the relationship between standards and labour productivity. The R-squared value and the highly significant F-statistic demonstrate the strength of the model. The R-squared suggests that 97% of the variation in labour productivity is explained by the independent variables in the model.

However, a significant limitation of this model is the high multicollinearity observed in the independent variables, evidenced by the high VIF scores. As a rule of thumb, VIF values below 5 are often considered acceptable, indicating that the level of multicollinearity is relatively low. Multicollinearity occurs when there is a strong linear relationship or dependency between the predictors, in this case the stock of standards, the capital-employment ratio and the time trend. When multicollinearity is present, it can affect the reliability and interpretability of the results. Multicollinearity makes it difficult to isolate the individual effects of, say, standards and capital-employment ratio on labour productivity. The regression coefficients may become unstable, and their interpretation becomes challenging. It becomes harder to determine the true impact of each variable on the outcome because they are not acting independently.

As a remedy, it is generally recommended to remove variables that contribute to multicollinearity but are less critical to the analysis in order to reduce the multicollinearity issues and obtain more reliable and interpretable results. However, in this case, there was not much leeway to remove variables as we were constrained by a Cobb Douglas framework where capital-employment ratio and standards had to be present in the same equation. If we did not follow a single equation approach, i.e. if it was possible to use the recommended 2SLS approach, we would have been able to estimate the effect of standards separately in another equation and avoided a situation of high multicollinearity. However, as discussed previously, this was not possible due to data limitations on TFP. To address multicollinearity, in the ISO methodological guidance note, it is stated that “the practitioner will need to balance the inclusion of strongly related variables with the need to exclude them” and that “in general, it is more advisable to include strongly related variables and treat them appropriately rather than exclude them.” Given the above, we deemed it was not possible to exclude any independent variables without significantly changing the entire modelling framework and recommend that the above results be treated with care.

No significant autocorrelation was detected within the model by using a Durbin-Watson test.[88]

There is also no heteroskedasticity[89] in our model, estimated using the Breusch-Pagan test. The p-value for this test was 0.59, which is well above the threshold of 0.05, suggesting that there is no evidence of heteroscedasticity within our model.

8.4.2 Limitations and Caveats

Aside from the conceptual discussion about different methodological approaches to estimate the impact of standards on labour productivity through a single-equation approach or a two-stage approach via TFP, the only major practical limitations or weaknesses with our analysis as it relates to Uganda is the high multicollinearity in the model, which could be a result of the short time frame considered.

Indeed, a key limitation of this analysis is the small number of observations driven by the lack of historical data for most of the variables of interest. Having only 19 observations makes the model weaker and can make inference harder if it is not optimally specified.

As part of the preliminary testing stage, we carried out several checks to get a sense of the data and make sure we were correctly specifying our model. One of the more simple but effective tools at an early stage is to plot the data (such as by looking at correlograms and plots of the residuals) to get a better understanding of any trends present in the data, as well as any outliers which might affect our results. Beyond this, we used tools such as the Durbin-Watson test, the Augmented Dickey-Fuller (ADF) test, or the Breusch-Pagan and White tests to test for autocorrelation, stationarity, and heteroscedasticity, respectively.

The assumption about constant returns to scale, or CRS, (see Section 8.3) is worth discussing in more detail. While the Cobb-Douglas framework with CRS remains commonly employed due to its ease of use and interpretation, the empirical literature on the extent to which CRS is a realistic characteristic that countries exhibit is relatively sparse and slightly ambiguous. McCombie and Roberts (2007) showed that the values for returns to scale depend on how these are estimated and that these often yield significantly different results. Many countries to which this ISO standards framework has been applied have been found to exhibit lower returns to scale. For example, Golany and Thore (1997) present an empirical evaluation of the returns to scale across 72 developed and developing countries between 1970 and 1985 – a period covered by many of the other studies assessing the economic impact of standards.[90] They conclude that the United Kingdom, the Scandinavian countries, Australia, and New Zealand

88 Autocorrelation, also known as serial correlation, refers to the correlation between the error terms or residuals of a model at different time points. In simpler terms, it measures the degree to which the current error term of a model is related to the error terms of previous observations. Autocorrelation violates the assumption of independent errors, which affects the efficiency and precision of coefficient estimates. The standard errors of the coefficients may be underestimated or overestimated, leading to inaccurate hypothesis testing and confidence intervals.

