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Please address correspondence to
Banco de Portugal, Economics and Research Department
Av. Almirante Reis 71, 1150-012 Lisboa, Portugal
T +351 213 130 000 | estudos@bportugal.pt

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Content

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Editor's note[1]

Pedro Duarte Neves

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1. This issue of Banco de Portugal *Economic Studies* includes three studies. The first describes the pattern of revisions to the main aggregates of the Quarterly National Accounts since 2010. The second presents the degree to which digital technologies have been adopted by Portuguese firms. The third proposes an assessment of the Portuguese health system's efficiency. The three studies have made it possible for the results obtained for Portugal to be contextualised within the European Union.

2. The information available to produce national accounts by the deadlines set for their release is incomplete, requiring the use of statistical inference techniques. This is especially relevant for quarterly accounts. It is therefore inevitable that, as the relevant information becomes available, the national accounts are revised.[2]

The opening study of this issue – by Cardoso, Gouveia and Rua – analyses the revisions to the Quarterly National Accounts (QNA) for the period 2010-22. The study offers highly insightful information for a better understanding of how the economy is performing. The main findings of the study, from the editor's perspective, are as follows:[3]

Revision to GDP flash estimate (chain rate of change):

(i) The GDP flash estimate has a high level of information: the revisions to the GDP chain's rate of change had a mean of approximately zero and a mean absolute revision of less than $\frac{3}{4}$ of a tenth;

E-mail: pneves@bportugal.pt

1. The analyses, opinions and conclusions expressed in this editorial are entirely those of the editor and do not necessarily coincide with those of Banco de Portugal or the Eurosystem.

2. See "How is GDP calculated?", Statistics Portugal, August 2018.

3. The authors use a wide range of statistical measures for revisions: the editor prioritises one of them, the mean absolute deviation. The editor also chooses to put more emphasis on revisions to year-on-year rates of change than to quarter-on-quarter rates of change, with the sole exception of the GDP flash estimate. The editor has also opted for rounding to the first decimal place.

Revision to Quarterly National Accounts (year-on-year rate of change):

(ii) The first and second revisions to GDP year-on-year rates of change are very small; on average they are close to zero, the mean absolute deviation is less than a tenth (0.1 percentage points);

(iii) However, some expenditure components show deeper revisions; taking the first revision to the QNA as a reference, the mean absolute revision (in percentage points) is more than 0.5 percentage points in the following components: GFCF in machinery (2.1 percentage points), GFCF in transport equipment (1.5 percentage points), imports of services (1 percentage point), other GFCF (0.9 percentage points), imports of goods (0.7 percentage points) and exports of services (0.7 percentage points);

(iv) Revisions to expenditure components show statistically significant correlations that carry information; revisions to exports have a statistically significant correlation with the revisions to imports (positive) and private consumption (negative); furthermore, the revisions to imports have a positive statistical association with the revisions to GFCF and the change in inventories; this pattern of revisions may reflect the use of "apparent" expenditure indicators in National Accounts' production;

(v) In terms of GVA components, the mean absolute revision is more significant in the case of agriculture, forestry and fishing (1.8 percentage points) and energy, water and sanitation (1.0 percentage points); the revisions are quantitatively greater in the case of GVA than GDP, reflecting the lower reliability of supply-side estimates;

Revision to Quarterly National Accounts after six quarters, by inclusion of provisional National Accounts (year-on-year rate of change):

(vi) Revisions to QNA by inclusion of provisional National Accounts are higher than the first revisions – a mean revision of 0.1 percentage points and a mean absolute revision of 0.3 percentage points for GDP – but still relatively subdued;

Revision to Quarterly National Accounts after three years, by inclusion of final National Accounts (year-on-year rate of change):

(vii) The most significant aspect of revisions resulting from the inclusion of final National Accounts is that, over the period under review, they showed a positive mean (0.3 percentage points, in the case of GDP) which is statistically different from zero; the mean absolute revision increases to 0.6 percentage points; the GVA revisions are also quantitatively higher (0.5 and 0.8 percentage points respectively);

(viii) The mean absolute revisions of expenditure components show a change in their ranking: GFCF in transport equipment (9.5 percentage points), GFCF in machinery (4.9 percentage points), other GFCF (3.4 percentage points), consumption of durable goods (2.3 percentage points), exports of services (1.9 percentage points) and imports of services (1.7 percentage points);

(ix) Nominal GDP revisions are generally higher than GDP growth revisions;

finally, and probably the most important finding of the study,

(x) The profile of revisions to the economy's real rates of change (in volume) tends to be procyclical, i.e. upward revisions prevail in years of higher output growth and downward revisions prevail in years of lower economic activity.

3. The analysis of revisions to National Accounts estimates is key for a better understanding of how an economy develops and works, both in the short run and in identifying more structural trends. Against this background, the statistical authorities of Portugal, Spain and Italy released analyses of the revisions to National Accounts for the 2020-22 period[4] last September, shedding light on what actually happened during the pandemic and the economic rebound that followed.

A structurally bigger question is whether or not there are systematic patterns in National Accounts. Unfortunately, despite various analyses of the subject, the editor is not aware of any summary of the key findings. Nevertheless, some evidence agrees[5] with Cardoso, Gouveia and Rua's finding that GDP revisions tend to be procyclical in nature: in other words, the most pronounced positive revisions tend to take place in years of higher economic growth; negative revisions in years of negative or zero growth.

The confirmation of this finding entails a major corollary: revisions to output gap estimates – which can be construed as a global summary measure of the degree of use of productive resources in an economy – will also tend to show procyclical behaviour. This is relevant for the real-time interpretation of indicators using output gap estimates, such as monetary policy rules, natural interest rate estimates, natural unemployment estimates or budget balances adjusted for cyclical developments. This justifies an invitation to the reader to revisit the seminal study "The Unreliability of

4. Quarterly National Accounts by institutional sector (benchmark year 2016), second quarter 2023, Statistics Portugal, 22 September 2023, Contabilidad Nacional Anual de España Años 2020-2022, National Institute of Statistics, 18 September 2023; Conti Economici Nazionali, Anni 2020-2022, Istitut Nazionale di Statistica, 22 September 2023.

5. See, for instance, "Revisions analysis of initial estimates of annual constant price GDP and its components", Peter Symons, Office for National Statistics, Economic Trends No 568 March 2001, "Do Revisions to GDP Follow Patterns?", Michael T. Owyang, On The Economy Blog, St. Louis Fed, 26 May 2014.

Output-Gap Estimates in Real Time".[6]

4. Knowing the revision pattern is all the more important where an economic policy goal is set in terms of a National Accounts variable. The Federal Open Market Committee (FOMC) of the US Federal Reserve sets its long-term inflation target in terms of the annual change in the National Accounts' PCE (Personal Consumption Expenditures Price Index), also referred to as the "private consumption deflator."

Opting for this variable was the result of a very thorough technical analysis that led, in February 2000, to the PCE replacing the Consumer Price Index (CPI) as the reference measure for the inflation target. This explains the option for the PCE over the CPI:[7] (i) expenditure weights, reflecting changes in relative prices and income, vary from time to time for the PCE, while the CPI weights only change when the reference basket is updated; (ii) the PCE has a more complete coverage of goods and services than the CPI; (iii) the PCE can be revised to include relevant past information, which is not the case with the CPI.[8] Despite this choice, the FOMC monitors how these two indicators develop when conducting monetary policy. The core inflation measures of both indicators – excluding energy and food components – are also monitored on a regular basis by monetary policymakers and the public at large.

The PCE thus registers regular changes stemming from the National Accounts revision process. This introduces uncertainty into real time inflation measurement. A recent paper[9] by Federal Reserve Bank of New York economists presents some key findings, focusing on core inflation behaviour:

(i) Around 1/6 of the revisions to the core PCE annualised inflation measure were greater than 1 percentage point;
(ii) Almost all of the revisions to the core PCE are the result of changes in core services prices and not from changes in core goods prices;

6. "The Unreliability of Output-Gap Estimates in Real Time", Athanasios Orphanides and Simon van Norden, The Review of Economics and Statistics, Vol. LXXXIV, Number 4, November 2002. This study concludes that the revisions to the output gap estimates are due to two main reasons: the revisions to the National Accounts and, above all, the revisions to the output trend estimate (associated with the "end-of-sample" problem).

7. See: "President's Message: CPI vs. PCE Inflation: Choosing a Standard Measure", James Bullard, President of the Federal Reserve Bank of St. Louis, 1 July 2013; "Monetary Policy Report to the Congress pursuant to the Full Employment and Balanced Growth Act of 1978", Board of Governors of the Federal Reserve System, 17 February 2000.

8. The seasonally adjusted CPI series has naturally changed, reflecting an adjustment in the estimates of seasonality patterns with the inclusion of new data.

9. "How Large Are Inflation Revisions? The Difficulty of Monitoring Price in real Time", Richard Audoly, Martin Almuzara, Richard Crump, David Melcangi, and Roshie Xing, Liberty Street Economics, Federal Reserve Bank of New York, 7 September 2023. This study uses data from 2001.

(iii) The CPI core measure has no relevant explanatory power for future revisions to the PCE core measure;

and also based on the analysis carried out,

(iv) There is significant uncertainty in the real-time measurement of core PCE which, according to the authors, could range between 3.7 and 4.7 per cent on the date the study was released (September 2023).

5. The second study of this Banco de Portugal *Economic Studies*, by Amador and Silva, reviews the adoption of digital technologies by Portuguese firms. For this purpose, two databases from Statistics Portugal are used: the "Survey on the Use of Information and Communication Technologies in Enterprises" and the "*Sistema de contas integradas das empresas.*" The authors distinguish between two dimensions: the adoption of Information and Communication Technologies (ICT), measured by factors such as the availability of PCs at the firm, an internet connection, website, ICT staff, online sales and online purchases; digital technologies using robots, 3D printing, cloud computing and big data.

The authors obtain very interesting results – in terms of statistical association – among which the editor highlights the following:

(i) As expected, the use of digital technologies has increased in Portuguese firms;
(ii) The degree of use of digital technologies varies considerably across sectors;
(iii) Digitalisation is greater in larger firms, in terms of sales volume and number of employees;
(iv) Firms using digital technologies to a greater extent tend to be more productive, pay higher wages and show a higher percentage of exports in their total sales.

Furthermore, the authors seek to find causal relationships. Notwithstanding the statistical difficulties in identifying them, the authors found a (positive) causal relationship between the use of digital technologies and labour productivity.

This study is a key contribution to understanding the degree of digitalisation in productive activity in Portugal. In a context of profound changes in economic activity – digitalising preferences, automation, artificial intelligence and the possibility of remote working – further progress must be made in identifying its main effects on productivity, the degree of use of productive factors and the competitiveness of the economy.

6. The final study, by Braz and Cabral, looks at the efficiency of the Portuguese health system in the context of the euro area. The methodological approach consists of the non-parametric estimation of a production frontier – Data Envelopment Analysis – representing the efficiency relationship between the use of resources (measured by

health expenditure per capita, in purchasing power parity) and the result obtained (as indicated by life expectancy). Countries with efficient health systems are on this production frontier (or close to it); countries with less efficient health systems are below this frontier, i.e. they could use fewer resources to obtain the same result, or they could obtain a better result with the resources they already use.

The study provides evidence that in Portugal, as in most euro area countries, there were efficiency gains from 2014 to 2019, the two specific time points considered in the analysis. In 2019 Portugal was in an intermediate position in the euro area in terms of health spending efficiency. This position reflects intermediate values, both in terms of results and the use of resources. In 2019 life expectancy at birth was 82 years in Portugal (ranking twelfth, in descending order, amongst the 19 countries included in the study); health expenditure, per capita and in purchasing power parity, also ranked twelfth, in descending order.

The aggregate analysis of the efficiency of resource use is one of the many aspects to be considered when evaluating a health system. Other criteria that could be looked at are: (i) fairness in the provision of health services, in terms of access and prices; (ii) quality of medical services provided, especially in terms of speed of service, as well as facilities, health professionals and medical techniques; (iii) multidimensional assessment of the results obtained by the health system.

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Non-technical summary

October 2023

From first to last: the National Accounts revisions

Fátima Cardoso, Carlos Melo Gouveia and António Rua

The aim of this article is to assess and analyse the revisions to the main macroeconomic aggregates released with the Quarterly National Accounts (QNA) for the period from 2010 up to 2022. The aim is to evaluate their reliability and understand the degree of similitude between the first estimates and subsequent estimates over the last decade as well as in the most recent period affected by the pandemic.

The QNA releases GDP data and its components, both from expenditure and supply sides, 60 days after the end of the reference quarter. A flash estimate for the volume GDP rate of change is also released 30 days after the end of the quarter. The deadlines for releasing the QNA in Portugal have been shortened, likewise in most European countries.

The QNA are revised for two main reasons. Firstly, due to the incorporation of statistical information for the reference quarter that was not available when it was released. Secondly, the compilation of the Annual National Accounts also leads to revisions of the QNA. In fact, in September of each year n, the final annual accounts for year $n-2$ are published at the same time as the provisional accounts for year $n-1$. Then, the QNA data are changed accordingly to match the annual final data, potentially leading to more significant revisions.

This article assesses the revisions to the QNA data using the 52 *vintages* from the first quarter of 2010 up to the last quarter of 2022. In particular, we analyse the revisions to the GDP flash estimate and in more detail the revisions to the QNA, namely GDP and the main expenditure and gross value added aggregates. In addition, the revisions to the annual data, resulting from the inclusion of the Annual National Accounts are assessed vis-à-vis the first annual estimates for each year (implicit in the release of the fourth quarter of the respective year) in real and nominal terms.

Chart 1 shows three of the measures used in the article to assess revisions to GDP volume rates of change, both year-on-year and quarter-on-quarter: the mean revision, the mean absolute revision and the standard deviation. The results show that, in the period immediately following the release of the first estimates, the revisions are not significant. However, for longer periods and, in particular, after the inclusion of the final annual accounts for the reference year, the revisions are typically larger and, on average, positive.

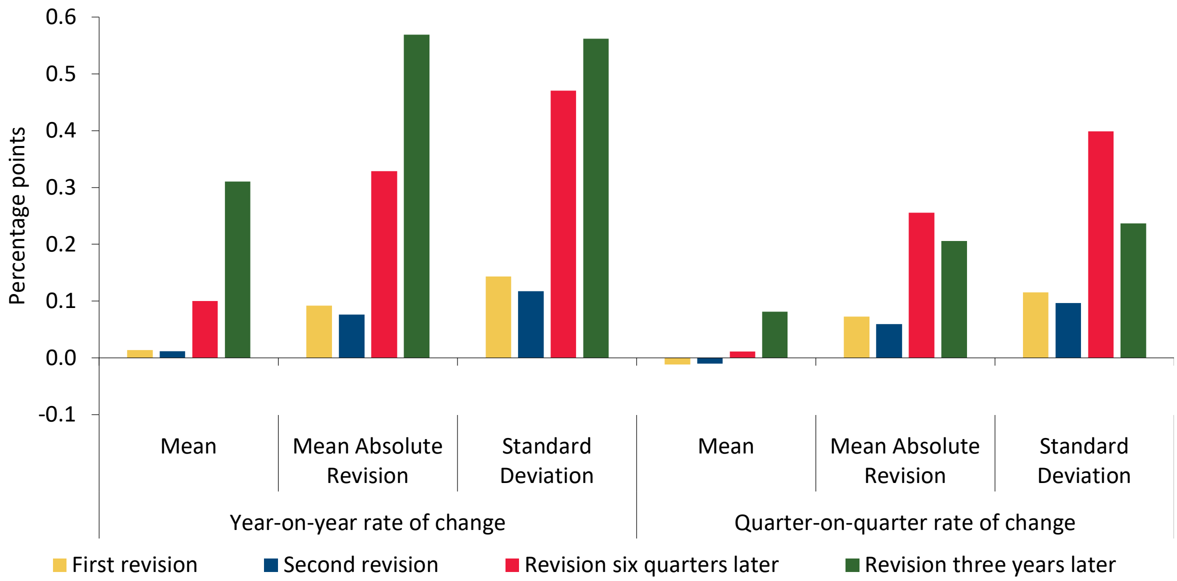

FIGURE 1: Descriptive statistics of the revisions of quarterly volume GDP.

Notes: First revision corresponds to the revision between the first QNA estimate and the second estimate and second revision corresponds to the revision between the second estimate and the third estimate. Revision six quarters later corresponds to the revision between the first estimate and the seventh estimate, i.e., six quarters after the first estimate. Revision after three years corresponds to the revision between the first estimate and the estimate after three years (12 quarters later). The first estimate is the first complete QNA release,i.e., not considering the GDP flash estimate.

Concerning the breakdown of the GDP, the expenditure components with the largest revisions are imports and GFCF. GVA revisions are higher than those for GDP, suggesting that supply-side estimates are less reliable, with sectoral GVA also showing higher volatility of the revisions.

Regarding the revisions in annual terms due to the inclusion of the final national accounts, the revisions to nominal GDP are generally higher than those to real GDP, as revisions to the deflator are typically in the same direction as those to volume. As with the quarterly data, the most revised components in terms of volume and price are imports and investment. The revisions to the real rates of change were mostly positive over the period under analysis, showing a pro-cyclical behaviour with negative revisions in the years with negative GDP change and upward revisions in years of economic growth. The data also suggests that in periods of larger absolute variations in GDP, the revisions tend to be higher, which seems to suggest some conservatism in the initial estimates.

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From first to last: the National Accounts revisions

Fátima Cardoso
Banco de Portugal

Carlos Melo Gouveia
Banco de Portugal

António Rua
Banco de Portugal
Nova SBE

October 2023

Abstract
This article analyses the revisions to the Quarterly National Accounts in Portugal, using real-time data for the period from 2010 to 2022, including the period of the COVID-19 pandemic. We assess the revisions of quarterly estimates for real GDP and its components on both the expenditure and supply sides, as well as the reliability of the GDP flash estimate. The revisions to the annual data due to the inclusion of the final Annual National Accounts are also studied, and in the case of GDP the analysis is extended to nominal and deflator revisions. The first GDP revisions are in general small, but considering a longer revision period, they become significant and tend to be positive. The expenditure components related to external trade, in particular imports and GFCF, are the ones with the largest revisions. GVA revisions are higher than those for GDP, suggesting that supply-side estimates are less reliable. (JEL: C49, C89, E01)

1. Introduction

The Quarterly National Accounts (QNA) are a very important tool for macroeconomic analysis and to support economic policy and the decisions of economic agents. Over time, the Portuguese national accounts, as in most European countries, have been released on a progressively more regular and timely schedule. As the trade-off between the timeliness and reliability of statistics is well known, the usefulness of the QNA is largely due to the fact that they provide a coherent set of macroeconomic indicators with a short time lag. However, the first estimates of the QNA are, by nature, preliminary and subject to revisions throughout time, reflecting the integration of data sources only available at later stages. Given the importance of these statistics, an analysis of the magnitude and evolution of the revisions is a useful tool for a better understanding and evaluation of these data at the various points in time.

The quality of statistical information involves several dimensions, the most important of which are accuracy (that is, the degree of similitude to the true value of

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E-mail: fcardoso@bportugal.pt; cgouveia@bportugal.pt; arua@bportugal.pt

the variable being measured) and timeliness, both of which are fundamental for the information to be relevant to users. When assessing the quality of national accounts statistics, in addition to accuracy and timeliness of release, other criteria must also be considered, such as coverage, coherence and comparability with data from other countries (see, for example, Eurostat (2021)). However, in national accounts it is difficult to directly assess the accuracy of estimates, and the main tool in this regard is revision analysis. The analysis of revisions consists of comparing an estimate at a given point in time with those released at later points in time for the same reference period. On the assumption that revisions improve accuracy of statistics, the analysis of revisions, and, in particular, revisions bias, should be seen as indicators of reliability rather than accuracy (see, for example, Symons (2001) and Zwijnenburg (2015)). Thus, the reliability of an initial estimate refers to the consistency between that initial estimate and subsequent estimates of the same variable, although this may not have a direct correspondence in terms of accuracy.

It should be noted that revisions are part of the statistical production process, so it should not be inferred that a statistic with smaller revisions is necessarily of higher quality than a more revised one. For example, in some cases, the absence of revisions means that more accurate or higher quality data sources are not available afterwards, while, on the other hand, the delay in the availability of more complete statistical sources may justify more significant revisions later on, maintaining the usefulness of the less accurate preliminary estimates. However, the existence of significant revisions can harm the assessment of the economic situation and its forecast, which is why it is important to quantify the magnitude of the revisions.