89 Heteroskedasticity means that as the independent variable(s) change, the variability of the dependent variable also changes. This can have implications for the accuracy of our analysis because our model assumes that the variability of the dependent variable is constant across all levels of the independent variable(s).

90 See Section 1.5.

all exhibit decreasing returns to scale, while many less advanced economies exhibit increasing returns to scale.

Lastly, it has been touched upon in the discussion around Assumption 4 in Section 8.3, but it deserves further discussion here. The main weakness in switching from a two-stage model to a single-stage model is that we are no longer explicitly estimating the role of TFP as it relates to standards and labour productivity. While our estimate for the direct impact of standards on labour productivity is robust, we lose some useful context – we cannot prove that the positive impact of standards on labour productivity growth occurs through an increase in TFP.

8.4.3 Sensitivity Testing

We could not successfully gauge the consistency of the estimator for standards. We gradually added new variables and changed the structural specification of the regression model until we found a suitable model that satisfied the conditions required to use the Ordinary Least Squares (OLS) regression method. These conditions are assumptions that, when met, allow for accurate and reliable estimation of the regression model. We chose our ultimate model, i.e. Equation 14 because this was the only model that performed well without violating the assumptions that may affect the validity of the OLS results.

It performed well in terms of goodness of fit, measured by the R^2, and explains around 97% of the variation in the labour productivity observed during the period. Furthermore, while all the variables we chose in the model turned out to be statistically significant at the 10% significance level, the signs of their respective coefficients also align with general economic intuition.

Combinations of other variables yielded unsatisfactory models that we had to discard as they tended to be misspecified, overfitted, or suffered from unacceptably high levels of multicollinearity. This is the reason why we could not shortlist a few suitable models to assess the consistency of the estimator for standards.

Finally, since we could not control for patents, it is likely that we are overestimating the effect of standards on TFP given the omission of patents.

Chapter 9: Summary and Conclusion

This chapter brings together the findings and insights from the previous six chapters to summarise the results from the six country analyses, and provides a concluding discussion about the overall applicability and effectiveness of the ISO methodology in a developing context.

9.1 Summary of the findings

We were successful in applying the ISO theoretical framework across all six countries; that is, we were able to investigate the relationship between standards and labour productivity, whether directly or indirectly through changes in TFP, to assess the economic impact associated with an increase in the stock of standards.

For Colombia and Indonesia, we were able to follow the two-stage approach, as outlined in the ISO Methodological Guidance document, whereas for the other four countries – Brazil, Jamaica, Senegal, and Uganda – we had to employ a single-stage regression approach as this had more predictive power in explaining the relationship between standards and labour productivity growth.

Table 30 below shows the key results from all six countries. Note that the comparability of the results shown below between any two studies is limited due to differences in the time periods considered as well as the exact model specifications employed. Additionally, there are differences in the driving forces of economic growth between countries at different stages of economic and political development, plus the fact that these six countries belong to very different parts of the world.

Therefore, these results are presented for illustrative purposes and are meant to be compared only at a high-level with the knowledge that they are not direct, apple-to-apple comparisons. The usual caveats for each of these results apply, and a full explanation and interpretation of their limitations can be found in their respective chapters.

Table 30: Summary of results for the six countries

Country	Brazil	Colombia	Jamaica	Indonesia	Senegal	Uganda
Publication year	2023	2023	2023	2023	2023	2023
Analysis period	1995-2019	1990-2019	2001-2019	1994-2019	1991-2019	2001-2019
Estimated function	Labour productivity	Labour productivity	Labour productivity	Labour productivity	Labour productivity	Labour productivity
Elasticity of stock of standards	**0.149**	**0.057**	**0.02***	**0.16**	**0.078**	**0.096**
Share of labour productivity growth	178.4%	21.6%	-	21.2%	78.0%	51.6%
Growth rate of GDP, % p.a.	2.2%	3.4%	*0.6%*	6.5%	3.8%	6.5%
Share of GDP growth	44.1%	7.9%	-	14.5%	17.1%	23.7%
Contribution of standards to GDP growth, % points	0.99%	0.3%	-	0.9%	0.7%	1.55%

Source: ABNT, ICONTEC, BSJ, BSN, ASN, UNBS, ILO, FRED, World Bank, IMF, Penn World Tables, and Cebr analysis

*Note: The coefficient for Jamaica refers to the ***cumulative sale of standards*** rather than the stock of standards due to data availability issues.

9.2 Discussion of the findings

The key result to note from Table 30 above is the elasticity of stock of standards from the row highlighted in bold. This should be interpreted as: for every 1% increase in the stock of standards, there is an associated X% increase in labour productivity.

The other main results from the table above are the share of labour productivity and GDP growth (that is attributable to standards), and the contribution of standards to GDP growth in percentage points. Although the latter is a more straightforward calculation which depends only on a country's elasticity of stock of standards and its growth rate of standards, the other two estimates should be treated with more caution. The extrapolation derived to estimate the share of labour productivity growth and GDP growth attributable to the increase in standards is based on a point-to-point analysis for each respective analysis period considered (i.e. 1995-2019 for Brazil, 1990-2019 for Colombia, and so on), whereby a constant growth rate of these variables between these years is assumed.

It is worth noting that, aside from Colombia with exactly 30 observations, all analyses presented here fall below the recommended number of observations as outlined by ISO; it is preferable to have at least 30 periods of data such that the Central Limit Theorem applies, though the very lower bound (or minimum recommended amount) for the number of observations is likely to be around 15. [91] This means that, while we have enough observations for robust regression analyses, the estimates for the share of labour productivity and GDP growth are much more sensitive to outliers and disturbances during the respective time periods considered. For example, the most dramatic result shown above is for Brazil, where we estimate the share of labour productivity growth – which was 0.56% per year – that is attributable to an increase in standards between 1995 and 2019 to be 178%. If instead of anchoring the analysis in 2019 we did so, for example, in 2013, right before the economic crisis of the mid-2010s began in Brazil, then this estimated share of labour productivity growth attributable to standards would decrease from 178% to 96%. This is because the average labour productivity growth between 1995 and 2019 was only 0.56%, whereas it had been 1.03% prior to the economic crisis which began after 2013. This has the effect of overestimating the share of productivity growth attributed to standards, as we see in Table 5 above with the estimated share of 178%, compared to 96% if we anchored the analysis between 1995 and 2013. Similarly, the share of labour productivity growth attributable to Standards in Senegal and Uganda is relatively high because of this same issue. Because we are not looking at any highly developed economies and the time series considered are not very long, the average growth across the economies during their respective periods is inherently more volatile and highly susceptible to outliers and shocks. For a full country-specific explanation of how each of these estimates should be interpreted for each country, please see the 'Discussion' subsections found in each of the individual country write-ups from Chapters 3-8.

That said, while the interpretation of the above extrapolated estimates should be made with caution, we should stress that the underlying elasticity of standards on labour productivity derived from our respective models remains a reliable and robust estimate. It is the implied

91 For datasets with less than 15 observations, it is harder to estimate the coefficients that describe the relationship between our variables of interest, and it can also lead to wider confidence intervals around the estimated coefficients (confidence intervals five us a range within which we are reasonably confident that the true value lies).

share of growth for both labour productivity and GDP growth that is attributable to standards where caution should be applied.

Despite the less than intuitive results above, the underlying intuition behind the impact of standards remains unchanged: standards boost economic growth by increasing output per employee through mechanisms such as improving production activity and efficiency, ensuring quality and precision, and disseminating technical knowledge. Such enhancements result in cost savings, increased output per worker, and specialisation, fostering economies of scale. The specific channels through which standards affect growth are intricate and intertwined with other factors not explored within this study, such as education, technology, and innovation, each playing a complementary role in driving productivity.

9.3 Concluding thoughts

As discussed within the relevant sections found in Chapters 3-8, the applicability and effectiveness of the prescribed ISO framework is examined in detail for each country, including a review of each of the six assumptions found in the ISO methodology guidance document. Here, we will instead give our brief thoughts on the extent to which the ISO framework works in the context of developing countries.

In short, despite some limitations, the framework has been successful in providing evidence of the impact of standards on productivity in a developing context. Although in some cases (namely Brazil, Jamaica, Senegal and Uganda) we had to deviate slightly from the exact steps suggested within the ISO methodology guidance document, we stayed within the Cobb-Douglas production function and wider theoretical framework. This approach succeeded in producing robust and significant estimates for the impact of standards on labour productivity.