The analysis of revisions to macroeconomic data, in particular the revisions to GDP and its components released in QNA, has been carried out for several countries over the last few years. See, for example, Aruoba (2008) for the USA, Meader (2007) for the UK, Kholodilin and Siliverstovs (2009) and Strohsal and Wolf (2020) for Germany, Helliesen and Skjerpen (2022) for Norway or Bishop *et al.* (2013) and ABS (2021) for Australia. It should be noted that this issue has been repeatedly addressed by various international institutions such as the ECB and the OECD (for example, Branchi *et al.* (2007) for the euro area, and McKenzie (2006) and Zwijnenburg (2015) for comparative analyses of GDP revisions for various OECD countries). More recently, Jorda *et al.* (2020) and ONS (2022) examine GDP revisions for the United States and the United Kingdom in the exceptional context of the COVID-19 pandemic.

For Portugal, José (2004) evaluated the revisions of Portuguese QNA for the period between the last quarter of 1991 and the first quarter of 2004 and Cardoso and Rua (2011) studied the revisions for the period between the last quarter of 2002 and the first quarter of 2011. This article seeks to revisit the reliability of the Portuguese QNA for the most recent period, considering the period of QNA releases between the first quarter of 2010 and the last quarter of 2022.

The article is organized as follows. Section 2 presents the data and methodology, describing the type of revisions and the statistical criteria used for evaluation. Section 3 assesses the quarterly revisions to GDP and the main expenditure and GVA aggregates. Despite the large amount of information available in this type of analysis, we give greater prominence to the revisions of real GDP as it is the main macroeconomic aggregate in monitoring the evolution of activity. Section 4 analyses the annual revisions resulting from the inclusion of the Annual National Accounts (ANA), extending the analysis to nominal and deflator revisions. Section 5 concludes.

2. Data and methodology

2.1. Data

In this article, we assess the revisions to GDP and its components using the data disclosed in all of Statistics Portugal's QNA releases since the first quarter of 2010 to the fourth quarter of 2022. Compared to the periods analysed in previous studies, this sample period corresponds to a more regular and homogeneous set of releases, in terms of both the detail of the estimates and the calendar release schedule.

The first QNA release considered coincides with the beginning of the compilation of the QNA on a 2006 basis, when important methodological changes were introduced, namely the introduction of the new classification of economic activities (NACE Rev.3) and new aggregates for GVA. These led to a revision of the whole QNA series at the time of the release of the first quarter of 2010.

From now on, we refer to the **first estimate** as the data corresponding to the first complete release of the QNA for a given quarter (including GDP and its main expenditure components as well as GVA breakdown), which is currently disclosed 60 days after the end of the reference quarter (this deadline was 70 days until the publication of the first quarter of 2014). For the entire period under analysis, each release includes a collection of quarterly data for the period from the first quarter of 1995 to the reference quarter. Revisions to any of the previous quarters can occur in each release simultaneously with the first estimate for the reference quarter.

The data to be analysed correspond to GDP and the main expenditure components, as well as GVA and its breakdown by main branches of activity, with particular emphasis on GDP revisions. The revisions to these aggregates will therefore be assessed using a set of 52 data collections (known as vintages in the literature) corresponding to the releases over the 13-year period mentioned above.

In addition to the full release of the QNA, Statistics Portugal discloses in advance a **flash estimate** only for the GDP volume rate of change (in year-on-year and in quarter-on-quarter terms), without the respective levels or any breakdown by GDP components. Since the release for the second quarter of 2020, the flash estimate is currently disclosed 30 days after the end of the reference quarter (whereas previously it was released 45 days after the end of the quarter). These flash estimates will be assessed in a separate subsection, given the different nature and lesser detail of this publication, and only the revision implied in the first QNA estimate will be analysed.

It is also possible to analyse the revisions implicit to the annual figures obtained by aggregating the quarterly figures, i.e., revisions to the ANA estimates. For each year, the first estimates of the ANA are published at the same time as the QNA for the fourth quarter of the respective year and simply correspond to the aggregation of the four quarters of that year. In addition to these estimates (which are called preliminary annual accounts and with the detail of the QNA release), there are two types of ANA publications, with much greater detail and using additional sources (namely annual sources): the provisional ANA with an intermediate detail, and the final ANA, compiled in greater detail and incorporating a wider range of statistical sources. Currently, in September of each year n, final annual accounts for year $n-2$ are released at the same time as the provisional accounts for year $n-1$. The quarterly estimates of the immediately subsequent release include and are consistent with these annual figures.

In order to assess the revisions to the QNA due to the inclusion of the ANA, we have to take into account the release calendar of the ANA for each year. In the case of ANA, which could potentially lead to more significant revisions, the release lag underwent some changes during the period under analysis. Table 1 presents the release calendar for the final ANA published during the period under study, as well as the lag in quarters compared to the first ANA estimate (implicit in the QNA publication for the fourth quarter of the reference year). Currently, the final ANA are reflected in the QNA publication with a lag of seven quarters vis-à-vis the preliminary estimate for the whole year. The provisional ANA correspond to annual estimates that are more complete than the preliminary estimate obtained on the basis of quarterly data, but still with less detail than the final ANA. The provisional ANA started to be released in September 2018 (for the year 2017), when Statistics Portugal began to reflect information, albeit partial, from the *Informação Empresarial Simplificada* (IES). Since then, the provisional ANA have been released in September of each year without any changes to the calendar (i.e., three quarters after the first estimate for the whole year).

Reference year of ANA	Date of ANA release	First release of QNA after ANA release	Lag *vis-à-vis* the release of the 4th quarter of the corresponding year (in quarters)
2007	9 Jun. 2010	Q1 2010	9
2008	31 Mar. 2011	Q1 2011	9
2009	9 Dec. 2011	Q3 2011	7
2010	7 Dec. 2012	Q3 2012	7
2011	29 Aug. 2014	Q2 2014	10
2012	26 Mar. 2015	Q1 2015	9
2013	23 Sep. 2015	Q3 2015	7
2014	23 Sep. 2016	Q3 2016	7
2015	22 Sep. 2017	Q3 2017	7
2016	21 Sep. 2018	Q3 2018	7
2017	23 Sep. 2019	Q3 2019	7
2018	23 Sep. 2020	Q3 2020	7
2019	23 Sep. 2021	Q3 2021	7
2020	23 Sep. 2022	Q3 2022	7

TABLE 1. Release calendar of final annual national accounts (ANA)

In addition to the release calendar, it is also important to mention some of the methodological changes that took place during the period under analysis. One important issue refers to base year changes, which occur approximately every five years in order to incorporate significant changes in statistical sources, methodologies and the conceptual framework. Besides the change to the 2006 base that occurred with the first vintage analysed here, this period also encompasses the change to the 2011 base (with the release of the final 2011 ANA and the QNA for second quarter of 2014) and the change to the 2016 base (with the release of the final 2017 ANA and QNA for third quarter of 2019). Simultaneously with the base year change, Statistics Portugal carries out a retropolation exercise and publishes revised data for the entire period since 1995 (annual and quarterly) providing series compliant with the most recent base. The change to the 2011 base occurred at the same time as the adoption of the European System of Accounts 2010, leading to substantial methodological changes, which, according to Statistics Portugal, justified revisions of larger magnitude than usual. It should also be noted that key data sources for compiling national accounts (such as the IES, which currently covers around 500,000 firms) were made available or their coverage extended. In addition, in the first release of the QNA after the change to the 2011 base (referring to the second quarter of 2014, see Statistics Portugal (2014a) and Statistics Portugal (2014b)), the QNA data started being adjusted for seasonality and calendar effects, whereas previously the quarterly data were only seasonally adjusted. In the change to the 2016 base, the methodological changes were less relevant than those seen in the previous base change (see Statistics Portugal (2019)).

It should be noted that for the revision analysis, this article only takes into account the QNA releases. However, there are interim data updates on Statistic Portugal's website that do not give rise to QNA releases. In particular, with the release of the Quarterly Accounts by Institutional Sector (85 days after the reference quarter), Statistics Portugal may change the QNA data for the same quarter (disclosed 60 days after the quarter) but these revisions, which are usually minor, are not reflected in a new QNA publication. Similarly, in recent years, Statistics Portugal has revised the QNA data available in the website at the time of the release of the ANA data (in September of each year), but in this article we consider that the revisions occur in the first release of the QNA after the ANA dissemination (which currently takes place in the following November).

2.2. *Methodology*

Simultaneously with the release of the first estimate for quarter t, it is published the second estimate of quarter $t-1$, the third estimate of quarter $t-2$ and so on. Given the previously discussed database, it is possible to analyse several types of revisions.

In the case of quarterly data, we analyse revisions to volume rates of change, in year-on-year terms and *vis-à-vis* the previous quarter. Among the various possible revision horizons, we focus the analysis on a set of more relevant revisions. In this sense, it is important to assess whether the estimates are likely to be significantly revised in a short period of time (one or two quarters later). On the other hand, it is important to assess the extent to which the initial estimates are significantly revised when ANA (which imply annual restrictions to the quarterly data) are included. Bearing in mind the annual accounts calendar release presented above, so that all quarters of the year include the provisional annual accounts (as mentioned above, only released for the most recent years), it is necessary to analyse the revisions after six quarters.[1] In a similar fashion, all quarters of a given year only reflect the final annual accounts after two and a half years after the first estimate.

Hence, we present: the **first revision**, which corresponds to the revision from the second estimate vis-à-vis the first one; the **second revision**, which results from comparing the third estimate to the second; the **revision six quarters later** and the **revision three years later**, both compared to the first estimate allowing to assess the impact of including provisional and final ANA, respectively. The flash estimate, which is only available for GDP rate of change, was assessed separately. In this case, the **flash estimate revision** implicit in the first estimate of QNA is evaluated.

The analysis of quarterly revisions has been carried out using a set of statistical measures usually considered in this type of study (see, for example, Di Fonzo (2005) and Cardoso and Duarte (2009)). For ease of exposition, a revision is defined as the difference between the rates of change (year-on-year or quarter-on-quarter, in the case of quarterly data) between a final estimate and an initial estimate (here understood as the estimates after and before the revision).

As a sign indicator, the mean revision is computed. The closer the mean is to zero, the less biased the initial estimate is. In this sense, a test of the statistical significance of the mean was carried out, i.e., a test of whether the mean is statistically different from zero. A statistically significant and positive (negative) mean indicates that the variable is undervalued (overvalued) in the initial estimate, suggesting a bias in the estimates. The proportion of revisions with a positive sign can also be seen as an indicator of the sign of the revision of the initial estimate (a high proportion of negative or positive revisions indicates bias of the initial estimate).

Since revisions of opposite sign offset each other, the main indicator used to measure the size of revisions is the mean absolute revision, i.e., the average of the absolute values of the revisions. Alternatively, in order to take into account the scale of the variable, the relative mean absolute revision was also computed, i.e., the ratio between the average of the absolute values of the revisions and the absolute values (in this case, of the rates of change) of the variable under analysis (corresponding to the final estimate). This measure can be interpreted as the proportion of the estimate that is revised on average during the revision period. Although the usefulness of this measure is limited when analysing rates of change (since for very low rates, this measure can reach very high values), it can be useful, particularly for comparing aggregates with different scales (for example, GDP and GFCF). In addition, the proportion of sign concordance for the rates of change (when comparing the initial estimate with the final estimate) as well as for the direction of rates (acceleration/deceleration) has been computed. The measure of concordance in terms of sign consists of calculating, for each type of revision, the proportion of cases in which the sign of the rate of change does not change before and after the revision. Similarly, concordance in terms of direction consists of the proportion

1. Note that when the provisional ANA are released, the figures for the fourth quarter of the respective year incorporate the third revision while those for the first quarter already incorporate six quarters of revisions to the first estimate.

of cases in which the direction of the rate of change (i.e., acceleration or deceleration) is identical before and after the revision.

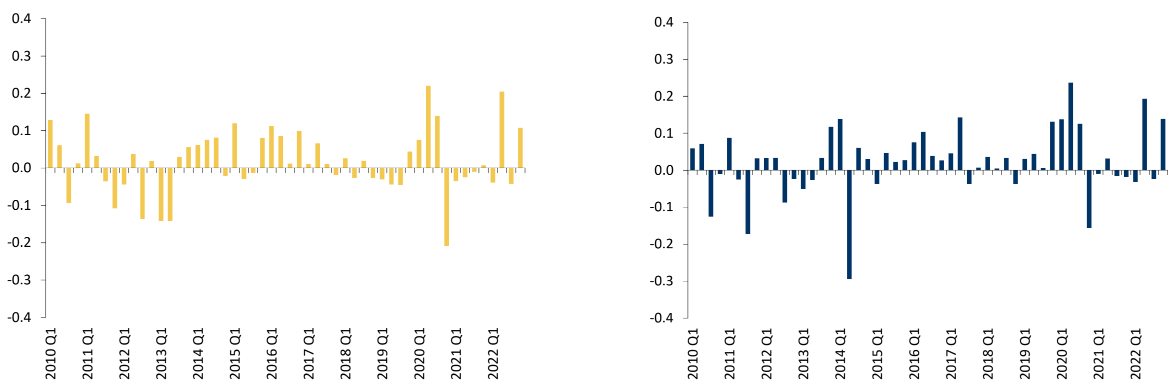
Revisions should not only be small, but also have low volatility. In addition to the revision size indicators, the standard deviation of revisions and the noise-to-signal ratio are presented as volatility indicators. The noise-to-signal ratio corresponds to the ratio between the standard deviation of the revisions and the standard deviation of the final estimate, which accounts for the volatility of the variable. In the case of the noise-signal ratio, a ratio greater than one means that the noise (standard deviation of revisions) is greater than the signal (standard deviation of revisions). Other reference values for this measure to be considered "low" are relatively *ad-hoc*, with a value of less than 0.5 being considered relatively low (see Cardoso and Duarte (2009)).

We also compute the correlation coefficient between the revisions and the revised estimate and test its statistical significance. Significant correlations indicate that in periods of more marked changes in GDP (positive or negative), revisions tend to be larger and in the same direction, which may be associated with some conservatism in the first estimates.

3. Analysis of quarterly revisions

3.1. Revision of the GDP flash estimate

In this subsection, we analyse the revisions to the GDP rates of change released with the flash estimate. Figure 1 shows the revisions to the year-on-year and quarter-on-quarter rates of change for GDP in volume terms.



(A) Revision to the year-on-year rate of change

(B) Revision to the quarter-on-quarter rate of change

FIGURE 1: Revisions to the GDP flash estimate, in percentage points.

Table 2 presents a set of summary measures regarding these revisions. In general, the revisions are small in magnitude. The average of the revisions is approximately zero and the average in absolute terms is less than 0.1 p.p.. The largest absolute revisions to the year-on-year rates of change occurred during the first year of the COVID-19 pandemic (0.22 p.p. revision in the second quarter of 2020 and -0.29 p.p. in the fourth

	Year-on-year rate of change	Quarter-on-quarter rate of change
Mean	0.02	0.02
Mean absolute revision	0.07	0.07
Relative mean absolute revision	0.09	0.34
Minimum	-0.21	-0.29
First quartile (25th percentile)	-0.03	-0.02
Median value (50th percentile)	0.01	0.03
Third quartile (75th percentile)	0.08	0.06
Maximum	0.22	0.24
Standard deviation	0.09	0.09
Noise-to-signal ratio	0.02	0.03
Correlation between revision and estimate	-0.01	-0.14
Proportion of positive revisions	0.58	0.65
Sign concordance	1.00	0.96
Direction concordance	0.90	0.96

TABLE 2. Descriptive statistics of the revisions to GDP flash estimate, in volume

Note: The measures are in percentage points with the exception of the following: relative mean absolute revision, noise-to-signal ratio, correlation between revision and estimate, proportion of positive revisions and concordance in terms of sign and direction.

quarter of 2020). In the case of the quarter-on-quarter rates of change, the greatest positive revision also occurred in the second quarter of 2020 and the most negative value occurred in the second quarter of 2014, which coincides with the first release on a 2011 basis incorporating the change to ESA2010 which, as mentioned above, involved important methodological changes. The revisions to the flash estimate have both a relatively low standard deviation and noise-to-signal ratio. However, it should be noted that the relative mean absolute revision (i.e., taking into account the scale of the variable) is greater in the case of the quarter-on-quarter rates of change than in year-on-year rates of change. In general, the results obtained point to a high information content of the flash estimate when compared to the first estimate.

3.2. QNA GDP revisions

Table 3 shows the main summary measures regarding the revisions to the rates of change in real GDP (year-on-year and quarter-on-quarter) implicit in the QNA releases. This table presents the measures for the first revision, the second revision and the revisions after six quarters and three years compared to the first estimate for each quarter. Figure 2 displays the corresponding revisions over the period analysed in the case of the first revision and the revisions after six quarters and three years. Naturally, the revisions after six quarters can only be calculated to the second quarter of 2021 and the revisions after three years for the period to the fourth quarter of 2019.[2]

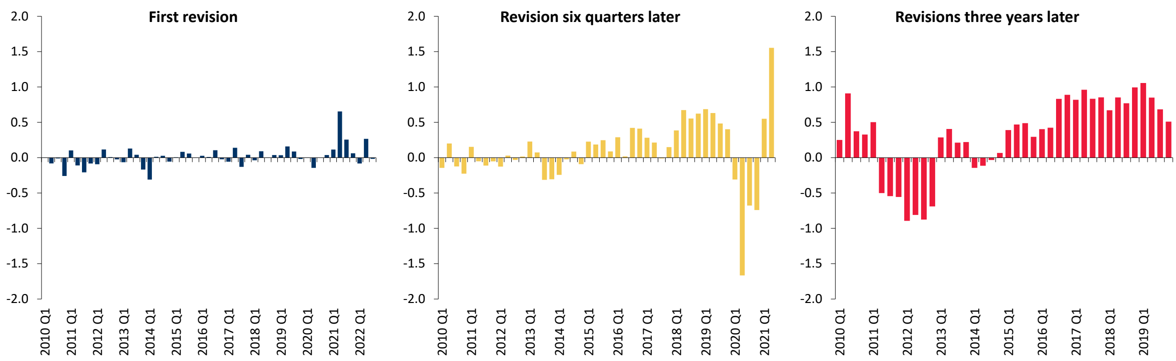
Firstly, it should be emphasised that the first and second revisions of GDP growth rates, in year-on-year and quarter-on-quarter terms, are on average small. For longer

2. As a sensitivity analysis, revisions to GDP data to the fourth quarter of 2019, i.e., excluding the period affected by the pandemic, were also assessed for the same revision horizons and the results are qualitatively similar.

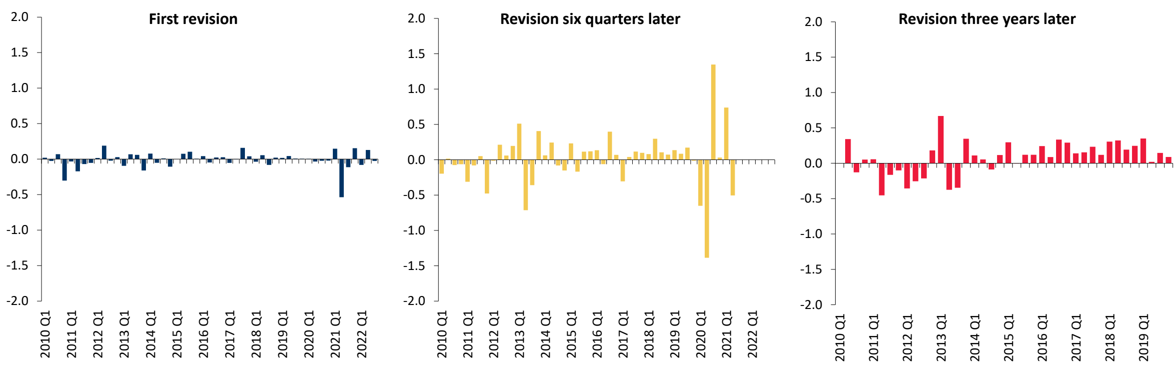
	Year-on-year rate of change				Quarter-on-quarter rate of change			
	First revision	Second revision	Revision six quarters later	Revision three years later	First revision	Second revision	Revision six quarters later	Revision three years later
Mean	0.01	0.01	0.10	0.31*	-0.01	-0.01	0.01	0.08*
Mean absolute revision	0.09	0.08	0.33	0.57	0.07	0.06	0.26	0.21
Relative mean absolute revision	0.03	0.02	0.12	0.24	0.05	0.04	0.19	0.15
Minimum	-0.31	-0.40	-1.67	-0.89	-0.54	-0.20	-1.39	-0.45
First quartile (25th percentile)	-0.06	-0.03	-0.11	0.04	-0.05	-0.06	-0.08	-0.02
Median value (50th percentile)	0.00	0.01	0.09	0.40	0.00	-0.01	0.06	0.12
Third quartile (75th percentile)	0.07	0.05	0.36	0.82	0.04	0.01	0.14	0.24
Maximum	0.65	0.41	1.55	1.06	0.19	0.47	1.35	0.67
Standard deviation	0.14	0.12	0.47	0.56	0.12	0.10	0.40	0.24
Noise-to-signal ratio	0.03	0.02	0.10	0.11	0.04	0.03	0.12	0.07
Correlation between revision and estimate	0.45*	0.43*	0.81*	0.82*	-0.14	0.18	0.81*	0.42*
Proportion of positive revisions	0.53	0.54	0.61	0.75	0.55	0.42	0.61	0.73
Sign concordance	1.00	1.00	1.00	1.00	0.98	1.00	0.96	0.95
Direction concordance	0.98	0.98	0.89	0.90	0.94	0.86	0.87	0.83

TABLE 3. Descriptive statistics for quarterly GDP revisions in volume

Notes: The measures are in percentage points with the exception of the following measures: relative mean absolute revision, noise-to-signal ratio, correlation between the revision and estimate, proportion of positive revisions and sign and direction concordance. In the case of the mean and the correlation between the revision and the estimate a * corresponds to a value statistically different from zero with a significance level of 5%.