There were data-related challenges for all six analyses. These ranged from insufficient historical data for patents, to lack of consistent data on the stock of standards for Jamaica or lack of robust TFP data for Senegal and Uganda. In the case of missing patents data, this simply meant that it could not be used as a control variable for any of the six models. The lack of stock of standards data in Jamaica meant we had to use the sale of standards instead. And the lack of robust TFP data in the case of Senegal and Uganda meant we had to employ a single-stage model as opposed to the two-stage approach outlined in the ISO methodology. However, none of these data-related issues were enough that it stopped us from producing a sufficiently robust model for each of the countries.

Overall, we find that the effectiveness of the results is relatively high given the quality of the models in explaining movements in labour productivity for each of the six countries. Furthermore, the framework is also successful in terms of its applicability, though as mentioned above it could not be applied exactly as outlined in the ISO methodology guidance document for all of the countries. However, the fact that the exact steps from the methodology could not be followed is not a consequence of the prescribed framework itself, rather the reality of analysing developing countries which do not have the extensive resources that highly developed nations have to successfully monitor and report on statistics from their respective economies.

Finally, whilst we are confident in the robustness of the results presented within this study, caution as well as a sound understanding of the relevant limitations, is advised.

Chapter 10: Glossary

Autocorrelation: the degree of correlation of the same variables between two successive time intervals. It measures how the lagged version of the value of a variable is related to the original version of it in a time series. Autocorrelation is a problem because it leads to inefficient estimates (they do not have minimum variance) hence our confidence in the result is lowered.

Cochrane–Orcutt regression: a procedure in econometrics which adjusts a linear model for serial correlation (autocorrelation) in the error term.

Constant returns to scale: When an increase in inputs (capital and labour) cause the same proportional increase in output.

Elasticity: measures the percentage change of one variable in response to a percentage change in another.

Logged / Log of: Taking the natural logarithm of a number or series.

Multicollinearity: a statistical concept that exists whenever an independent variable is highly correlated with one or more of the other independent variables in a multiple regression equation. Multicollinearity is a problem because it undermines the statistical significance of an independent variable.

Omitted variable bias: refers to any variable not included as an independent variable in the regression that might influence the dependent variable.

Overfitting: an error that occurs in data modelling as a result of a particular function aligning too closely to a minimal set of data points. The model may have good performance on the data on which it was tested, but little or no predictive power on new data in the future.

Regressor: also known as an independent variable or an explanatory variable.

Ridge regression: a model tuning method that is used to analyse any data that suffers from multicollinearity.

Stationarity: this condition is met if the statistical properties of a time series (such as its mean or variance) do not change over time. It is a necessary property of time series analysis, and when it is not met, it means that the data has to be modified so that it is transformed into a stationary process.

Stepwise regression: the step-by-step iterative construction of a regression model that involves the selection of independent variables to be used in a final model. It involves adding or removing potential explanatory variables in succession and testing for statistical significance after each iteration.

Chapter 11: Bibliography

Abidemi, A. (2010). Capital-Labour Substitution and Banking Sector Performance in Nigeria (1960-2008). *Economic and Financial Review*, *48/2*. https://www.cbn.gov.ng/Out/2012/publications/reports/rsd/efr-2010/Economic%20and%20Financial%20Review%20Vol%2048%20No%202,%20June%202010/Capital-Labour%20Substitution%20and%20Banking%20Sector%20Performance.pdf

***About BSJ*. (2021). Bureau of Standards Jamaica. https://www.bsj.org.jm/about/about-bsj**

Adetunji, A., Ibraheem, A., & Ademuyiwa, J. A. (2012). On Restricted Least Squares the Cobb-Douglas Production Function for the Nigerian Economy. *Developing Country Studies*, *2*(8).

AFNOR. (2009). *The Economic Impact of Standardization: Technological Change, Standards Growth in France*.

Aghion, P., Bloom, N., Blundell, R., Griffith, R., & Howitt, P. (2005). Competition and Innovation: an Inverted-U relationship*. *Quarterly Journal of Economics*, *120*(2), 701–728. https://doi.org/10.1162/0033553053970214

Annual Report. (2017). In *Badan Standardisasi Nasional*.

Associação Brasileira de Normas Técnicas. (2011). *História da normalização - Brasil*.