(A) Revisions to the year-on-year rates of change



(B) Revisions to the quarter-on-quarter rates of change

FIGURE 2: Revisions to the real rates of change of GDP in the QNA, in percentage points.

revision periods, GDP estimates are more revised, although on average the revisions remain relatively contained. In the case of year-on-year rates of change, the average revision is 0.1 pp when considering the revision after six quarters, i.e., already incorporating the provisional ANA. After three years, when the final ANA for the quarter in question are already available, the average of the revisions is positive and higher than the one after six quarters, rising to 0.3 p.p., which is statistically different from zero. In the case of quarter-on-quarter rates of change, the average revision after three years is 0.08 p.p., which is also statistically different from zero. The existence of a positive mean revision is not specific to the Portuguese case. For example, Zwijnenburg (2015) analyses the revisions for a number of countries and concludes that in general GDP growth is underestimated in the initial estimates.

The correlation coefficient between the revisions and the rate of change in GDP volume is statistically significant, suggesting that periods of larger GDP changes (growth or decreases) are associated with more substantial revisions in the same direction.

It should be noted that the largest revisions occurred during the COVID-19 pandemic (such as the 1.7 p.p. revision to the year-on-year rate of change in GDP in the second quarter of 2020 after six quarters). This result is not unique in the literature. In this regard, Jorda *et al.* (2020) establish a relationship between periods of greater economic turbulence and larger GDP revisions. Nevertheless, considering revisions after three years (which can only be calculated to 2019), there are substantial revisions to year-on-year rates of change between 2016 and 2019, with an average revision of around 0.8 p.p. over this period. For the period as a whole, the average absolute revision after three years is close to 0.6 p.p. for the year-on-year rates of change and around 0.2 p.p. for the quarter-on-quarter rates of change (with mean relative absolute revisions of 24% and 15%, respectively).

As for the proportion of positive revisions, this percentage is close to half in the case of the first and second revisions, but three years after the first estimate the proportion of positive revisions is clearly higher (75% of positive revisions in the case of year-on-year rates of change and 73% in the case of quarter-on-quarter rates of change), signalling an underestimation of the initial estimates compared to the final ones.

The measures of sign and direction concordance (acceleration/deceleration) suggest that the first estimates are highly informative regarding the profile of GDP evolution, especially in the case of year-on-year rates of change, and slightly lower in the case of the quarter-on-quarter rates of change as the revision period increases. Nevertheless, considering the revisions of the quarter-on-quarter rates of change after three years, the sign of the rate of change remains unchanged from the first estimate in 95% of the cases and the direction remains unchanged in 83% of cases.

3.3. *Revisions to the main expenditure components*

The above analysis can be conducted to the main expenditure components as a way of gauging which GDP components are subject to the largest revisions (see Tables A.1 and A.2 in the Annex). The first revisions of the main expenditure components are generally higher than those of GDP. While exports present an average revision of approximately zero, the components of domestic demand and imports are generally revised upwards, resulting in far less significant revisions to the GDP aggregate. Based on the mean or mean absolute revision of the first revisions by main aggregate, the most revised expenditure component is GFCF, followed by imports. The average of the first revisions to the year-on-year rates of change for GFCF is almost 0.6 p.p. and for imports 0.3 p.p., both statistically different from zero. The mean absolute revision is over 0.6 p.p. in both cases. In average terms, the least revised components are public and private consumption, with the average not being statistically different from zero. However, taking into account the volatility of the respective rates of change, i.e., considering the relative mean absolute revision, the most revised component is public consumption, if we exclude the change in inventories whose revisions are measured in contributions to the change in GDP and not in rates of change. Considering a higher level of detail, it should be noted that in average terms the consumption of durable goods is more revised than the consumption of non-durable goods and within GFCF, the most revised component is GFCF machinery. Regarding foreign trade aggregates and considering the mean absolute revision, it should be noted that imports are more revised than exports, in particular goods. For both exports and imports, the services component is more revised than the goods component in mean absolute terms.

As for the dispersion of revisions, the aggregates with the largest standard deviation are imports, GFCF and exports. Within GFCF, the components with greater dispersion are those with the highest import content (GFCF machinery and GFCF transport equipment). Concerning exports and imports, the revisions of services also present a larger volatility than the goods component.

Year-on-year rate of change

	Private consumption	Public consumption	GFCF	Change in inventories[a]	Exports	Imports
Private consumption	1					
Public consumption	-0.15	1				
GFCF	-0.05	0.03	1			
Change in inventories[a]	0.05	0.06	0.27	1		
Exports	-0.36*	0.07	0.18	-0.08	1	
Imports	0.17	0.27	0.46*	0.69*	0.40*	1

Taxa de variação em cadeia em volume

	Private consumption	Public consumption	GFCF	Change in inventories[a]	Exports	Imports
Private consumption	1					
Public consumption	-0.15	1				
GFCF	-0.03	0.03	1			
Change in inventories[a]	-0.09	0.09	0.12	1		
Exports	-0.33*	0.14	-0.30*	-0.18	1	
Imports	0.18	0.29*	0.24	0.63*	0.28*	1

TABLE 4. Correlation matrix between first revisions to GDP components, in volume

Notas: [a] Contribution to the GDP rate of change. Values marked with * correspond to a value statistically different from zero at a 5%.

Given that GDP is generally less revised than its components, it is interesting to analyse whether the revisions between the various components are correlated. The existence of significant correlations between revisions could indicate common sources of revision that may or may not offset each other at the GDP level. Table 4 shows the correlations between the first QNA revisions, for the year-on-year and the quarter-on-quarter rates of change, of the main expenditure components. Positive and significant correlations can be identified between the revisions to imports and the expenditure components with the highest import content, namely investment (GFCF and change in inventories). These correlations reflect the fact that these expenditure variables are estimated using import indicators, and it is natural that a revision of imports also translates into a revision of domestic demand aggregates. For example, in the case of revisions to the year-on-year rate of change, the correlation coefficient between the revision of imports and that of the change in inventories (as a contribution to the change in GDP) is 0.69 and the correlation coefficient between imports and GFCF is 0.46. Thus, despite imports being significantly revised, given that part of these revisions is reflected in the other expenditure components, the impact on GDP is mitigated.

On the other hand, the negative correlation between the revisions to exports and private consumption is probably related to the methodology used to estimate private consumption. In particular, the fact that some short-term indicators of private consumption correspond to indicators of consumption in the economic territory (for example, indicators of sales or turnover in the national territory) makes it difficult to break them down into consumption by residents and consumption by non-residents (classified in national accounts as exports). This breakdown is typically supported by the use of balance of payments information on tourism. Therefore, it would be natural for revisions in this export component (not accompanied by a revision in the territory consumption indicators) to be reflected in an opposite revision in the consumption by residents. This is further corroborated by the fact that this correlation at a more detailed level is more significant in the case of the relationship between the revisions of non-durable consumption and exports of services including tourism, since expenditure on durable goods is essentially attributed to consumption by residents.

Regarding the revisions after three years by expenditure aggregates, it should be noted that these are larger than the first revisions for most components. In the case of year-on-year rates of change, all the main aggregates present positive mean revisions and are statistically different from zero in most cases (with the exception of public consumption). The most revised components, both on average and in absolute terms, are again GFCF, with an average revision of over 1.0 p.p., and imports (average revision close to 0.9 p.p.). In the case of quarter-on-quarter rates of change, the revisions after three years are also generally positive, but in contrast to year-on-year rates of change, only the revisions to GFCF and GDP are statistically different from zero. The revisions to imports are on average higher than that of exports, both in year-on-year and quarter-on-quarter terms. It should be noted that in the case of quarter-on-quarter revisions, the mean absolute revision is over 1.0 p.p. for both foreign trade flows, visible for both goods and services, as well as for GFCF.

Concerning concordance, both in terms of the sign of the rate of change and the acceleration/deceleration between the various estimates, it is quite high for most expenditure aggregates, signalling that the evolution profile is not substantially changed by revisions to the estimates, even after three years. However, it should be emphasised that the percentages of concordance are, in general, higher in the case of the year-on-year rate of change estimates than in the quarter-on-quarter rate of change, suggesting that the former are more reliable.

3.4. Revisions to GVA and its components

Regarding the supply side, it is also possible to assess the revisions to the QNA by analysing the same set of descriptive statistics for the quarterly GVA and its main aggregates (see Tables A.3 and A.4 in the Annex). Likewise the expenditure components, the first revisions and revisions after three years are reported, for both year-on-year and quarter-on-quarter rates of change. Considering the first revisions, the average is generally not statistically different from zero, both in the case of total GVA and for most of the main sectors published in the QNA. Only in the case of GVA in construction and for the quarter-on-quarter rates of change is the average of the revisions significant. It should be noted that this sector has a mean value and mean absolute revision to quarter-on-quarter rates of change higher than for year-on-year revisions. This lower reliability of quarter-on-quarter rates of change when compared to year-on-year rates of change (which is also the case for some expenditure aggregates, namely GFCF in construction) seems to be associated with significant one-off changes in the seasonal profile of the series, and may suggest difficulties in adjusting for seasonality. In the case of GVA and GFCF in construction, there was a significant revision of the quarter-on-quarter rates with less impact on the year-on-year rates of change with the release for the second quarter of 2014, when the QNA data began to be adjusted not only for seasonality but also for calendar effects. Taking the mean absolute revision, the revision of total GVA is slightly higher than that of GDP. Among the most revised aggregates, both year-on-year and in quarter-on-quarter terms, the GVA in agriculture, forestry and fishing and in energy, water supply and sewerage stand out.

The revisions to total GVA after three years are more significant than those to GDP, with averages statistically different from zero. For example, considering the revisions to year-on-year rates of change after three years, the mean absolute revision to total GVA is 0.76 p.p. while that of GDP is 0.57 p.p. (mean revisions of 0.53 p.p. and 0.31 p.p., respectively). By branch of activity, in average terms, the year-on-year rates of change present revisions significantly different from zero in the cases of industry, transport and other services. In terms of mean absolute revision, the agriculture and energy sectors continue to be the most revised. These are also the aggregates with the highest standard deviation of year-on-year revisions, followed by construction. In terms of the sign and direction concordance of the estimates, it should be noted that these percentages are generally lower in the case of the GVA components when compared to the main expenditure aggregates, although they remain relatively high, especially in terms of year-on-year rates of change. This suggests that the initial supply-side estimates are less reliable, which may be related to the fact that detailed sectoral information was not available when the first QNA estimates were published. In fact, the reliability and timeliness of expenditure side indicators is typically greater, which means that the compilation of Portuguese QNA tends to favour the calculation of GDP from the expenditure side.

3.5. *International comparison*

Given that the revision process is common to other countries, it can be informative to assess how revisions in Portugal compare with other cases. To this end, a comparison was made with the revisions observed for the euro area as a benchmark and, additionally, with the United States of America. Table 5 summarises the measures from the analysis of quarterly real GDP revisions, considering the same sample period and comparable timetables to those used in the rest of the article for Portugal. Such a comparison should be read with caution because, although we consider the same revision horizons, the available information at each point in time might differ from country to country.

Regarding the revision of the first estimate in year-on-year rates of change, the measures for Portugal do not differ significantly from the results for the euro area and the USA, particularly considering the mean revision or the mean absolute revision. In the case of the euro area, the mean revision is slightly higher and statistically different from zero and the percentage of positive revisions is well above 50%, suggesting a downward bias in the first estimates that is not visible for Portugal. In the case of the first revisions to the quarter-on-quarter rates of change, the results are similar.

	Mean	Mean absolute revision	Relative mean absolute revision	Standard--deviation	Noise-to--signal ratio	Proportion of positive revisions	Sign concordance	Direction concordance
Year-on-year rate of change								
First revision								
Portugal	0.01	0.09	0.03	0.14	0.03	0.53	1.00	0.98
Euro area	0.05*	0.08	0.03	0.09	0.03	0.71	1.00	0.88
USA	0.01	0.11	0.04	0.17	0.07	0.59	1.00	0.92
Revision three years later								
Portugal	0.31*	0.57	0.24	0.56	0.11	0.75	1.00	0.90
Euro area	0.25*	0.32	0.15	0.29	0.09	0.80	0.98	0.85
USA	0.00	0.32	0.12	0.42	0.18	0.60	1.00	0.78
Quarter-on-quarter rate of change								
First revision								
Portugal	-0.01	0.07	0.19	0.12	0.04	0.55	0.98	0.94
Euro area	0.03*	0.04	0.17	0.05	0.02	0.63	1.00	0.92
USA	0.02	0.08	0.35	0.12	0.07	0.63	0.98	0.96
Revision three years later								
Portugal	0.08*	0.21	0.15	0.24	0.07	0.73	0.95	0.83
Euro area	0.08*	0.15	0.15	0.16	0.06	0.68	0.97	0.73
USA	0.02	0.26	0.26	0.34	0.20	0.50	0.97	0.65

TABLE 5. Descriptive statistics for revisions to the GDP volume rate of change – international comparison

Notes: The measures are in percentage points with the exception of the following: relative mean absolute revision, noise-to-signal ratio, proportion of positive revisions and concordance in terms of sign and directon. In the case of the mean, * corresponds to a value statistically different from zero at a significance level of 5%.

Focusing on the revisions after three years, the comparison is less favourable for Portugal, especially when it comes to revisions to year-on-year rates of change. Both the mean and the mean absolute revision, which is a more relevant indicator for measuring the magnitude of revisions, is higher in Portugal that the recorded for the euro area and USA. For this type of revisions, and for both types of rate of change, likewise in the euro area, the fact that the means are significantly different from zero and the high percentage of positive revisions suggest a bias in the estimates towards lower rates of change than those that will be published after the release of the ANA. In contrast, in the US there is no such bias.

4. Revisions with ANA

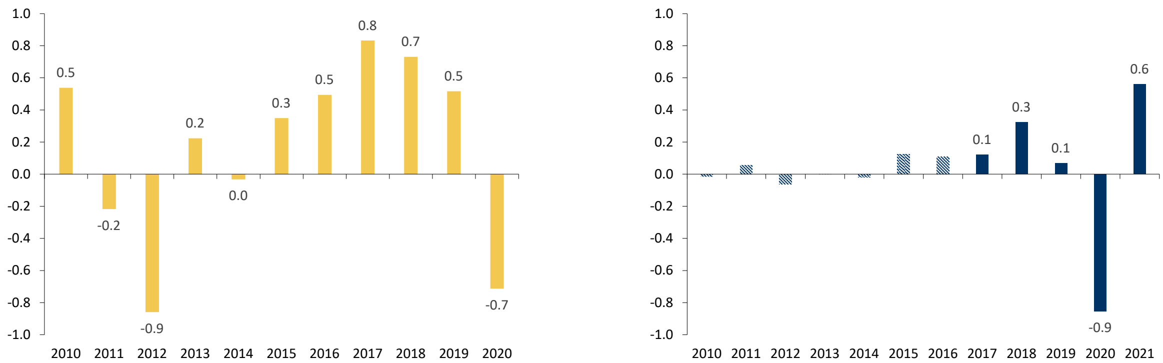
This section analyses the revisions resulting from the release of ANA, both provisional ANA and, more importantly, final ANA. The revisions will be analysed on an annual basis, and the revisions for each year after the inclusion of the respective ANA (provisional or final) will be compared with the first estimate for each year (called by Statistics Portugal as the preliminary annual estimate) corresponding to the annual value implicit in the first release of the QNA for the fourth quarter of each year.

These results roughly correspond to the revisions after three years in the case of the final accounts and the revisions after six quarters for the provisional accounts presented in section 3, but now analysed in annual terms. In this case, we have the final revisions until 2020 (as there are only two years between the first annual estimate, implicit in the fourth quarter of each year, and the final accounts) and the revisions until 2021 for the provisional accounts.

4.1. Revisions to the annual rates of change in real GDP

Figure 3 displays the revisions to the year-on-year rates of change of real GDP that occurred with the inclusion of the ANA. In Figure 3(A), the revision presented corresponds to that which occurred with the release of the final ANA for each year. As mentioned above, the time lag between the estimates was not identical throughout the period, with the last few years corresponding to seven quarters after the release of the first estimate of the year. Figure 3(B) displays the revision that occurred with the release of the provisional ANA for the years in which they were published (from 2017 onwards) compared to the first estimate of the year released in the QNA. For previous years, the shaded bars in the graph correspond to the revision that occurred with the same time lag as the provisional ANA are currently released (i.e., three quarters after the first estimate).

Concerning the revisions with the final ANA, the revisions to the rates of change in volume are generally positive. However, this is not the rule, and there were years when these revisions were negative, with the most significant downward revisions in 2012 and 2020. With the exception of 2013, in all the years in which the change in GDP was negative, there were downward revisions with the inclusion of the final ANA, while in the period of economic growth from 2015 to 2019, the revisions were systematically upward. This profile of revisions seems to suggest some pro-cyclicality in the revisions of real GDP. This may be related to the QNA estimation methodology, which, using econometric methods based on the relationships between national accounts variables and indicators available quarterly, introduces some smoothing into the estimates. Thus, in periods of greater variation (whether of growth or decline in activity), the first estimates will tend to reveal some conservatism that will be corrected in later estimates



(A) Revisions with final ANA

(B) Revisions with provisional ANA

FIGURE 3: Revisions of annual volume rates of change due to inclusion of ANA, in percentage points.

using more detailed sources of information. For example, Symons (2001), after analysing revisions to UK GDP, concluded that these revisions are biased upwards in years of higher growth and downwards in years of recession. In addition, the years with the highest revisions to the rates of change (in absolute terms) seem to be associated with periods of greater variation in activity, as was the case in 2012 and 2020 with significant falls in GDP associated with the sovereign debt crises and the COVID-19 pandemic and, in the opposite direction, in the years 2017 and 2018, which correspond to the years of higher growth. This suggests, as mentioned in Jorda *et al.* (2020), that, in the presence of marked fluctuations in activity, the uncertainty regarding the rates of change in absolute terms seems to increase.

With regard to the revisions due to the provisional ANA, it can be seen that these revisions were small until 2017, and became more significant from that year onwards, when the provisional ANA began to be published. The provisional ANA incorporate detailed annual sources that were not available when the preliminary estimate for the fourth quarter of the year was released, namely IES data. For this reason, the revisions for the most recent period also reflect the existence of a wider range of information available in a shorter period of time than before (when the main annual sources were only taken into account for the final accounts).

Comparing the revisions resulting from the provisional (in the years actually available) and final ANA, it can be seen that the release of the provisional accounts makes it possible to partially anticipate the revisions resulting from the final accounts, as these intermediate revisions go in the same direction as the final revisions. The provisional ANA for 2021 corroborate the idea of larger revisions in periods of higher change (as is the case for the 2020-2021 period, which was particularly affected by the pandemic) and that the sign of the revisions is generally associated with the sign of the change in GDP. In fact, the 2021 ANA implied a significant upward revision of the real change in GDP in 2021 and were released at the same time as the final 2020 ANA, which confirmed the downward revision of 2020 (albeit lower than that suggested by the respective provisional accounts).