Astorga, P., Bergés, A. R., & FitzGerald, V. (2011). Productivity Growth in Latin America during the Twentieth Century. *Review of Income and Wealth*, *57*(2), 203–223. https://doi.org/10.1111/j.1475-4991.2011.00447.x

Barro, R. J., & Wolf, H. C. (1988). *Data appendix for economic growth in a cross-section of countries* [Dataset].

BERL Economics. (2011). *The Economic Benefits of Standards to New Zealand*.

Blind, K. (2009). Standardisation as a catalyst for innovation. *The Review of Economic Studies*, 1–27. https://repub.eur.nl/pub/17558/EIA-2009-039-LIS.pdf

Blind, K., & Gauch, S. (2008). Research and standardisation in nanotechnology: evidence from Germany. *Journal of Technology Transfer*, *34*(3), 320–342. https://doi.org/10.1007/s10961-008-9089-8

Blind, K., Jungmittag, A., & Mangelsdorf, A. (2011). The economic benefits of standardization - An update of the study carried out by DIN in 2000. *Deutsches Institut Für Normung e.V. (DIN)*. https://opus4.kobv.de/opus4-bam/frontdoor/index/index/docId/25073

Blind, K., Petersen, S. S., & Riillo, C. a. F. (2017). The impact of standards and regulation on innovation in uncertain markets. *Research Policy*, *46*(1), 249–264. https://doi.org/10.1016/j.respol.2016.11.003

Blind, K., Ramel, F., & Rochell, C. (2021). The influence of standards and patents on long-term economic growth. *Journal of Technology Transfer*, *47*(4), 979–999. https://doi.org/10.1007/s10961-021-09864-3

Cárdenas, M. (2007). Economic Growth in Colombia: a reversal of “fortune”? *Ensayos Sobre Política Económica*, *53*, 220–259. https://doi.org/10.32468/espe.5305

Cebr. (2014). *The Economic Contribution of Standards to the UK Economy*. https://www.bsigroup.com/LocalFiles/en-GB/standards/BSI-standards-research-report-The-Economic-Contribution-of-Standards-to-the-UK-Economy-UK-EN.pdf

***Departamento Administrativo Nacional de Estadística (DANE)*. (n.d.). https://www.dane.gov.co/**

Department of Trade and Industry. (2003). The Empirical Economics of Standard. In *DTI Economics*.

Diagne, A., & Demont, M. (2007). Taking a new look at empirical models of adoption: average treatment effect estimation of adoption rates and their determinants. *Agricultural Economics*, *37*(2–3), 201–210. https://doi.org/10.1111/j.1574-0862.2007.00266.x

Donohue, J. J., & Levitt, S. D. (2001). The impact of legalized abortion on crime. *Quarterly Journal of Economics*, *116*(2), 379–420. https://doi.org/10.1162/00335530151144050

Elgin, C., Kose, A., Yu, S., & Ohnsorge, F. (2021). Understanding Informality. In *Australian National University*. https://cama.crawford.anu.edu.au/sites/default/files/publication/cama_crawford_anu_edu_au/2021-09/76_2021_elgin_kose_ohnsorge_yu.pdf

Fajnzylber, P., & Lederman, D. (1999). Economic Reforms and Total Factor Productivity Growth in Latin America and the Caribbean (1950-95): An Empirical note. In *The World Bank eBooks*. https://doi.org/10.1596/1813-9450-2114

Fragile States Index. (n.d.). *E3: Human Flight and Brain Drain*. https://fragilestatesindex.org/indicators/e3/

Fraser, I. (2002). The Cobb-Douglas production function: an antipodean defence? *Economic Issues Journal Articles*, *7*(1), 39–58. https://www.econ.iastate.edu/tesfatsi/ProductionCobbDouglasFct.EmpValid.Fraser.pdf

Fu, H. (2019, May 15). Data for development impact: Why we need to invest in data, people and ideas. *World Bank Blogs*. https://blogs.worldbank.org/voices/data-for-development-impact-why-we-need-to-invest-in-data-people-and-ideas

Goedhuys, M., & Sleuwaegen, L. (2016). International standards certification, institutional voids and exports from developing country firms. *International Business Review*, *25*(6), 1344–1355. https://doi.org/10.1016/j.ibusrev.2016.04.006

Golany, B., & Thore, S. (1997). The economic and social performance of nations: efficiency and returns to scale. *Socio-economic Planning Sciences*, *31*(3), 191–204. https://doi.org/10.1016/s0038-0121(96)00032-8

Goldstein, M. (1998). *The Asian Financial Crisis: Causes, Cures, and Systemic Implications*. Peterson Institute.