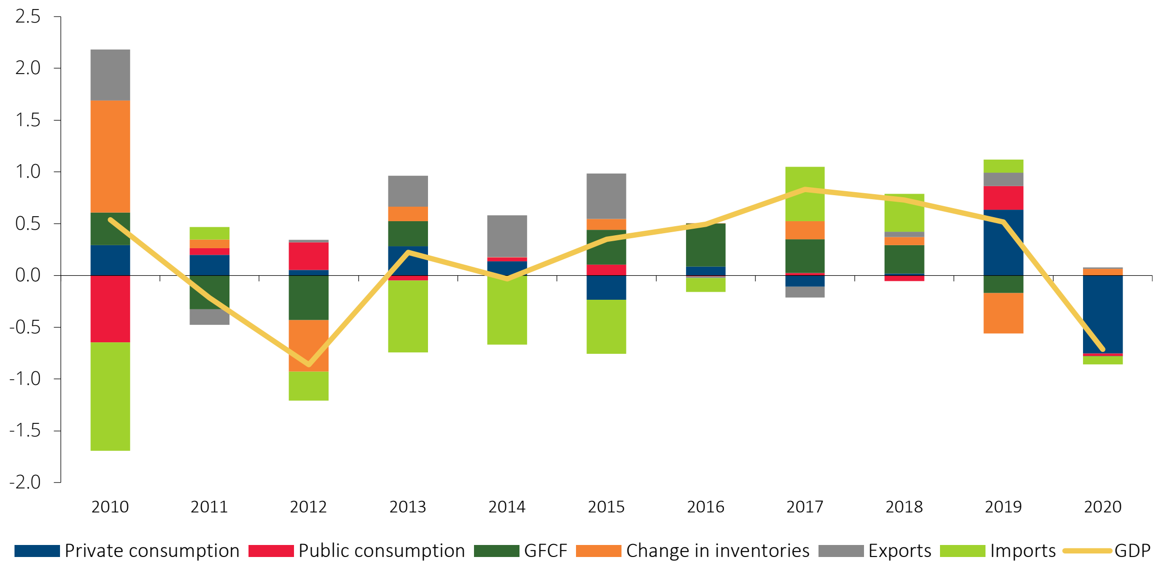


FIGURE 4: Contributions of expenditure components revisions to the annual GDP volume rates of change revisions, due to the inclusion of the final ANA, in percentage points.

In addition, it is important to see which components contributed the most to the GDP revisions due to the inclusion of the ANA. Figure 4 shows the contributions to the revisions to the annual rate of change of real GDP by expenditure components, taking into account the revision resulting from the final ANA. Naturally, the contribution to the revision takes into account both the magnitude of the revisions to each expenditure aggregate and their respective relative weight in GDP.

The year 2010 underwent revisions with significant contributions to the revision of GDP from various components, namely imports and investment, the latter mainly due to changes in inventories. According to Statistics Portugal, these more significant revisions are related to the entry into force this year of the Accounting Standardisation System, which introduced profound changes to the accounting information reported in the IES (main source of information) and, additionally, to a reassessment of external trade data using complementary administrative information. In the recession of 2011-2012, the downward revision of GDP resulted mainly from the revision of investment. In the 2013-2015 period, the GDP revision was relatively small, and the revisions to external trade variables, particularly imports, were more significant. In these years, the revisions to exports and imports were in the same direction, so the impact on GDP was mitigated. It should be noted that an upward revision in imports is reflected in a negative contribution to the revision of the change in GDP. In general, the components with the greatest contribution to the annual GDP revisions to 2018 were imports and investment which, as previously documented with quarterly data, are the most revised components. In 2019 and 2020, the revisions to private consumption made a significant contribution to the GDP revision (upwards in 2019 and downwards in 2020). The downward revision of GDP in 2020, a year particularly affected by the pandemic, is almost entirely explained by the revision of private consumption.

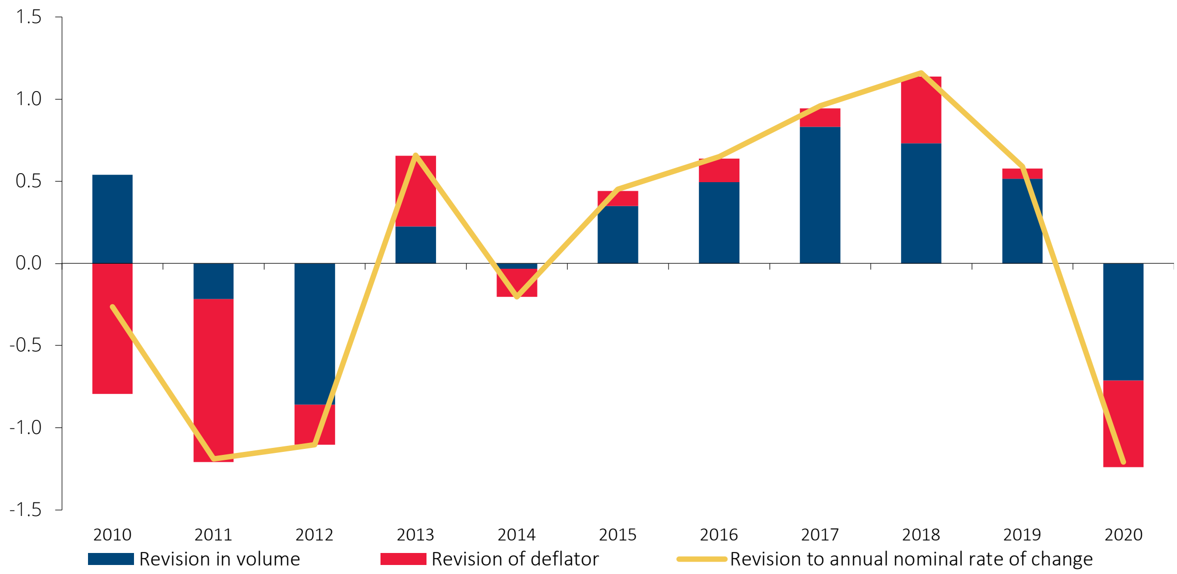


FIGURE 5: Revisions to the annual GDP rates of change, in nominal terms, volume and deflator, due to inclusion of the final ANA, in percentage points.

4.2. *Revisions to the annual rates of change in nominal GDP and deflator*

The inclusion of the ANA leads to revisions in the nominal rates of change, which in turn reflect re-assessments of the change in volume and/or the deflators. Figure 5 shows the revision of the annual rates of change in nominal GDP broken down into the revisions of the rates of change in volume, already discussed above, and the GDP deflator. In 2010 and 2011, the downward revision of the nominal change mainly reflects a downward revision of the deflator. Between 2015 and 2019, the revision to the nominal rate of change mainly reflects upward revisions to the real change in GDP, but also smaller revisions in the same direction to the rate of change in the deflator. The downward revision in 2020 reflects the downward revision of the volume and the deflator. Thus, the volume revisions in the period after 2015 are smaller in magnitude than the nominal revisions, since the deflator revisions in these years were in the same direction as the volume revisions.

Given that the breakdown of the revision in volume has already been analysed above, it is now interesting to see which expenditure components contribute the most to the revision of the GDP deflator. Figure 6 shows the contributions by expenditure component in the case of the revisions resulting from the inclusion of the final ANA. In general terms, it can be concluded that the components whose price evolution is most revised are external trade flows (which, as in the case of volume, are more marked in imports) and investment. In the case of private consumption, despite its high weight, it is generally not the component that contributes the most to the revision of the GDP deflator, given that the main source for compiling the private consumption deflator is the Consumer Price Index, which is not subject to revisions. Exceptionally, in 2011 there was a significant contribution from private consumption to the downward revision of the GDP deflator, which may be related to changes in the structure of consumer spending, namely an increase in the weight of rents. It should be noted that this revision

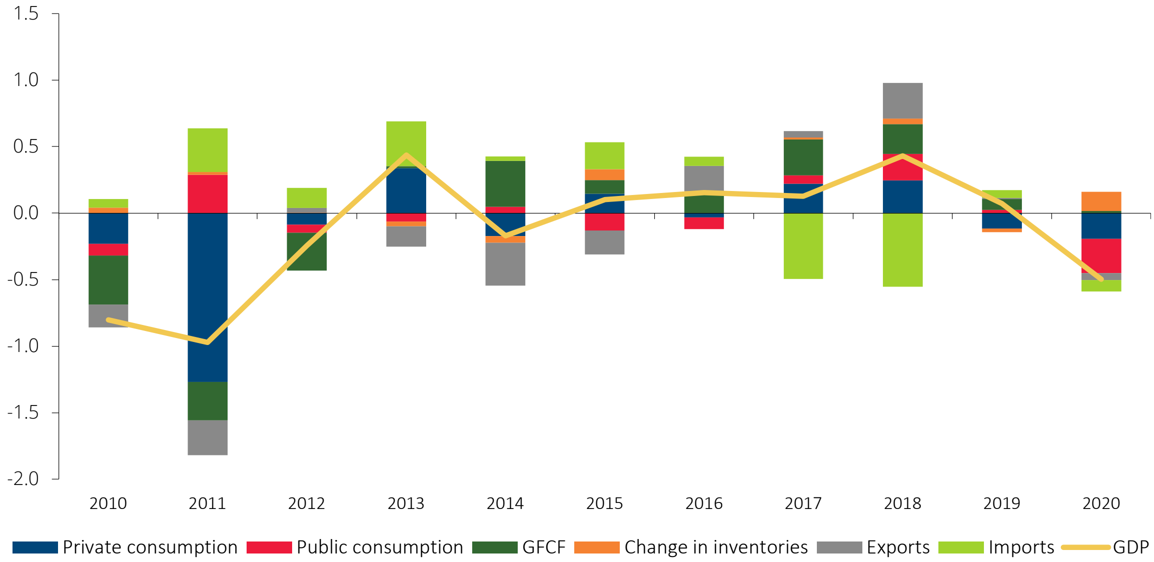


FIGURE 6: Contributions of expenditure components revisions to the annual GDP deflator rates of change revisions, due to the inclusion of final ANA, in percentage points.

incorporates the 2011 ANA, the publication of which, as already mentioned, coincides with the introduction of the ESA 2010 and the change to the 2011 base, which included new structural sources, namely the 2011 Census and the 2010-2011 Household Survey.

5. Conclusions

This article analyses the revisions to the QNA data for the main macroeconomic aggregates, with special focus on GDP. We considered real time data corresponding to the releases for the period from the first quarter of 2010 to the fourth quarter of 2022 and a set of statistical measures commonly used in the literature were computed.

The results show that the GDP flash estimate is not substantially revised at the time of the first complete QNA are released. In the releases immediately following the first estimate for each quarter, the revisions are also not significant. However, when longer revision periods are assessed, the revisions take on larger magnitudes. In particular, revisions after three years have positive and statistically significant means. In addition, the percentage of positive revisions for longer revision horizons is clearly higher than 50 percent, suggesting a downward bias in the first GDP estimates. This evidence, which is not unique to the Portuguese case, seems to indicate some conservatism of the first estimates, in the absence of more complete information relevant to the compilation of the final ANA. However, measures such as the concordance in terms of the sign and direction of the rates of change suggest a high level of information content of the first estimates, as the evolution profile does not differ significantly with revisions over time.

When comparing the first revision for real GDP for the euro area and the United States over the same period, the Portuguese QNA have a reliability slightly better than the euro area and similar to the US. However, considering revisions for longer periods that already include information from the ANA, the revisions for Portugal are larger than those for the euro area as a whole and the United States.

In terms of the GDP components from the expenditure side, GFCF and imports have the largest revisions. However, positive and significant correlations between the revisions to imports and the other expenditure components, mitigate the impact on GDP revisions. From the supply side, it should be noted that GVA is revised more than GDP and the information by branches of activity is, in general, less reliable than that from the expenditure side.

Regarding the annual revisions that occurred after the inclusion of the final accounts for the years 2010 to 2020, it should be noted that the revisions to the real rates of change are generally positive. The profile of the revisions seems to be pro-cyclical, with negative revisions in the years in which the change in GDP was negative, except for 2013, while in the period of economic growth from 2015 to 2019, the revisions were systematically upwards. Revisions to nominal GDP are generally higher than those to real GDP. The impact on volume is partially mitigated by the existence of revisions to the GDP deflator, generally in the same direction as the nominal revisions.

It should be noted that one of the reasons for the revisions due to the final ANA results from the late arrival of quasi-census data regarding the supply side. However, since the publication of provisional ANA, the GDP of the subsequent release of QNA has presented revisions of a larger magnitude than those previously observed with the same time lag. Comparing the revisions that occurred with the release of the provisional ANA with the revisions of the final ANA, we observe that the inclusion of provisional ANA allows to anticipate the revisions of the final accounts. This result shows the importance of obtaining more complete and reliable information as early as possible, allowing any revisions to be reflected in the data in a timelier manner. Despite the natural process of revisions to which national accounts statistics are subject, the increasing use of other sources of information may also help to mitigate revisions by widening the range of information available in real time. Naturally, the continuous search for new indicators and the improvement of the statistical relationships used to compile the QNA estimates are also a way of mitigating revisions and strengthen the reliability of national accounts in real time.

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Appendix

	Mean	Mean absolute revision	Relative mean absolute revision	Standard-deviation	Noise-to-signal ratio	Proportion of positive revisions	Sign concordance	Direction concordance
First revision								
GDP	0.01	0.09	0.03	0.14	0.03	0.53	1.00	0.98
Private consumption	0.06	0.17	0.05	0.27	0.05	0.63	1.00	1.00
Durable goods	0.11	0.37	0.03	0.65	0.04	0.43	1.00	1.00
Non-durable goods and services	0.06	0.18	0.06	0.28	0.06	0.63	1.00	0.92
Public consumption	-0.01	0.39	0.21	0.64	0.25	0.57	0.96	0.84
GFCF	0.52*	0.63	0.10	0.60	0.07	0.82	0.96	0.92
GFCF machinery	1.78*	2.14	0.24	2.04	0.15	0.75	0.94	0.84
GFCF transport equipment	-0.23	1.52	0.08	2.80	0.10	0.55	0.98	0.94
GFCF construction	0.11	0.44	0.06	0.64	0.07	0.57	1.00	0.94
GFCF other	0.24	0.90	0.31	1.39	0.33	0.65	0.94	0.94
Change in inventories[(a)]	-0.02	0.12	0.31	0.19	0.32	0.49	0.88	0.88
Exports	-0.02	0.39	0.05	0.53	0.05	0.53	1.00	0.94
Goods exports	-0.02	0.38	0.06	0.49	0.06	0.53	0.96	0.94
Services exports	0.00	0.68	0.05	1.42	0.07	0.59	0.98	1.00
Imports	0.23*	0.63	0.08	0.80	0.09	0.73	1.00	0.94
Goods imports	0.31*	0.70	0.09	0.83	0.09	0.73	1.00	0.94
Services imports	-0.24	1.02	0.11	2.23	0.18	0.61	0.94	0.96
Revision three years later								
GDP	0.31*	0.57	0.19	0.56	0.11	0.75	1.00	0.90
Private consumption	0.27*	0.40	0.11	0.44	0.09	0.75	1.00	0.93
Durable goods	1.73*	2.30	0.20	2.13	0.15	0.78	1.00	0.93
Non-durable goods and services	0.13	0.44	0.15	0.58	0.13	0.55	1.00	0.80
Public consumption	0.09	1.09	0.55	1.47	0.56	0.65	0.92	0.73
GFCF	1.02*	2.13	0.33	2.20	0.26	0.73	0.95	0.93
GFCF machinery	0.34	4.91	0.56	7.02	0.53	0.63	0.87	0.73
GFCF transport equipment	-0.77	9.49	0.46	13.54	0.47	0.50	0.95	0.75
GFCF construction	0.94*	1.75	0.24	1.90	0.21	0.65	1.00	0.88
GFCF other	3.29*	3.36	0.93	2.23	0.54	0.93	0.55	0.63
Change in inventories[(a)]	0.02	0.46	1.03	0.60	1.02	0.55	0.74	0.65
Exports	0.64*	0.77	0.10	0.74	0.07	0.80	0.97	0.85
Goods exports	0.25	0.75	0.11	1.02	0.12	0.55	0.97	0.83
Services exports	1.50*	1.91	0.20	1.77	0.09	0.83	0.89	0.95
Imports	0.86*	1.39	0.19	1.46	0.16	0.83	1.00	0.85
Goods imports	0.88*	1.48	0.21	1.61	0.18	0.78	1.00	0.88
Services imports	0.77*	1.73	0.22	2.20	0.18	0.78	0.95	0.85

TABLE A.1. Descriptive statistics of revisions to year-on-year rates of change by expenditure components, in volume

Notes: [(a)] Contribution to the GDP rate of change. The measures are in percentage points with the exception of the following: relative mean absolute revision, noise-to-signal ratio, proportion of positive revisions and concordance in terms of sign and direction. In the case of mean and correlation, * corresponds to a value statistically different from zero at a significance level of 5%.

	Mean	Mean absolute revision	Relative mean absolute revision	Standard- -deviation	Noise-to- -signal ratio	Proportion of positive revisions	Sign concordance	Direction concordance
First revision								
GDP	-0.01	0.07	0.05	0.12	0.04	0.55	0.98	0.94
Private consumption	0.01	0.21	0.14	0.35	0.10	0.49	0.86	0.96
Durable goods	-0.07	0.62	0.11	1.10	0.13	0.47	0.94	1.00
Non-durable goods and services	0.02	0.24	0.18	0.41	0.13	0.49	0.86	0.94
Public consumption	0.03	0.19	0.17	0.30	0.23	0.55	0.98	0.98
GFCF	0.58*	0.69	0.26	0.80	0.22	0.78	0.84	0.98
GFCF machinery	2.07*	2.38	0.50	2.30	0.27	0.78	0.84	0.82
GFCF transport equipment	0.09	1.77	0.12	3.25	0.13	0.57	0.98	0.96
GFCF construction	0.06	0.70	0.23	1.33	0.40	0.59	0.92	0.92
GFCF other	0.01	0.41	0.38	0.62	0.51	0.61	0.80	0.86
Change in inventories[(a)]	0.01	0.17	0.44	0.24	0.49	0.57	0.82	0.90
Exports	-0.03	0.39	0.10	0.55	0.07	0.53	0.90	0.96
Goods exports	0.00	0.46	0.13	0.63	0.08	0.45	0.94	0.98
Services exports	-0.14	0.62	0.12	0.98	0.11	0.59	0.96	0.92
Imports	0.28*	0.57	0.16	0.75	0.12	0.73	0.96	0.92
Goods imports	0.38*	0.64	0.17	0.79	0.12	0.75	0.96	0.96
Services imports	-0.32	0.96	0.17	1.91	0.27	0.51	0.92	0.98
Revision three years later								
GDP	0.08*	0.21	0.15	0.24	0.07	0.73	0.95	0.83
Private consumption	0.07	0.46	0.28	0.61	0.18	0.60	0.89	0.80
Durable goods	0.20	2.42	0.48	3.02	0.37	0.50	0.79	0.68
Non-durable goods and services	0.05	0.54	0.37	0.66	0.22	0.50	0.74	0.73
Public consumption	0.01	0.39	0.32	0.54	0.41	0.65	0.84	0.85
GFCF	0.67*	1.66	0.67	1.99	0.56	0.68	0.89	0.75
GFCF machinery	1.57*	3.82	0.93	4.78	0.56	0.63	0.71	0.68
GFCF transport equipment	-0.54	7.89	0.59	11.18	0.44	0.55	0.89	0.85
GFCF construction	0.25	1.82	0.66	2.29	0.69	0.53	0.82	0.78
GFCF other	0.81*	1.12	0.97	1.32	1.09	0.73	0.53	0.73
Change in inventories[(a)]	-0.01	0.39	0.84	0.52	1.06	0.53	0.68	0.75
Exports	0.12	1.03	0.29	1.32	0.17	0.55	0.84	0.83
Goods exports	0.05	1.18	0.32	1.51	0.19	0.50	0.87	0.85
Services exports	0.25	1.35	0.33	1.74	0.19	0.63	0.76	0.70
Imports	0.34	1.31	0.39	1.78	0.28	0.68	0.82	0.80
Goods imports	0.42	1.57	0.45	2.21	0.34	0.68	0.82	0.80
Services imports	-0.08	1.90	0.41	2.73	0.39	0.58	0.89	0.90

TABLE A.2. Descriptive statistics of revisions to quarter-on-quarter rates of change by expenditure components, in volume

Notes: [(a)] Contribution to the GDP rate of change. The measures are in percentage points with the exception of the following: relative mean absolute revision, noise-to-signal ratio, proportion of positive revisions and concordance in terms of sign and direction. In the case of mean and correlation, * corresponds to a value statistically different from zero at a significance level of 5%.

	Mean	Mean absolute revision	Relative mean absolute revision	Standard-deviation	Noise-to-signal ratio	Proportion of positive revisions	Sign concordance	Direction concordance
First revision								
GVA	0.03	0.15	0.06	0.22	0.05	0.51	1.00	0.94
Agriculture, forestry and fishing	0.08	1.79	0.47	2.94	1.00	0.59	0.86	0.80
Industry	0.04	0.30	0.10	0.48	0.08	0.49	0.96	0.94
Energy, water supply and sewerage	-0.16	0.99	0.35	1.59	0.35	0.43	0.92	0.92
Construction	0.13	0.33	0.06	0.50	0.08	0.55	1.00	0.94
Trade, hotels and restaurants	0.13	0.26	0.05	0.66	0.07	0.63	0.98	0.94
Transportations and communications	0.07	0.49	0.13	0.91	0.14	0.59	0.98	0.90
Financial and real estate activities	-0.11	0.40	0.37	0.59	0.27	0.39	0.86	0.92
Other services	0.07	0.29	0.12	0.45	0.12	0.63	0.96	0.94
Revision three years later								
GVA	0.53*	0.76	0.31	0.71	0.16	0.78	0.97	0.85
Agriculture, forestry and fishing	0.14	3.70	1.09	4.54	1.54	0.55	0.74	0.63
Industry	1.60*	1.91	0.60	1.72	0.28	0.83	0.79	0.85
Energy, water supply and sewerage	0.80	4.56	1.38	5.44	1.21	0.63	0.50	0.50
Construction	0.15	2.77	0.47	3.50	0.54	0.48	0.89	0.83
Trade, hotels and restaurants	0.28	0.91	0.19	1.07	0.11	0.60	0.92	0.78
Transportations and communications	0.98*	2.03	0.61	2.23	0.33	0.65	0.74	0.70
Financial and real estate activities	-0.47	1.47	1.40	1.88	0.85	0.50	0.76	0.68
Other services	0.78*	1.18	0.56	1.30	0.35	0.78	0.95	0.63

TABLE A.3. Descriptive statistics of revisions to year-on-year rates of change by GVA components, in volume

Notes: The measures are in percentage points with the exception of the following: relative mean absolute revision, noise-to-signal ratio, proportion of positive revisions and concordance in terms of sign and direction. In the case of mean and correlation * corresponds to a value statistically different from zero at a significance level of 5%.

	Mean	Mean absolute revision	Relative mean absolute revision	Standard-deviation	Noise-to-signal ratio	Proportion of positive revisions	Sign concordance	Direction concordance
First revision								
GVA	-0.03	0.14	0.11	0.19	0.07	0.51	0.94	0.96
Agriculture, forestry and fishing	0.04	0.53	0.59	0.84	0.78	0.63	0.78	0.84
Industry	0.02	0.50	0.24	0.86	0.17	0.45	0.90	0.86
Energy, water supply and sewerage	-0.17	0.55	0.35	0.94	0.45	0.45	0.90	0.90
Construction	0.24*	0.48	0.17	0.81	0.32	0.67	0.96	0.90
Trade, hotels and restaurants	0.03	0.36	0.14	0.72	0.11	0.51	0.92	0.90
Transportations and communications	-0.07	0.43	0.21	0.72	0.20	0.47	0.92	0.88
Financial and real estate activities	-0.16	0.47	0.51	0.70	0.82	0.45	0.76	0.88
Other services	-0.02	0.21	0.16	0.35	0.13	0.53	0.92	0.94
Revision three years later								
GVA	0.15*	0.37	0.31	0.42	0.14	0.73	0.89	0.83
Agriculture, forestry and fishing	0.08	1.14	1.14	1.42	1.32	0.53	0.61	0.70
Industry	0.45	1.39	0.65	1.73	0.33	0.58	0.71	0.65
Energy, water supply and sewerage	0.14	1.88	1.15	2.57	1.23	0.55	0.68	0.70
Construction	0.15	1.88	0.73	2.36	0.92	0.50	0.68	0.78
Trade, hotels and restaurants	0.03	0.62	0.24	0.81	0.13	0.45	0.79	0.78
Transportations and communications	0.32	1.18	0.67	1.53	0.42	0.60	0.58	0.58
Financial and real estate activities	-0.22	0.84	1.11	1.04	1.22	0.45	0.79	0.75
Other services	0.25*	0.52	0.44	0.66	0.24	0.55	0.79	0.68

TABLE A.4. Descriptive statistics of revisions to quarter-on-quarter rates of change by GVA components, in volume

Notes: The measures are in percentage points with the exception of the following: relative mean absolute revision, noise-to-signal ratio, proportion of positive revisions and concordance in terms of sign and direction. In the case of mean and correlation * corresponds to a value statistically different from zero at a significance level of 5%.

Non-technical summary

October 2023

A view on ICT and digitalization in Portuguese firms

João Amador, Cátia Silva

ICT adoption and digitalization are at the core of the technological transformation unfolding in firms around the world in the last three decades. Although the topic is very important, the literature on the impacts of ICT adoption and digitalization on the performance of firms is still very limited, even more when it comes to establish causal impacts. The fact that the phenomenon is still relatively recent and the scarcity of firm-level data on the adoption of these technologies may explain the reduced number of contributions.

In this article we analyse ICT adoption and digitalization by Portuguese firms. We document the distribution of these technologies along firms' characteristics. In addition, we verify whether firms that adopt these technologies more intensively are also those performing better. Moreover, we take some initial steps towards evaluating the causal impact on TFP, labour productivity, wages and export intensity of adopting a bundle of three ICT technologies.

We merge information from the survey "*Inquérito à Utilizaçao das Tecnologias de Informação e Comunicação nas Empresas*", which contains detailed information about firms' adoption of ICT and digital technologies, with "*Sistema de contas integradas das empresas*", which contains a large number of balance sheet and income statement variables. We select a set of relevant ICT and digitalization technologies and separate them in two groups. As for ICT we consider: existence of a PC at the firm, internet connection, website, ICT staff, online sales and online payments. As for the digitalization dimension we consider robots, 3D print, cloud computing and big data.

As documented in other studies, we observe strong differences across sectors and an overall progress in the adoption of both types of technologies. There is also evidence of concentration of these technologies in the firms that are larger in terms of turnover or employment. The more salient cases of complementary technologies are the pairs PC-internet, website-cloud, ICT staff-cloud and ICT staff-website. The article also concludes that firms that use ICT more intensively are also more productive, pay higher wages and are more export driven. When it comes to the adoption of digital technologies these results hold but they seem more muted. For both types of technologies, their adoption is associated with higher ratios of investment in intangibles on turnover and total investment.

Proofing causality between the adoption of these technologies and firms' performance is much more relevant but also quite demanding given the limited span of data. A Differences-in-Differences (DiD) approach using as identification strategy the moment when firms reply affirmatively to the existence of a specific technology requires the observation of firms during long periods before and after the moment of adoption. Even so, we test a staggered DiD considering the event of a simultaneous adoption of a compound of three ICT technologies (website, online sales and online purchases) and separately take four performance variables: TFP, labour productivity, wages and export intensity. The causal evidence of impacts is not strong, though it points towards positive effects on labour productivity (Figure 1) and wages.

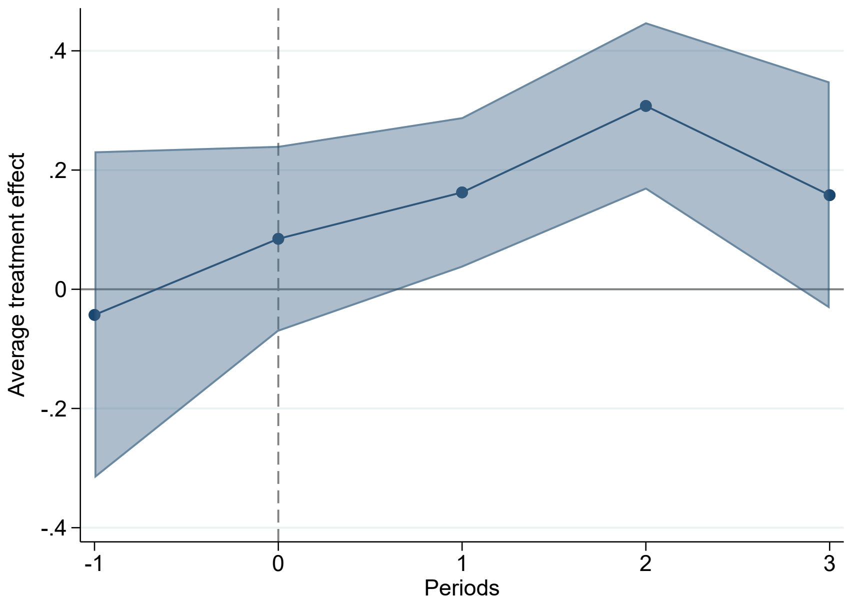

FIGURE 1: Impact of adopting simultaneously a bundle of three ICT technologies (website, online sales and online purchases) on labour productivity.

Note: Average treatment effect for the treated subpopulation. The grey area limits the 95 percent confidence intervals.

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A view on ICT and digitalization in Portuguese firms

João Amador
Banco de Portugal
Nova SBE

Cátia Silva
Oxford Economics

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Abstract
Information and Communication Technologies (ICT) and digitalization are at the core of the technological transformation unfolding around the world in the last three decades. These are mainly general porpuse technologies that find usage in almost all sectors of activity and have a positive impact on productivity and growth. Given the strong effects and the conspicuouscy of these technologies, large amounts of public funds have been spent to create infrastrutures and incentivize ICT and digitalization investments by firms. In this article we present some facts about ICT and digitalization adoption in Portuguese firms at a granular level and scratch the surface in terms of effects on variables like productivity, wages and export intensity. We conclude that there is progress and strong heterogeneity in ICT and digitalization in Portuguese firms and those using such technologies more intensively are also those performing better. (JEL: O3, O4, J24)

1. Introduction

It is widely accepted that technology is an important driver of firms' and overall economic performance ((Basu *et al.* 2022)). Technology has been steadily improving along centuries and its progress has been accelerating in the most recent decades. The most prominent advances in the last decades relate with information and communication technologies (ICT) and digital technologies. The former group of includes the utilization of computers and internet to communicate with clients, suppliers, settle transactions and organize internal production processes. The digitalization dimension is much more recent and involves the utilization of robots, 3D printing, big data and cloud computing in the production process. Of course, ICT adoption is a pre-requisite for the operation of the new digital technologies.

Although the topic is very important, the literature on the impacts of ICT adoption and digitalization on the performance of firms is still limited. There are several reasons for this fact. Firstly, the diffusion of technologies takes time and the impacts

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E-mail: jamador@bportugal.pt; cscsilva@bportugal.pt

on productivity are fully visible only after some years. This is especially true for digitalization, since only a very small number of firms has recently initiated its use. Secondly, there is scarce firm-level data available. This literature requires information on the adoption of technologies at the firm level, as well as knowledge about the characteristics of the firms. Thirdly, given data limitations, it is very difficult to go beyond correlation analysis to establish causal relationships between these technologies and firms' performance.

Nevertheless, some contributions are worth referring. As regards cross-country studies, Brodny and Tutak (2022) examines digitalization of small and medium-sized EU27 firms to determine their digital maturity and whether and how the economic parameters of individual countries affect the process. Results show large differences among individual EU27 countries and between the old (EU14) and the new (EU13) members in terms of SMEs digitalization. The annual survey carried out by the European Investment Bank (EIB) on 12800 firms from all EU countries and the US also conveys these differences ((European Investment Bank 2023)). Zolas *et al.* (2020) offers a similar look focusing on the adoption and use of advanced technologies, including artificial intelligence, cloud computing, robotics, and the digitization of business information, by a large sample of US firms. Authors find that digitization is quite widespread but advanced technology adoption is rare and generally skewed towards larger and older firms.

The literature on ICT and digitalization adoption by Portuguese firms is also interesting. Examples of these studies are Barbosa and Faria (2022), which carries out estimations over the entire distribution of firm's productivity and finds that heterogeneous digital technologies affect differently the dynamics of productivity and the convergence to the frontier, and Candeias *et al.* (2022) that studies the implications of automation on productivity and employment in the automotive sector concluding that it increases productivity in firms and does not substitute workers but it changes work organization. Barros (2021) provides a comprehensive assessment of the digital area in Portugal including firms and themes like digital adoption, e-commerce, innovation, artificial intelligence, cybersecurity and skills, while benchmarking with other countries. The challenges pointed for Portugal in this article are digital skills and literacy, digital inequality regarding geography, gender, age, level of literacy or income, the future of teleworking, cybersecurity and privacy, and investment in innovation and R&D. Moreover, linkages with the Portuguese Recovery and Resilience Plan (RRP) are also established. In a different vein, Cortes *et al.* (2022) discusses the digital transition in the Portuguese RRP, presenting its governance structure, the different initiatives, how their execution is monitored, and which information is available to the general public.

The literature on the causal impacts of ICT adoption and digitalization on the performance of firms is also very limited. One of such studies is Abramovsky and Griffith (2006), which considers the impact of ICT on firms' activity location decisions and whether to produce in-house or outsource and offshore services. The paper uses instrumental variables and explores within industry firm-level variation in UK establishments. Another contribution is Gilbert *et al.* (2020), which assesses the impact of ICT and digitalization on productivity and labour share for a sample of French manufacturing firms using a leave-one-out type instrumental variable. In the same vein, Amador and Silva (2023) study the impact of ICT adoption on the productivity of Portuguese firms. In addition, Almeida and Sequeira (2023) takes data for Portuguese firms and uses a fixed effects panel quantile regression and an instrumental variable regression model to study the impact of robots, software, ICT and physical capital on productivity. Moreover, Borowiecki *et al.* (2021) analyses the role of intangibles and digital adoption for firm-level productivity in the Netherlands, drawing on a panel data set of Dutch firms. The paper uses an instrumental variables approach, as in Gal *et al.* (2019).

As for labour market implications, International Monetary Fund (2023) starts by defining non-digital employment as service and sales workers, skilled agricultural, forestry and fishery workers, craft and related trade workers, plant and machine operators and assemblers, and elementary occupations. On the basis of this classification of employment, the study finds that the share of jobs in digital occupations experienced a sharper increase in Portugal during the Covid-19 pandemic compared to the euro area. In addition, the Covid-19 shock is taken to assess causal impacts using a regression approach for 29 European countries and the US economy. The regression analysis provides some evidence that digital employment was shielded during the pandemics.

In this article we analyse ICT adoption and digitalization by Portuguese firms. Firstly, we document the distribution of these technologies along firms' characteristics. Secondly, we verify whether firms that adopt these technologies more intensively are also those performing better. Finally, we take some initial steps towards evaluating the causal impact of adopting a bundle of ICT technologies on productivity, wages and export intensity using a staggered Differences-in-Differences procedure. A similar exercise cannot be implemented for digitalization because the number of years available in the database for this type of technologies is very small.

The article selects a set of important technologies and separates them in two groups. As for ICT we consider: existence of a PC at the firm, internet connection, website, ICT staff, online sales and online payments. As for the digitalization dimension we consider robots, 3D print, cloud computing and big data.

Some results are worth highlighting from the outset. As expected, we observe an overall progress and strong differences across sectors in the adoption of both types of technologies. There is also evidence of concentration of these technologies in the firms that are larger in terms of turnover or employment. The paper also concludes that firms that adopt ICT more intensively are also more productive, pay higher wages and are more export driven. When it comes to the adoption of digital technologies these results hold but they are more muted. Taking both types of technologies, adoption is associated with higher ratios of investment in intangibles on sales and on total investment. The causal evidence of impacts from adopting a bundle of ICT items is not strong, though it points towards positive effects on labour productivity and wages.

The article is organized as follows. The next section compares the intensity of ICT and digital technologies adoption in Portugal with that of other countries. Section 3 presents the two very rich firm-level databases that are merged and used in the article. Section 4 presents the results and it is organized along four subsections. Subsection 4.1 presents evidence of the distribution of ICT and digitalization along sector and time dimensions, subsection 4.2 examines the concentration of technologies along firms' size distribution and the correlation of adoption between pairs of technologies, subsection 4.3 examines the distribution of productivity, wages and export intensity for high and low ICT and digital firms. Subsection 4.4 presents a similar exercise but focused on investment in intangibles. Section 5 goes one step further and uses staggered difference-in-differences to assess the impact of simultaneously adopting a bundle of ICT technologies on the performance of firms. Section 6 offers some concluding remarks.

2. International comparison

In this section we frame the situation of Portuguese firms in an international context. Nevertheless, international comparisons of ICT adoption and digitalization by firms are not easy. Ensuring comparability across countries, while encompassing the different dimensions of these technologies, requires relying on indices computed by international organizations. One of them is the *Digital Adoption Index* published by the World Bank ((World Bank 2016)). It is a worldwide index that measures countries' digital adoption across three dimensions of the economy: people, government, and business. The index covers 180 countries on a 0–1 scale and the most recent year available is 2016. Figure 1 presents the distribution of the business sub-index, which comprises technologies necessary for firms to promote development in the digital era, along the 183 countries in the database and signals the position of Portugal. Portugal ranks 38th, it is the 20th among the EU27 countries, and posts an index of 0.75 in 2016 (0.82 for the EU27).

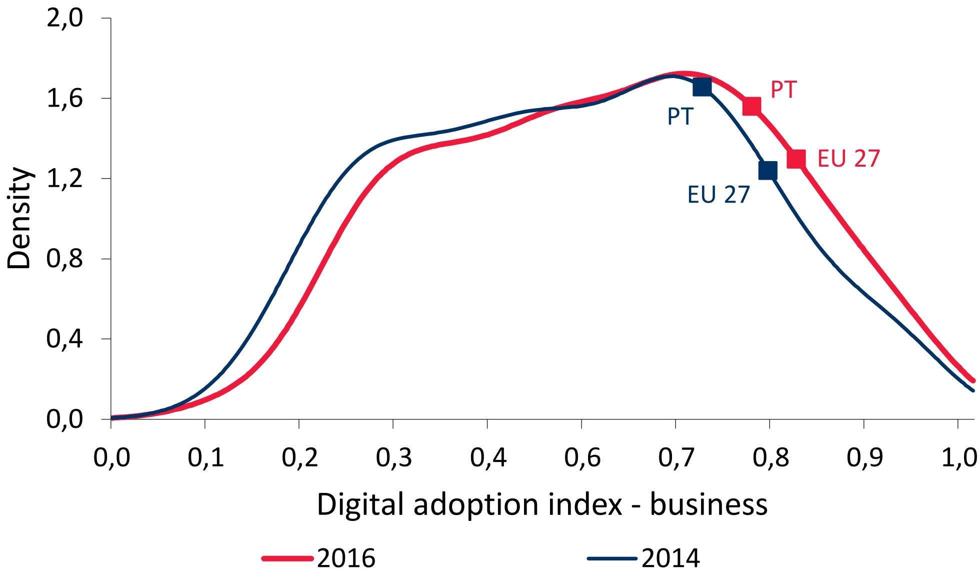


FIGURE 1: Digital adoption index - Business

Note: Figure plots the kernel distributions of the Digital adoption index in 2014 and 2016, signalling the position of Portugal and the EU 27, the latter is defined as a simple average of the Member countries. Source: World Bank.

Another important index is published by the EIB (European Investment Bank (2023)). The *Corporate Digitalization Index* is based on firm-level data provided by the EIB Investment Survey.[1] It comprises six components: adoption of advanced digital technologies, digital infrastructure, investment in software and data, investment in training, use of a strategic monitoring system and uptake of digitalization during COVID-19. Regarding the adoption of advanced digital technologies, which is arguably the most informative dimension, manufacturing firms are surveyed about the use of 3D printing, robotics, the internet of things and big data/artificial intelligence technologies, while firms in services are also surveyed about the use of virtual reality and platforms that connect customers with businesses or customers with other customers. Figure 2 ranks the share of firms using advanced digital technologies in the EU countries and the US in 2022. According to the survey, in Portugal the share of firms using advanced digital technologies was 64 percent, which compares with 69 percent in the EU and 71 percent in the US.