Haimowitz, J., Warren, J., & Du Canada, C. B. (2007). *Economic value of standardization*.

Harris, R., & Liu, A. (1999). Verdoorn's law and increasing returns to scale: country estimates based on the cointegration approach. *Applied Economics Letters*, *6*(1), 29–33. https://doi.org/10.1080/135048599353834

Havranek, T., Irsova, Z., Gechert, S., & Kolcunova, D. (2019). Death to the Cobb-Douglas Production Function? A Meta-Analysis of the Capital-Labor Substitution Elasticity. *Leibniz Information Centre for Economics*. https://doi.org/10.31222/osf.io/6um5g

Hayes, A. F., & Cai, L. (2007). Using heteroskedasticity-consistent standard error estimators in OLS regression: An introduction and software implementation. *Behavior Research Methods*, *39*(4), 709–722. https://doi.org/10.3758/bf03192961

Ho, J. Y., & O'Sullivan, E. (2017). Strategic standardisation of smart systems: A roadmapping process in support of innovation. *Technological Forecasting and Social Change*, *115*, 301–312. https://doi.org/10.1016/j.techfore.2016.04.014

Hossain, A. (2006). Sources of economic growth in indonesia, 1966-2003. *Applied Econometrics and International Development*, *6*(2), 183–202. https://dialnet.unirioja.es/servlet/articulo?codigo=7477308

Huang, T., Chiang, T., & Pan, J. (2015). Fertility and Crime: Evidence from Spatial Analysis of Taiwan. *Journal of Family and Economic Issues*, *36*(3), 319–327. https://doi.org/10.1007/s10834-015-9440-9

Husain, S. (2016). A test for the Cobb Douglas production function in manufacturing sector: The case of Bangladesh. *International Journal of Business and Economics Research*, *5*(5), 149. https://doi.org/10.11648/j.ijber.20160505.13

ISO - Standards. (n.d.). ISO. Retrieved April 1, 2023, from https://www.iso.org/standards.html

ISO. (2021). *Economic impact of standards - Methodological guidance*.

Liao, D. & Standards Council of Canada. (2021). *Every Standard Counts – How Standardization Boosts the Canadian Economy*.

Lorenz, A., Raven, M., & Blind, K. (2017). The role of standardization at the interface of product and process development in biotechnology. *Journal of Technology Transfer*, *44*(4), 1097–1133. https://doi.org/10.1007/s10961-017-9644-2

Manders, B., De Vries, H. J., & Blind, K. (2016). ISO 9001 and product innovation: A literature review and research framework. *Technovation*, *48–49*, 41–55. https://doi.org/10.1016/j.technovation.2015.11.004

McCombie, J., & Roberts, M. (2007). Returns to scale and regional growth: the static-dynamic Verdoorn law paradox revisited. *Journal of Regional Science*, *47*(2), 179–208. https://doi.org/10.1111/j.1467-9787.2007.00505.x

Menon. (2018). *The Influence of Standards on the Nordic Economies* (No. 31/2018).

Miller, E. (2008). *An Assessment of CES and Cobb-Douglas Production Functions*. https://www.cbo.gov/sites/default/files/cbofiles/ftpdocs/94xx/doc9497/2008-05.pdf

Muchdie, M. (2016). Technical Efficiency and Return to Scale in The Indonesia Economy During The New Order and The Reformation Governments. *Jurnal Ekonomi Pembangunan: Kajian Masalah Ekonomi Dan Pembangunan*, *17*(2), 136. https://doi.org/10.23917/jep.v17i2.2430

Newey, W. K., & West, K. D. (1987). A simple, positive Semi-Definite, heteroskedasticity and autocorrelation consistent covariance matrix. *Econometrica*, *55*(3), 703. https://doi.org/10.2307/1913610

Nurse. (2004). *Diaspora, migration and development in the Caribbean: Policy paper FPP-04-6*.