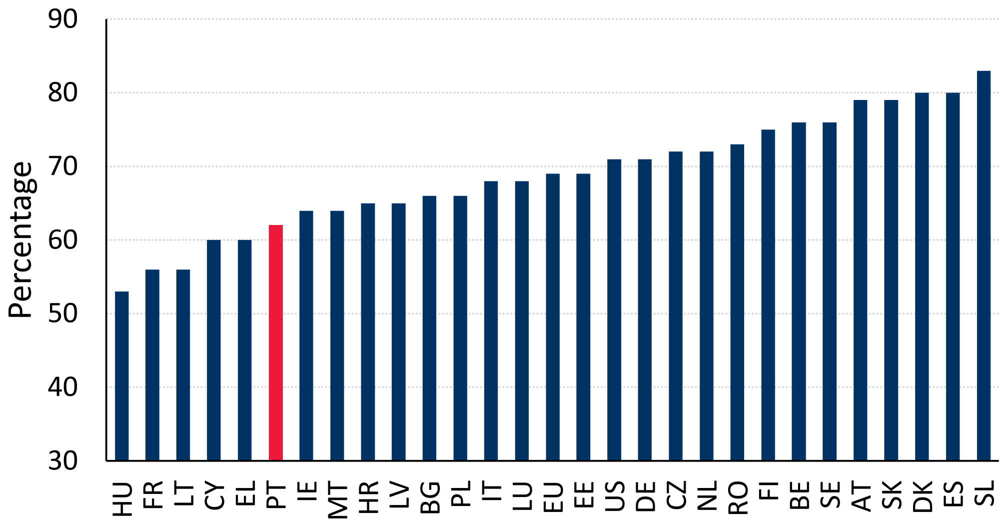


FIGURE 2: Share of firms using advanced digital technologies
Source: EIB Investment Survey, 2022.

A third source of international comparisons is the *Digital Intensity Index* published by the Eurostat, derived from the survey on ICT usage and e-commerce in firms. The index describes the extent to which EU firms use different technologies and was computed for the first time in 2015. The index is based on 12 variables, each of them having a score of 1 point, and sets four levels of digital intensity for each firm: very low (between 0 and 3 points), low (between 4 and 6 points), high (between 7 and 9 points) and very high (between 10 and 12 points). Figure 3 presents the breakdown of firms along the four categories of digital intensity for each EU country in 2022, considering firms with 10 or

1. The sub-population of interest for the survey is the non-financial corporate sector in the 27 EU Member countries, the UK and the US, with at least five employees, belonging to one of the NACE categories C (manufacturing) to J (information and communication).

more persons employed and all economic activities, except the financial sector. Results show strong differences across EU countries and the breakdown for Portugal is close to that of the euro area. The share of Portuguese firms with very low, low, high and very high digital intensity was 29.1, 35.4, 30.8 and 4.7 percent, respectively.

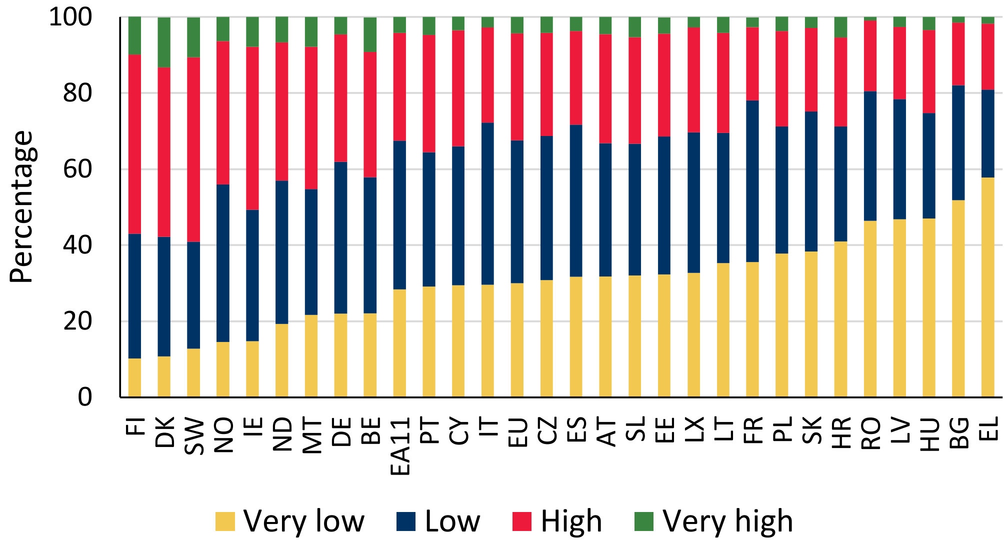


FIGURE 3: Digital Intensity Index

Source: Eurostat. The sample includes firms with at least 10 employees or self-employed persons. Data for 2022.

By considering different alternative indices we obtain a more robust assessment of the reality. Overall, Portuguese firms seem to be placed in a an intermediate position in terms of ICT adoption and digitalization in the EU context, but their relative position is tilted towards the lower end of the distribution when it comes to the adoption of more advanced digital technologies.

3. Database

In this article we use firm-level data to assess the adoption of ICT and digitalization technologies by Portuguese firms and the possible impacts on productivity, wages and export intensity. For this purpose we merge two very rich datasets. The first set of data contains firm's answers to "*Inquérito à Utilizaçao das Tecnologias de Informação e Comunicação nas Empresas*" (IUTICE), a survey conducted by the Portuguese national institute of statistics (Statistics Portugal). This statistical operation is carried out annually within the framework of EU legislation (EC regulation No. 808/2004), which establishes a set of harmonization guidelines, thus ensuring the availability of comparable statistical results across member states. This is the set of data underlying the computation of digitalization statistics by the Eurostat, such as the *Digital Intensity Index* reported in Figure 3. The IUTICE was initiated in 2003 and we use information up until 2020. The set of firms surveyed is not constant and the size of the sample has changed along the years, with a notable increase after 2010, which improved its representativeness. The set of questions posed to firms has changed substantially along the different vintages of the survey. Questions initially included availability of PC in the firm, internet connection, website, electronic payments, electronic invoicing, ICT staff and ICT training. In its latest editions some basic dimensions of ICT, such as having a PC or access to internet, were dropped and the survey added questions regarding the existence of robots, 3D printing or the utilization of big data and cloud computing.

The second set of data is the "*Sistema de contas integradas das empresas*", also compiled by Statistics Portugal. This database builds on mandatory legal reporting by Portuguese firms to Statistics Portugal, tax administration, Banco de Portugal and Ministry of Justice. It covers virtually the universe of Portuguese firms, including self proprietorships. This dataset contains a large number of balance sheet and income statement variables, which allow us to control for firm heterogeneity and to compute labour productivity (GVA per worker) and Total Factor Productivity (TFP). Merging the two datasets is straightforward since there is a common firm identifier.

4. Distributions and correlations

In this section we analyze the distribution of individual ICT and digitalization technologies in 2010 and 2018 along sectors of activity and firms' size. It should be highlighted that, although we could use data beyond 2018, we decide against it to avoid problems arising from the Covid-19 pandemic and, mostly, because the 2018 survey inquires about both recent digital technologies and older ICT ones. In addition, we identify whether there is evidence of complementarity in the adoption of individual technologies. Next, we take one step further and compare the performance of firms with high versus low ICT and digitalization adoption.

4.1. Sector and firm size

The number of firms surveyed in each vintage of the IUTICE is different and the set of those responding changes over time. The number of firms surveyed increased from 1282 in 2004 to 5383 in 2020, and it almost doubled from 2009 (2230 firms) to 2010 (4355 firms). In order to ensure the representativeness of the sample each firm is associated with a set of weights that make it possible to extrapolate to the universe of firms. These weights exist for three dimensions: number of firms, turnover and number of employees. However, when the number of firms responding to the survey in a given sector is very small it is not feasible to extrapolate results.

Figure 4 presents the mean, median, P25 and P75 of the distribution of the number of ICT and digital technologies adopted in each firm. Given the set of technologies considered, there is a maximum of 6 and 4 in the ICT and digital dimensions, respectively. Results show that the adoption of these technologies is much smaller in the digital dimension (median of zero) than in the ICT dimension (median of 2).

Table 1 presents the share of firms adopting each ICT technology in 2010 and 2018 within each of the sectors of activity that correspond to the NACE 1-digit classification.

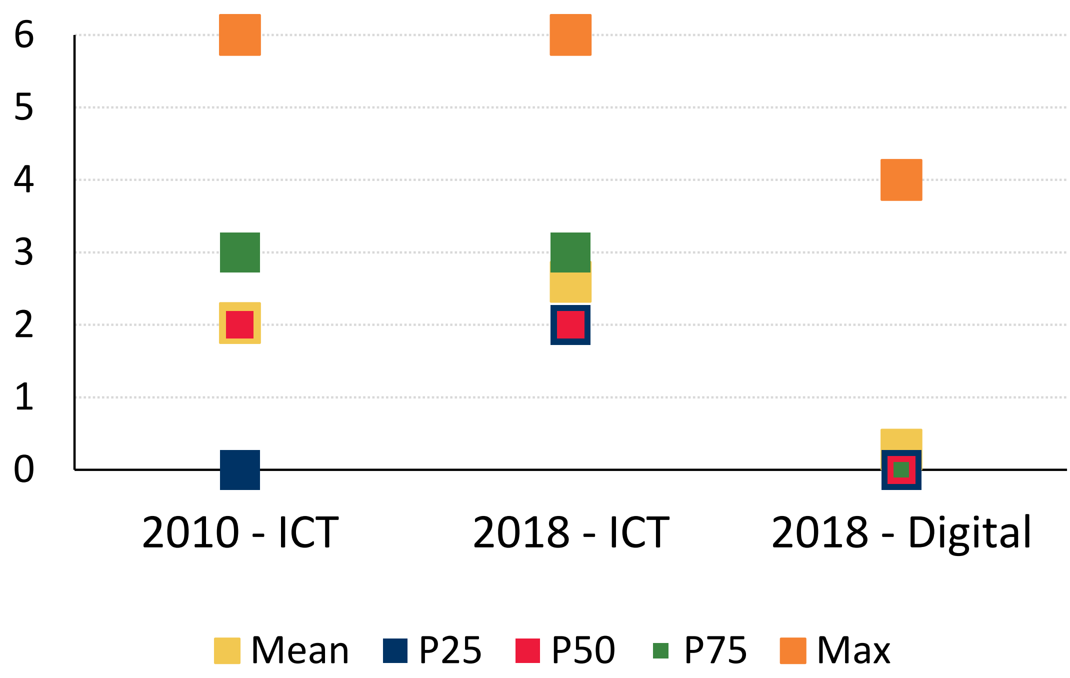


FIGURE 4: Summary statistics for number of technologies adopted

Note: ICT (PC; internet; website; online sales; online purchases), digital(robots; cloud; big data; 3D print). The questions regarding the adoption of digital technologies only start in the 2018 survey.

	PC		Internet		Website		Online sales		Online purchases		ICT staff	
	2010	2018	2010	2018	2010	2018	2010	2018	2010	2018	2010	2018
Extractive	76,1	-	61,2	-	17,9	-	11,7	-	12,2	-	5,7	-
Manufacturing	78,9	95,4	69,8	92,4	28,3	42,0	13,7	5,7	16,0	19,7	12,9	9,7
Electricity & gas	69,0	84,7	38,9	81,4	35,2	48,0	-	6,1	31,1	16,3	7,0	22,7
Water	-	-	88,2	-	43,7	79,2	5,4	15,6	10,8	29,7	16,4	19,8
Construction	7-	87,6	63,5	85,5	17,0	28,1	4,8	2,3	12,0	13,8	10,3	4,4
Wholesale & retail	75,9	96,0	63,2	92,7	24,5	40,6	13,5	11,5	22,3	26,0	9,3	9,6
Transport	46,2	79,3	42,6	76,5	15,9	23,9	6,3	7,1	4,8	12,1	9,9	5,0
Accommodation	43,2	84,5	31,3	68,8	15,6	31,7	3,9	12,8	6,2	11,6	3,8	4,8
Information & com.	97,5	96,9	97,0	96,6	72,1	73,4	24,9	19,3	45,3	45,9	54,5	61,6
Real estate	76,6	86,0	73,0	82,2	42,1	37,7	7,8	7,7	11,9	17,3	11,3	3,8
Consult. & science	96,4	99,3	95,3	98,7	33,4	47,4	12,6	8,6	25,1	28,0	22,3	15,4
Administrative act.	88,0	98,4	84,4	95,8	50,7	55,4	15,2	14,4	22,1	23,9	10,6	11,5
Other services	97,8	97,3	68,6	97,3	47,5	72,0	29,8	20,5	52,5	73,1	50,3	72,3

TABLE 1. Share of firms that adopt ICT technologies within sectors (2010 and 2018): weighting on the number of firms

Note: Sectors of Agriculture, Education, Health & social or Arts & sports are not reported due to the small number of responding firms.

As expected, PCs and internet connections are present in the large majority of firms in all sectors and there is an increase from 2010 to 2018. The existence of a website is also quite strong, with shares close to 40 percent in Manufacturing and Wholesale and Retail in 2018, around 25 percent in Construction and Transportation and 75 percent in Information and Communication. Online purchases are more prevalent than online sales in all sectors, except Accommodation. The latter technology is present in less than 20 percent of the firms in any sector of activity. The existence of ICT staff at the firm is also not prevalent across sectors either, even if it stands at about 60 percent in Information and communication activities.

Tables 2 and 3 replicate the previous exercise using the weights of turnover and number of employees, respectively. Results may change because there is heterogeneity in terms of turnover and labour intensity within each sector. Results show that the largest firms are also the ones adopting the ICT and digital technologies. The shares of PC and internet increase to numbers above 90 percent. In other technologies the shares of adopting firms also increases along the different sectors. Online sales remain a less common technology with the share in Construction standing as low as 6.6 and 5.2 percent in terms of turnover and employment, respectively.

Table 4 presents results parallel to those of the three previous tables but selecting the four digital technologies studied: robots, cloud, big data and 3D print. The lower number of technologies and the fact that information is only available for 2018 make it possible to condense results in just one table.

Results show that robots are clearly more prevalent in the Manufacturing sector and in the largest of those firms in terms of turnover and employment. When we weight the firms according to these variables robots become more prevalent in the Transport sector. Not surprisingly, as for cloud computing, the highest prevalence is in the Information and communication activities. Nevertheless, the shares of adoption in other sectors are also higher when firms are weighted according to turnover and number of employees, thus showing that the largest firms are the main adopters of this digital technology. As for big data, results are qualitatively similar to those presented for cloud computing. Finally, as for 3D print, the shares of firms adopting is typically very small. 3D print is only relevant in Manufacturing activities, mostly when firms are weighted according to their size,and to a lesser extent in Consulting & science and Other services.

Tables A.1 to A.4 in Annex A present the distribution of ICT and digital technologies along the sectors in the economy and not within each sector individually. The results are more robust the stronger the representativeness of the sample in sectoral terms. Not surprisingly, the largest sectors in the economy are also those with the largest prevalence of firms adopting these technologies.

	PC		Internet		Website		Online sales		Online purchases		ICT staff	
	2010	2018	2010	2018	2010	2018	2010	2018	2010	2018	2010	2018
Extractive	97,1	-	92,8	-	62,6	-	7,7	-	54,4	-	52,5	-
Manufacturing	98,9	99,8	98,3	99,6	81,7	87,6	35,7	21,0	35,3	45,0	62,8	58,2
Electricity & gas	97,8	99,2	95,5	99,1	93,6	97,9	-	56,8	27,7	80,3	53,4	51,8
Water	-	-	99,7	-	85,6	92,1	12,5	7,9	28,6	47,1	49,3	57,9
Construction	93,8	97,0	92,8	96,6	64,2	71,4	11,6	6,6	31,4	35,5	35,2	36,4
Wholesale & retail	96,5	99,6	94,5	99,1	70,5	81,6	34,5	32,6	50.0	56,0	45,6	46,2
Transport	94,4	99,5	94,0	99,3	76,9	90,7	33,6	47,3	50.0	53,4	59,7	52,0
Accommodation	78,5	95,9	69,7	91,0	51,1	72,6	23,2	37,8	30,1	42,4	26,1	31,6
Information & com.	99,3	99,9	99,3	99,9	95,8	97,5	44,6	57,0	76,6	81,2	86,9	90,4
Real estate	78,8	94,2	77,2	91,1	56,6	60,1	6,0	9,7	18,1	26,9	27,2	15,5
Consult. & science	99,6	99,5	99,6	99,4	75,8	84,3	18,4	14,8	39,2	47,6	56,1	50,2
Administrative act.	99,3	99,9	99,2	99,7	88,6	89,8	37,2	29,8	48,9	53,0	49,1	57,4
Other services	99,9	99,8	97,9	99,8	92,5	91,3	43,7	24,0	81,8	77,8	86,6	81,1

TABLE 2. Share of firms that adopt ICT technologies within sectors (2010 and 2018): Turnover weights

Note: Sectors of Agriculture, Education, Health & social or Arts & sports are not reported due to the small number of responding firms.

	PC		Internet		Website		Online sales		Online purchases		ICT staff	
	2010	2018	2010	2018	2010	2018	2010	2018	2010	2018	2010	2018
Extractive	90,1	-	81,9	-	45,0	-	13,4	-	33,5	-	23,9	-
Manufacturing	95,2	99,3	92,8	98,4	62,0	74,9	29,1	11,6	31,2	38,9	40,8	43,8
Electricity & gas	98,0	99,4	95,2	99,2	95,0	96,9	-	32,2	38,5	87,9	70,4	70,4
Water	-	-	98,3	-	90,8	95,6	8,3	12,6	27,4	51,8	55,8	66,0
Construction	89,9	96,2	86,8	95,3	45,8	57,1	10,8	5,2	26,5	26,9	25,0	23,8
Wholesale & retail	91,9	99,2	87,0	98,4	60,9	74,2	29,3	32,7	45,7	52,0	33,7	34,0
Transport	89,5	97,4	89,0	96,8	67,1	78,8	29,9	38,2	35,5	39,2	51,8	46,8
Accommodation	75,8	94,6	64,5	89,0	45,7	67,1	17,9	29,9	28,4	38,2	22,3	24,4
Information & com.	99,6	99,6	99,3	99,6	93,1	96,4	41,8	40,3	60,5	67,6	79,2	90,3
Real estate	87,0	93,8	85,2	91,8	62,7	64,7	8,1	19,3	22,3	24,1	24,9	17,0
Consult. & science	99,3	99,9	99,0	99,6	61,9	79,2	13,0	14,9	32,8	46,7	43,1	49,2
Administrative act.	99,3	99,9	98,9	99,8	85,4	94,5	24,3	8,7	40.0	58,2	36,0	56,6
Other services	99,7	99,6	90,6	99,6	83,2	89,4	28,4	17,4	86,3	73,7	78,2	74,7

TABLE 3. Share of firms that adopt ICT technologies within sectors (2010 and 2018): Number of employees weights

Note: Sectors of Agriculture, Education, Health & social or Arts & sports are not reported due to the small number of responding firms.

4.2. *Concentration and complementary technologies*

The fact that large firms are more likely to adopt ICT and digital technologies emerged in the previous subsection. Another way of approaching this issue is to focus on the concentration of adopting firms in the upper tail of the size distribution. Table 5 presents the share of firms adopting each technology in different brackets of the turnover and number of employees distribution, with narrower brackets for the top of the distributions. Results show that firms in the upper brackets represent proportionally larger shares of ICT and digitalization adopters. This fact is stronger in digital versus ICT

	Number				Turnover				Employment			
	Robots	Cloud	Big data	3D print	Robots	Cloud	Big data	3D print	Robots	Cloud	Big data	3D print
	2018	2018	2018	2018	2018	2018	2018	2018	2018	2018	2018	2018
Extractive	-	-	-	-	-	-	-	-	-	-	-	-
Manufacturing	11,1	13,1	7,0	5,2	48,3	48,4	37,4	15,3	33,9	32,1	20,5	11,6
Electricity & gas	4,5	12,0	19,7	-	1,1	82,6	64,0	-	10,4	63,3	78,4	-
Water	5,9	36,0	20,3	2,4	14,1	59,0	36,5	1,0	16,5	71,6	50,1	1,4
Construction	3,1	9,7	5,9	1,7	17,0	38,6	21,0	1,7	10,8	29,6	13,1	2,1
Wholesale & retail	1,6	13,1	6,7	1,3	5,2	45,9	25,8	3,8	4,0	43,5	24,6	2,7
Transport	1,7	11,6	13,4	0,5	23,3	65,2	44,8	0,3	20,6	44,9	39,2	0,6
Accommodation	1,0	7,9	5,7	0,8	1,0	33,6	17,4	1,9	1,1	27,9	13,2	1,7
Information & com.	1,0	48,8	18,7	3,1	0,5	72,7	64,0	2,6	0,8	73,2	45,5	2,9
Real estate	0,6	12,8	6,1	3,0	0,4	26,6	15,2	2,2	0,2	27,6	13,0	2,9
Consult. & science	0,7	27,9	9,6	3,7	1,2	45,5	17,3	8,0	1,0	50,5	17,0	6,2
Administrative act.	1,2	24,6	7,5	2,9	1,2	54,0	27,9	2,9	2,2	60,3	35,5	1,2
Other services	2,3	43,2	11,2	3,5	24,8	63,1	19,0	8,4	19,3	58,8	14,1	8,7

TABLE 4. Share of firms that adopt digital technologies within sectors (2018)

Note: Sectors of Agriculture, Education, Health & social or Arts & sports are not reported due to the small number of responding firms.

technologies and stronger in the distribution of employment than in the distribution of turnover.

Another important question is the complementarity of the technologies that were selected. Table 6 presents the correlation coefficients for pairs of technologies in 2018, highlighting in bold values above 0.3. Taking 2018 is particularly suitable because it is the vintage where the survey asks for the existence of both ICT and digital technologies. The more salient cases of complementarity are the pairs PC-internet, website-cloud, ICT staff-cloud and ICT staff-website. Conversely, the adoption of 3D print technologies jointly with other ICT and digitalization dimensions is relatively low, with the notable exception of robots.

VARIABLES	PC	Internet	Website	Online purchases	Online sales	ICT staff	Robots	Cloud	Big data	3d print
					Turnover					
$[0-50[$	0,49	0,48	0,37	0,40	0,41	0,36	0,32	0,37	0,39	0,39
$[50-75[$	0,29	0,29	0,31	0,28	0,26	0,27	0,33	0,33	0,27	0,28
$[75-90[$	0,13	0,13	0,17	0,18	0,18	0,20	0,16	0,15	0,17	0,17
$[90-95[$	0,04	0,05	0,07	0,06	0,06	0,08	0,11	0,07	0,09	0,15
>95	0,05	0,05	0,08	0,08	0,09	0,09	0,08	0,09	0,08	0,01
Total	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
					Employment					
$[0-50[$	0,24	0,24	0,20	0,24	0,24	0,24	0,15	0,22	0,21	0,19
$[50-75[$	0,33	0,33	0,26	0,28	0,26	0,24	0,25	0,27	0,28	0,23
$[75-90[$	0,27	0,28	0,31	0,28	0,28	0,29	0,30	0,31	0,29	0,40
$[90-95[$	0,10	0,10	0,14	0,13	0,12	0,13	0,20	0,12	0,11	0,13
>95	0,05	0,05	0,09	0,08	0,09	0,11	0,11	0,09	0,12	0,05
Total	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00

TABLE 5. Distribution of firms that adopt technologies along their position in the distributions of turnover and employment (2018)

VARIABLES	PC	Internet	Website	Online purchases	Online sales	ICT staff	Robots	Cloud	Big data	3d print
PC	1,00									
Internet	**0,78**	1,00								
Website	0,28	**0,36**	1,00							
Online purchases	0,16	0,20	**0,34**	1,00						
Online sales	0,10	0,12	**0,34**	0,25	1,00					
ICT staff	0,15	0,18	**0,42**	**0,34**	0,23	1,00				
Robots	0,07	0,09	0,17	0,14	*0,02*	0,24	1,00			
Cloud	0,14	0,18	**0,40**	**0,33**	0,21	**0,41**	0,12	1,00		
Big data	0,09	0,11	0,26	0,23	0,20	0,28	0,15	0,28	1,00	
3d print	*0,05*	0,06	0,12	0,12	*0,03*	0,12	0,23	0,08	0,11	1,00

TABLE 6. Correlation matrix of technology adoption (2018)

Note: Cells in bold signal correlations above 0.3 and cells in italics signal correlation not significant at 1 percent.

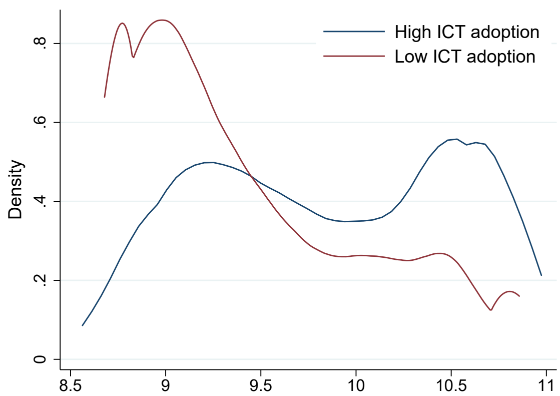
4.3. *Productivity, wages and exports*

In this subsection we assess the performance of firms with high and low ICT and digitalization adoption by comparing their kernel distributions for TFP, logarithm of labour productivity, logarithm of wages and ratio of exports on total turnover (export intensity). This is a purely descriptive procedure that does not control for other dimensions of heterogeneity, but which may still bring useful insights.

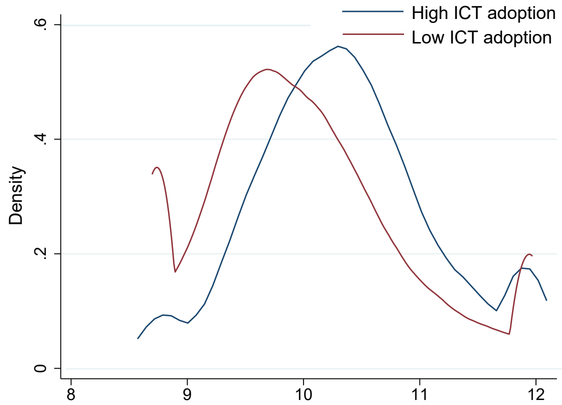
Firstly, we use a principal component analysis to separately obtain proxies that summarize firm's ICT and digitalization realities. This exercise reduces the dimensionality of these two datasets and the first principal component, the one with higher explanatory power, can be used to classify firms according to their degree of technological adoption. The first principal component obtained from the set of six ICT technologies explains 39.9 percent of total variability across firms (the second explains 23.2 percent) and the first principal component for the four digital technologies explains 40.2 percent (the second explains 24.6 percent). We define firms with the first principal component above or equal to the median of the distribution as those with high technology adoption and those below the median as those with low adoption.

Secondly, we take the set of performance variables from the database and also compute firm-level TFP according to the method developed by Levinsohn and Petrin (2003). An important issue in this estimation is the correlation between unobservable productivity shocks and input levels, which leads to biased estimates. In order to account for these unobservable shocks, the method uses a proxy variable in the estimation process. Although Wooldridge (2009) and Ackerberg *et al.* (2006) have later provided improvements to this estimation, the fundamentals remained unchanged. The procedure was implemented using the STATA command "prodest", which estimates the production functions using a control function approach. By default, the command requires the log gross output variable (in our case, the log of the GVA, at market prices), a set of free variables (typically the log of labor), a set of state variables (the log capital) and a set of proxy variables (in our case, the cost of goods sold). The capital stock corresponds to total fixed assets of the firm, as reported in the balance sheet. The inclusion of wages and export intensities as performance variables in connection with ICT and digitalization adoption links with the literature through the contributions by Acemoglu and Restrepo (2020), Acemoglu and Restrepo (2019) and Wang and Li (2017).

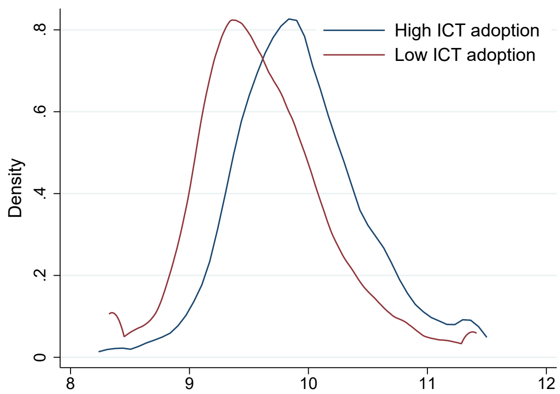
The four panels of Figure 5 compare the kernel distributions of each performance variable for high and low ICT and digital technologies adopters. Panels a) and b) show that firms with high adoption of these technologies post higher levels of TFP and labour productivity. As for the logarithm of wages the distribution of high technological adopters is shifted to the right, which is compatible with higher productivity levels for these firms. Finally, as for the export ratio, the distribution presents the well-known bimodal shape, with higher density for low and high ratios. The distribution of those firms identified as having higher ICT adoption presents a similar shape, but it has higher density in intermediate export intensity ratios. This is in accordance with the notion that firms export more in industries using ICT intensively, as referred in Wang and Li (2017).



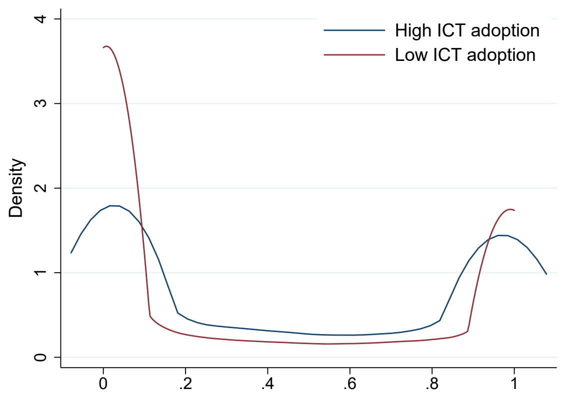
(A) TFP



(B) Labour productivity (ln)



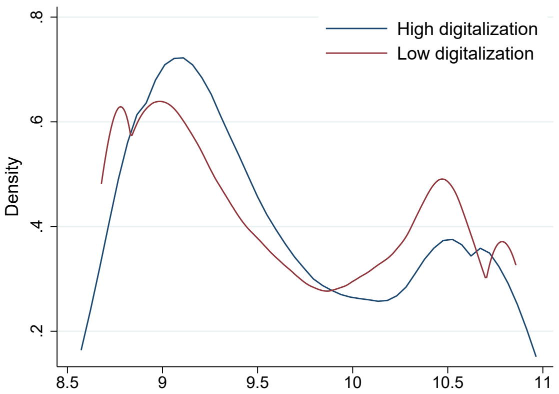
(C) Wages (ln)



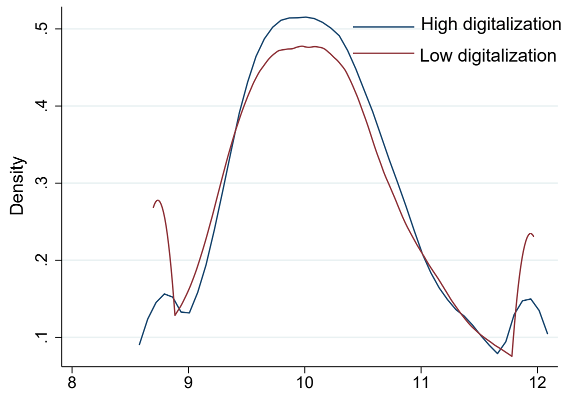
(D) Export intensity

FIGURE 5: High vs low ICT adoption, defined as those firms with a the first principal component equal or higher vs below the median of the distribution.

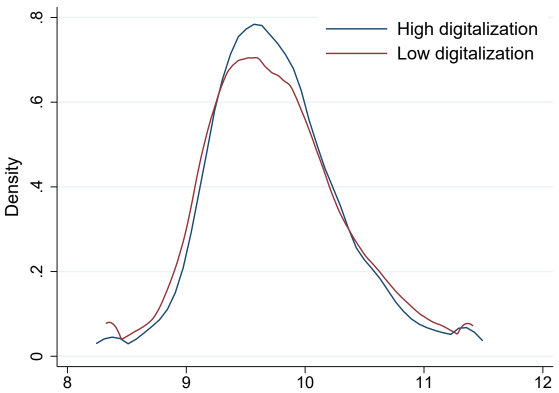
The four panels of Figure 6 replicate the previous exercise but focusing on the set of four digital technologies considered. The methodological choices to classify high and low adoption by firms and compute the TFP are unaltered. Results are qualitatively similar to those above but it is clear that the proximity between the two kernels in each panel is greater. Since these digital technologies are not very prevalent across firms, the separation threshold on the median may not set a sharp distinction between the two types of firms.



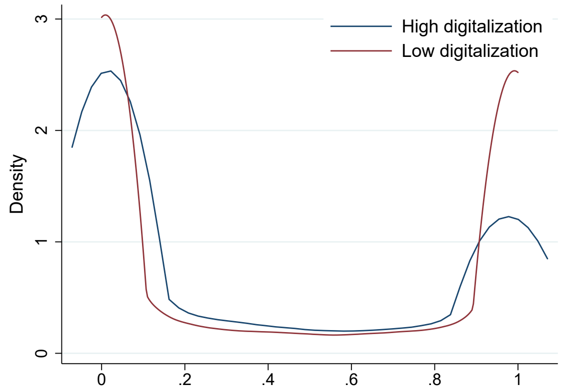
(A) TFP



(B) Labour productivity (ln)



(C) Wages (ln)

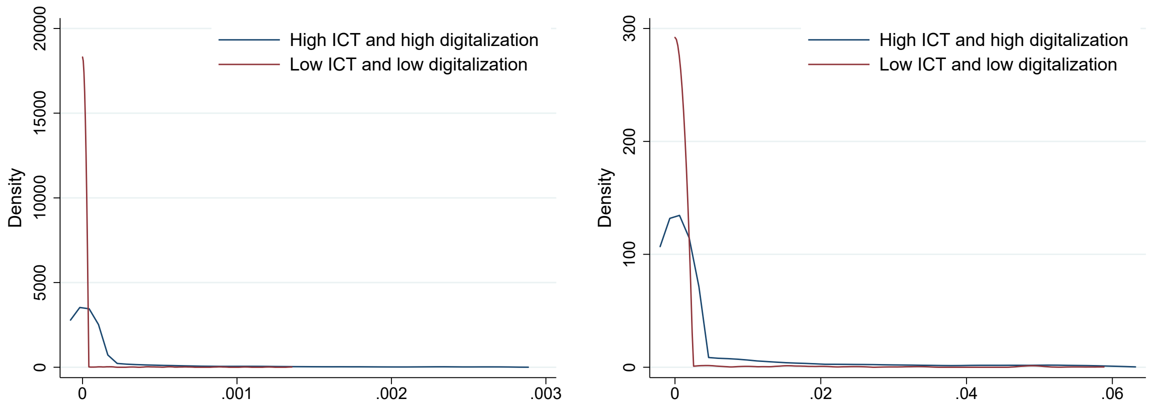


(D) Export intensity

FIGURE 6: High vs low digitalization adoption, defined as those firms with a the first principal component equal or higher vs below the median of the distribution.

4.4. *Investment in intangibles*

Intangibles and digitalization are closely related and often used as a single reality under the term intangible digital economy (e.g. Bertani *et al.* (2021)). Nevertheless, there are subtle differences. Intangible assets lack a physical presence but hold significant value to the business. These assets are typically long-term in nature and can contribute to a firm's competitive advantage, revenue generation, and overall value. Common



(A) Intangibles investment on turnover (B) Intangibles investment on total investment

FIGURE 7: Intangibles investment for high vs low technological adoption

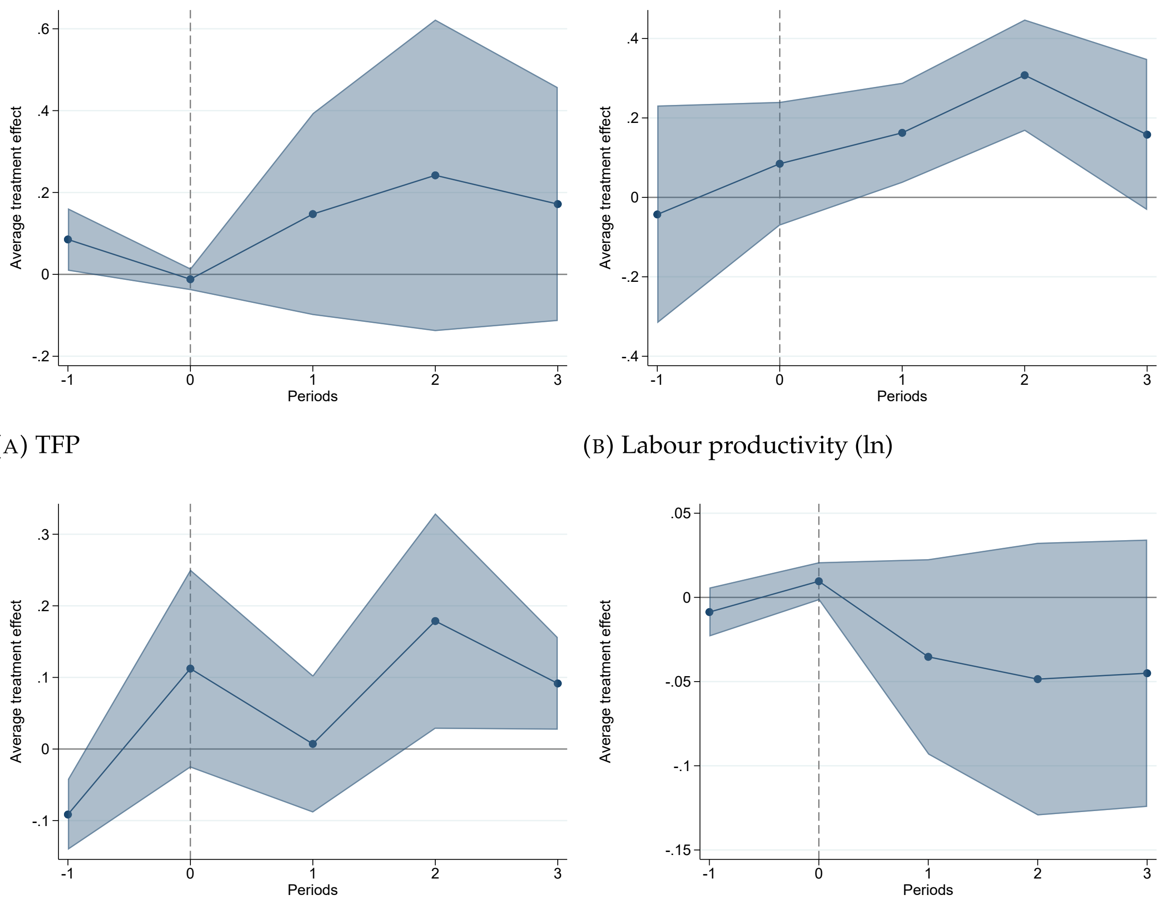
examples of intangibles are patents, trademarks, copyrights, customer lists, trade secrets and software. ICT and digitalization technologies correspond to the physical existence of specific machinery and hardware in the firm. For this reason we tried to assess the correlation between the investment in intangibles, as reported in firms' yearly income statements, and their degree of ICT and digital adoption.

Figure 7 presents the kernel densities of the ratios of investment in intangibles on turnover and investment in intangibles on total investment, after dropping ratios below the percentile 10 and above percentile 90, for firms that have both high adoption of ICT and digitalization technologies (above the median of the first principal component in both types of technologies) versus those that do not adopt either technology (below the median of the first principal component in both technologies). The amounts of investment in intangibles reported by Portuguese firms are very small. Although the density of investment ratios is very concentrated in the lower tail of the distribution, it is possible to observe that firms with higher ICT and digital adoption post ratios higher than those that have low adoption.

5. Impact of adopting a compound of ICT technologies

The results of the previous section are limited to associations between ICT and digital adoption and different variables of firms' performance. Proving causality between such adoption and performance is much more relevant but also quite demanding given the limited span of data. A staggered Differences-in-Differences (DiD) approach using as identification strategy the moment when firms reply affirmatively to the existence of a specific technology requires the observation of firms during long periods before and after the moment of adoption. Even then, the case for independence between the decision of technological adoption and firm's performance is not bullet proof. Even so, we test a staggered DiD as presented in Callaway and Sant'Anna (2021) and implement it using the STATA module *CSDID* ((Rios-Avila *et al.* 2021)). In this approach, the treatment effect parameters employ the DiD method with multiple time periods, considering variations in treatment timing, and assuming the validity of the "parallel trends assumption" after conditioning on observed covariates.