Ohnsorge, F., & Yu, S. (2022). *The long Shadow of Informality: challenges and policies*. https://doi.org/10.1596/978-1-4648-1753-3

Oliveira, F. H. P., Jayme, F. G., & Lemos, M. B. (2006). Increasing returns to scale and international diffusion of technology: An empirical study for Brazil (1976–2000). *World Development*. https://doi.org/10.1016/j.worlddev.2005.07.011

Ospina, L. V. U. (2022). The effect of crime on adolescent fertility in Colombia. *Revista Desarrollo Y Sociedad*. https://econpapers.repec.org/article/col000090/020260.htm

Perez-Reyna, D., & Osorio, D. (2018). The Monetary and Fiscal History of Colombia: 1960-2017. *Social Science Research Network*. https://doi.org/10.2139/ssrn.3238183

Personal remittances, received (% of GDP). (n.d.). World Bank. https://data.worldbank.org/indicator/BX.TRF.PWKR.DT.GD.ZS

Productivity in Jamaica: Address to the Jamaica Chamber of Commerce. (2011). In *Bank of Jamaica*. https://www.boj.org.jm/uploads/news/speech_-_jcc_luncheon,_2011-9-13.pdf

Qian, R., Araújo, J., & Nucifora, A. (2018). Brazil's productivity dynamics. *The World Bank Group*.

Querubín, P. B. (2002). *Crecimiento departamental y violencia criminal en Colombia*.

Riascos, A., & Vargas, J. F. (2011). Violence and growth in Colombia: A review of the quantitative literature. *The Economics of Peace and Security Journal*, *6*(2). https://doi.org/10.15355/epsj.6.2.15

Salazar, B. (2014, February 10). La violencia homicida en Cali: volver a la comunidad. *Razón Pública*. https://razonpublica.com/la-violencia-homicida-en-cali-volver-a-la-comunidad/

Salazar, B. (2016, May 16). La maldición de ser joven en Cali. *Razón Pública*. https://razonpublica.com/la-maldicion-de-ser-joven-en-cali/

Sandoval Garrido, L. E. (2021). Youth crime in Colombia. *Papeles De Poblacion*. https://doi.org/10.22185/24487147.2020.105.24

Schneider, M., & Enste, D. (2002). *Hiding in the Shadows: The Growth of the Underground Economy*. International Monetary Fund.

Spilimbergo, A., & Srinivasan, K. (2019). *Brazil: boom, bust, and road to recovery*. https://doi.org/10.5089/9781484339749.071

Standards Australia. (2012). *The Economic Benefits of Standardisation*.

Swann, G. M. (2010). International Standards and Trade: A Review of the Empirical literature. *RePEc: Research Papers in Economics*. https://EconPapers.repec.org/RePEc:oec:traaab:97-en

https://EconPapers.repec.org/RePEc:oec:traaab:97-en

Swann, G. M., & Lambert, R. (2017). Standards and innovation: a brief survey of empirical evidence and transmission mechanisms. In *Edward Elgar Publishing eBooks*. https://doi.org/10.4337/9781783470082.00009

Swann, P. (2000). The Economics of Standardization: Final Report for Standards and Technical Regulations Directorate Department of Trade and Industry. *UK National Archives*.

Thompson, A., & Sissoko, Y. (2019). The Price Of Cocaine And The Colombian Peso: An Empirical Investigation. *Global Economy Journal*, *19*(03). https://doi.org/10.1142/s2194565919500155

Thorbecke, W. (2019). The Weak Rupiah: Catching the tailwinds and avoiding the shoals. *RePEc: Research Papers in Economics*. https://ideas.repec.org/p/eti/dpaper/19006.html

Uotila, J., Keil, T., & Maula, M. (2017). Supply-Side network effects and the development of information technology standards. *Management Information Systems Quarterly*, *41*(4), 1207–1226. https://doi.org/10.25300/misq/2017/41.4.09

Vargas, J. F. (2003). *Conflicto Interno y Crecimiento Económico en Colombia* [Master Thesis].

Wiegmann, P. M. (2019). Managing innovation and standards. In *Springer eBooks*. https://doi.org/10.1007/978-3-030-01532-9

World Trade Report: Exploring the links between trade, standards and the WTO. (2003).

Worldwide governance indicators (WGI). (n.d.). https://info.worldbank.org/governance/wgi/Home/Documents

Zhang, H., Jiang, J., Zheng, L., & Xiang-Zhen, L. (2019). The interaction between standards development and economic growth of China. *International Journal of Quality Innovation*, *5*(1). https://doi.org/10.1186/s40887-019-0034-8

Cebr