The exercise considers the simultaneous adoption by the firm of a compound of three ICT technologies (website, online sales and online purchases) and is repeated for four performance variables: TFP, labour productivity, wages and export intensity. The control group corresponds to firms that do not adopt this bundle of technologies in the same year or that do not adopt them at all. The time span used for the presentation of the coefficients of the average treatment effect for the treated subpopulation (ATT) spans from the year before the adoption of the three technologies up to three years after. The variable year is included as a covariate and the four performance variables were subject to a winsorization procedure affecting percentiles 1 and 99. Moreover, observations before 2010 and with negative wages were eliminated.



(A) TFP

(B) Labour productivity (ln)

(C) Wages (ln)

(D) Export intensity

FIGURE 8: Impact of simultaneously adopting website, online sales and online purchases. Average treatment effect for the treated subpopulation. Grey area limits the 95 percent confidence intervals.

The four panels of Figure 8 plot the results of this tentative exercise. Although the 95 percent confidence intervals are large, it is possible to glimpse a positive effect from the adoption of these technologies on labour productivity, even if it fades three periods after adoption, and on wages, two and three periods after adoption. Such positive effects are compatible with what has been presented in the literature with different methods and for different countries. The Chi2 statistic, under the null hypothesis that all pre-treatment ATTs are equal to zero, is verified. Table B.1 in Appendix B presents the values of the estimated coefficients.

6. Final remarks

This article tries to add to the existing knowledge about the adoption of ICT and digital technologies by Portuguese firms. We present some facts regarding the distribution of these technologies across sectors and their association with firms' performance in a set of different dimensions. Results corroborate the view that there is heterogeneity across types of firms and there is early evidence of positive impacts on labour productivity and wages.

Many questions are left unanswered. One important issue is the association between the size and skill composition of the labour force and the adoption of these ICT and digital technologies. Another question concerns the role of public policies in promoting these investments at the firm-level, including the construction of basic ICT and digital infrastructures.

A major limitation is the lack of granular data spanning over a long time period with a large continuing set of firms, which would allow for a long panel balanced database. Having only one or two years of observations for new digital technologies in a few firms does not allow for strong causal inference. One promising way forward to address this limitation is to pool data from ICT and digitalization adoption from firms in different countries. Interesting insights would also emerge from cross-country comparisons. Therefore, international research cooperation and sharing of this type of data is warranted.

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Appendix A: Share of firms that adopt technologies along sectors

	PC		Internet		Website		Online sales		Online purchases		ICT staff	
	2010	2018	2010	2018	2010	2018	2010	2018	2010	2018	2010	2018
Extractive	0,2	-	0,2	-	0,1	-	-	-	-	-	-	-
Manufacturing	12,3	18,2	10,9	17,7	4,4	8,0	2,1	1,1	2,5	3,8	2,0	1,9
Electricity & gas	0,1	0,1	0,1	0,1	0,1	0,1	-	-	0,1	-	-	-
Water	0,2	0,3	0,2	0,3	0,1	0,2	-	-	-	0,1	-	0,1
Construction	9,0	10,3	8,1	10,1	2,2	3,3	0,6	0,3	1,5	1,6	1,3	0,5
Wholesale & retail	26,5	3-	22,1	29,0	8,6	12,7	4,7	3,6	7,8	8,1	3,2	3,0
Transport	2,8	5,0	2,5	4,8	0,9	1,5	0,4	0,4	0,3	0,8	0,6	0,3
Accommodation	5,0	10,5	3,6	8,5	1,8	3,9	0,4	1,6	0,7	1,4	0,4	0,6
Information & com.	2,1	2,2	2,1	2,2	1,5	1,7	0,5	0,4	1,0	1,1	1,2	1,4
Real estate	2,6	2,7	2,5	2,5	1,4	1,2	0,3	0,2	0,4	0,5	0,4	0,1
Consult. & science	8,6	9,8	8,5	9,8	3,0	4,7	1,1	0,8	2,2	2,8	2,0	1,5
Administrative act.	3,2	3,2	3,1	3,1	1,9	1,8	0,6	0,5	0,8	0,8	0,4	0,4
Other services	0,1	0,1	-	0,1	-	0,1	-	-	-	0,1	-	0,1
Total	72,9	92,5	64,1	88,2	26,0	39,2	10,9	9,1	17,4	21,0	11,7	9,9

TABLE A.1. Share of firms that adopt technologies along sectors (2010 and 2018)

Note: Sectors of Agriculture, Education, Health & social or Arts & sports are not reported due to the small number of responding firms.

	PC		Internet		Website		Online sales		Online purchases		ICT staff	
	2010	2018	2010	2018	2010	2018	2010	2018	2010	2018	2010	2018
Extractive	0,4	-	0,4	-	0,2	-	-	-	0,2	-	0,2	-
Manufacturing	25,3	28,7	25,1	28,7	20,9	25,2	9,1	6,1	9,0	12,9	16,1	16,7
Electricity & gas	2,7	5,9	2,6	5,9	2,6	5,8	-	3,4	0,8	4,8	1,5	3,1
Water	0,9	0,8	0,9	0,8	0,8	0,7	0,1	0,1	0,3	0,4	0,4	0,4
Construction	8,6	4,6	8,5	4,6	5,9	3,4	1,1	0,3	2,9	1,7	3,2	1,7
Wholesale & retail	40,1	39,9	39,2	39,6	29,3	32,6	14,3	13,0	20,7	22,4	18,9	18,5
Transport	5,2	6,1	5,2	6,1	4,2	5,6	1,8	2,9	2,7	3,3	3,3	3,2
Accommodation	2,0	3,0	1,8	2,8	1,3	2,2	0,6	1,2	0,8	1,3	0,7	1,0
Information & com.	4,5	3,6	4,5	3,6	4,3	3,5	2,0	2,1	3,5	3,0	3,9	3,3
Real estate	1,1	0,8	1,1	0,8	0,8	0,5	0,1	0,1	0,2	0,2	0,4	0,1
Consult. & science	2,7	2,8	2,7	2,8	2,1	2,4	0,5	0,4	1,1	1,3	1,5	1,4
Administrative act.	2,9	3,1	2,9	3,1	2,6	2,8	1,1	0,9	1,4	1,6	1,4	1,8
Other services	-	-	-	-	-	-	-	-	-	-	-	-
Total	96,4	99,4	95,0	98,9	75,0	84,9	30,8	30,4	43,7	53,0	51,6	51,3

TABLE A.2. Share of firms that adopt technologies along sectors (2010 and 2018)

Note: Sectors of Agriculture, Education, Health & social or Arts & sports are not reported due to the small number of responding firms.

	PC		Internet		Website		Online sales		Online purchases		ICT staff	
	2010	2018	2010	2018	2010	2018	2010	2018	2010	2018	2010	2018
Extractive	0,4	-	0,3	-	0,2	-	0,1	-	0,1	-	0,1	-
Manufacturing	26,0	29,2	25,3	28,9	16,9	22,0	8,0	3,4	8,5	11,4	11,1	12,9
Electricity & gas	0,3	0,4	0,3	0,4	0,3	0,4	-	0,1	0,1	0,3	0,2	0,3
Water	0,7	1,1	0,7	1,1	0,7	1,0	0,1	0,1	0,2	0,6	0,4	0,7
Construction	12,2	7,9	11,8	7,8	6,2	4,7	1,5	0,4	3,6	2,2	3,4	2,0
Wholesale & retail	21,8	23,8	20,6	23,6	14,4	17,8	6,9	7,8	10,8	12,5	8,0	8,2
Transport	5,2	6,4	5,1	6,4	3,9	5,2	1,7	2,5	2,0	2,6	3,0	3,1
Accommodation	6,3	8,7	5,4	8,2	3,8	6,2	1,5	2,7	2,4	3,5	1,9	2,2
Information & com.	2,6	3,3	2,6	3,3	2,5	3,2	1,1	1,3	1,6	2,3	2,1	3,0
Real estate	0,9	0,7	0,9	0,7	0,6	0,5	0,1	0,2	0,2	0,2	0,3	0,1
Consult. & science	3,6	4,3	3,6	4,3	2,3	3,4	0,5	0,6	1,2	2,0	1,6	2,1
Administrative act.	12,3	12,6	12,3	12,6	10,6	12,0	3,0	1,1	5,0	7,4	4,5	7,2
Other services	0,1	0,1	-	0,1	-	0,1	-	-	-	-	-	-
Total	92,5	98,6	89,1	97,4	62,5	76,4	24,4	20,4	35,9	45,0	36,6	41,8

TABLE A.3. Share of firms that adopt technologies along sectors (2010 and 2018)

Note: Sectors of Agriculture, Education, Health & social or Arts & sports are not reported due to the small number of responding firms.

	Number				Turnover				Employment			
	Robots	Cloud	Big data	3D print	Robots	Cloud	Big data	3D print	Robots	Cloud	Big data	3D print
	2018	2018	2018	2018	2018	2018	2018	2018	2018	2018	2018	2018
Extractive	-	-	-	-	-	-	-	-	-	-	-	-
Manufacturing	2,1	2,5	1,3	1,0	13,9	13,9	10,8	4,4	10,0	9,4	6,0	3,4
Electricity & gas	-	-	-	-	0,1	4,9	3,8	-	-	0,2	0,3	-
Water	-	0,1	0,1	-	0,1	0,5	0,3	-	0,2	0,8	0,5	-
Construction	0,4	1,1	0,7	0,2	0,8	1,8	1,0	0,1	0,9	2,4	1,1	0,2
Wholesale & retail	0,5	4,1	2,1	0,4	2,1	18,4	10,3	1,5	0,9	10,4	5,9	0,6
Transport	0,1	0,7	0,8	-	1,4	4,0	2,8	-	1,4	3,0	2,6	-
Accommodation	0,1	1,0	0,7	0,1	-	1,0	0,5	0,1	0,1	2,6	1,2	0,2
Information & com.	-	1,1	0,4	0,1	-	2,6	2,3	0,1	-	2,5	1,5	0,1
Real estate	-	0,4	0,2	0,1	-	0,2	0,1	-	-	0,2	0,1	-
Consult. & science	0,1	2,8	0,9	0,4	-	1,3	0,5	0,2	-	2,2	0,7	0,3
Administrative act.	-	0,8	0,2	0,1	-	1,7	0,9	0,1	0,3	7,6	4,5	0,2
Other services	-	-	-	-	-	-	-	-	-	-	-	-
Total	3,4	14,7	7,6	2,4	18,5	50,4	33,3	6,5	13,8	41,3	24,5	5,0

TABLE A.4. Share of firms that adopt technologies along sectors (2018)

Note: Sectors of Agriculture, Education, Health & social or Arts & sports are not reported due to the small number of responding firms.

Appendix B: Average treatment effects

	Coef.	Std. Err	z	P>|z|	95% conf interv	
			Total factor productivity			
ATT	0,097	0,078	1,250	0,212	-0,056	0,250
Pre avg	0,085	0,039	2,190	0,029	0,009	0,162
Post avg	0,137	0,115	1,190	0,233	-0,088	0,363
			Labour productivity			
ATT	0,171	0,049	3,480	0,000	0,075	0,267
Pre avg	-0,043	0,140	-0,310	0,759	-0,317	0,231
Post avg	0,178	0,046	3,890	0,000	0,088	0,268
			Wages			
ATT	0,106	0,038	2,810	0,005	0,032	0,180
Pre avg	-0,092	0,025	-3,620	0,000	-0,141	-0,042
Post avg	0,097	0,036	2,740	0,006	0,028	0,167
			Export intensity			
ATT	-0,032	0,024	-1,360	0,173	-0,078	0,014
Pre avg	-0,009	0,007	-1,170	0,241	-0,023	0,006
Post avg	-0,030	0,026	-1,130	0,260	-0,082	0,022

TABLE B.1. Coefficients of the staggered DiD exercise

Note: In each block lines correspond to the average treatment effect (ATT), average pre-treatment effect (Pre avg), average post-treatment effect (Post avg). The treated population corresponds to firms that adopt simultaneously a compound of three ICT technologies (website, online sales and online purchases) and entails 172 observations (out of a total of 58886 observations). The control group corresponds to firms that do not adopt this bundle of technologies in the same year or that do not adopt them at all.

Non-technical summary

October 2023

A macro approach to the relative efficiency of the Portuguese health system

Cláudia Braz and Sónia Cabral

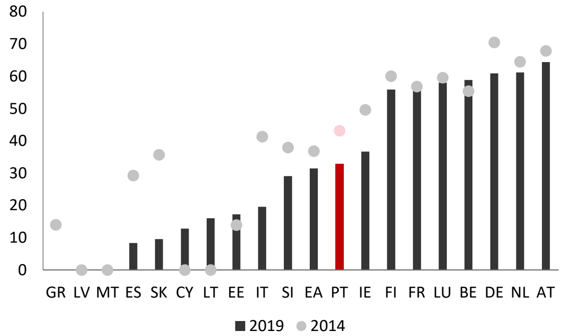
Portugal has a publicly funded healthcare system known as the National Health Service (*Serviço Nacional de Saúde, SNS)* since the late 1970s. Over time its architecture has evolved, in particular in the past two decades, through the implementation of various reforms. These reforms focused mainly on incorporating private sector practices, promoting integrated and patient-centred care, and facilitating the adoption of digital technologies. Despite the progress made, concerns persist regarding the appropriateness of healthcare expenditure in the country.

Portugal's total health expenditure is lower than the euro area average, having remained relatively stable as a percentage of GDP in the decade before the pandemic. However, there has been a significant reduction in the public component since 2009. In 2019, public funding accounted for around 60% of total health expenditure in Portugal, down from 70% in the early 2000s and lower than the euro area average (80%).

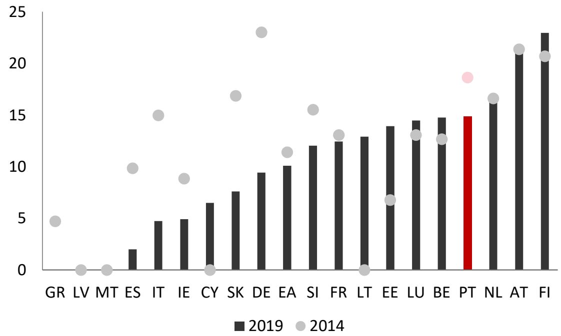
Evaluating the efficiency of resource utilisation in the health sector requires an appropriate methodology. This study uses Data Envelopment Analysis (DEA) to examine the relative efficiency of the Portuguese healthcare system in the context of the euro area. DEA derives a non-parametric production frontier based on the most efficient countries, allowing the assessment of each country's performance relative to this frontier.

Potential gains of efficiency can be quantified in two ways: by improving health outcomes while maintaining input levels (output-orientation) or by reducing inputs while keeping the existing levels of health outcomes (input-orientation). In our baseline specifications, DEA models are estimated using total health expenditure as the input and life expectancy or healthy life expectancy as the output. In an extension, we also take into account socioeconomic and life-style factors as inputs and obtain consistent results.

The findings of this study are in line with previous empirical research. DEA estimates point to significant health inefficiencies and to a large dispersion of efficiency measures among euro area countries (Figure 1). Estimated potential efficiency gains tend to be much larger in the input dimension than in the output dimension. This suggests that there is considerable scope in several countries for a decrease in total health expenditure while maintaining life expectancies. On the output dimension, potential gains are larger for healthy life expectancy than for life expectancy. From 2014 to 2019, around half of the countries, including Portugal, were able to reduce their health inefficiencies. Portugal's efficiency indicators are generally in an intermediate position in the euro area.



(A) Input inefficiency



(B) Output inefficiency

FIGURE 1: Inefficiency scores in % – DEA models with healthy life expectancy as output

Notes: DEA models with 1 input-1 output. The input is total per capita health expenditure in PPS (average of the last 5 years); the output is healthy life expectancy. The inefficiency of each country is measured as its distance to the technical efficiency frontier. In input-oriented models, this distance is measured in terms of inputs as the % decrease in input if the country moved to the frontier while maintaining its level of output. In output-oriented models, this distance is measured in terms of outputs as the % increase in output if the country moved to the frontier while maintaining its level of input. The countries in the x-axis are in ascending order of their inefficiency scores in 2019. A value of zero indicates that the country is in the efficiency frontier in that specific year.

DEA has methodological limitations. In particular, the results are very sensitive to the selection of the sample and only technical efficiency is evaluated, excluding factors such as care quality or equity in healthcare provision. Nevertheless, even if not taken at face value, the results still offer a useful ranking of health efficiency for euro area countries.

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A macro approach to the relative efficiency of the Portuguese health system

Cláudia Braz
Banco de Portugal

Sónia Cabral
Banco de Portugal

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Abstract
Over the past two decades, Portugal has achieved significant progress in improving its healthcare system by undertaking organisational restructuring and implementing a range of reforms. The country's health expenditure is lower than the euro area average and has a smaller proportion of public funding, which has declined since the financial crisis. Despite these efforts, efficiency concerns persist. To assess the technical efficiency of Portugal's health system within the euro area context, we used Data Envelopment Analysis (DEA). Our findings indicate that approximately half of the countries, including Portugal, were able to reduce their health inefficiencies between 2014 and 2019. Nonetheless, the results suggest that there is still significant scope to improve efficiency, particularly in terms of reducing total health expenditure. Regarding the output dimension, the potential gains in healthy life expectancy outweigh those in life expectancy. Portugal's efficiency scores generally rank in an intermediate position in the euro area. (JEL: H51, I1)

1. Introduction

The efficient allocation and utilisation of resources within a health system play a crucial role in delivering high-quality care and optimising health outcomes of the population. As countries strive to provide accessible and effective healthcare services, assessing the relative efficiency of their health systems becomes paramount. This study aims to explore and evaluate the relative efficiency of the Portuguese health system in the euro area context.

The Portuguese healthcare system, like many others worldwide, faces various challenges in meeting the needs of its population. These challenges include limited financial resources, an aging population, changing disease patterns, and an evolving technology. Thus, in the first part of this study the main characteristics of the Portuguese

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E-mail: crbraz@bportugal.pt; scabral@bportugal.pt

health system are described, with a special focus on the organisation and structure of the National Health Service (*Serviço Nacional de Saúde, SNS*), the evolution of selected financial, physical and human resources, and the most important reforms introduced in the last decades.

The complexity of the SNS structure at present is evident, stemming from its incremental development and successive changes over time. The vertical and horizontal integration process of healthcare services, which is still ongoing, further contributes to this complexity. In addition, several reforms have been implemented along the last two decades and are shortly described in this study.

Regarding resources in Portugal's healthcare system, the total current health expenditure as a percentage of GDP is lower than the euro area average. This expenditure has remained relatively stable in the years leading up to the pandemic. When measured in PPS (purchasing power standards) per inhabitant, there has been a steady increase, except during the Assistance Programme years. The allocation of expenditure by provider reveals the significant role of hospitals, constituting approximately 40% of the total expenditure, of which 70% is public in 2019. In terms of financing, the public component presently accounts for around 60% of the total health spending in Portugal. This is lower compared to the early 2000s when it was 70%, and also lower than the euro area average which stands at 80% in 2019. In terms of physical and human resources, a comparison with the euro area indicates that Portugal has fewer hospital beds, total doctors and nurses per 1000 inhabitants, though data availability hinders somewhat the comparison.

In order to evaluate the impact of resources and reforms on the actual health status of a population and assess the efficiency of health expenditure in a specific country, it is crucial to employ a suitable methodology. There are various alternatives available for this purpose. Quality indicators and performance metrics focus on specific aspects of healthcare performance, such as readmission rates, patient safety, waiting times, mortality rates, or adherence to clinical guidelines. These indicators provide a snapshot of performance but may not capture the overall system efficiency. Parametric methods, such as regression analysis, use statistical models to estimate the relationship between inputs and outputs in healthcare. These methods require assumptions about the functional form of the relationship and a sufficient number of observations. To overcome these difficulties, non-parametric methods are often utilised. In the second part of this study, a non-parametric technique will be used: Data Envelopment Analysis (DEA).

DEA is a linear programming method for evaluating the performance of different units based only on their combination of inputs and outputs. Efficiency gains can be measured in two ways: either by increasing health outcomes while maintaining inputs at current levels (output-orientation), or by decreasing inputs while keeping health outcomes at current levels (input-orientation). In our baseline specifications, we estimate both input-oriented and output-oriented DEA structures using total health expenditure as input, and life expectancy or healthy life expectancy as output.

DEA has been applied in numerous fields including banking, healthcare, transportation, energy and environment, and education (see Liu *et al.* (2013) for a survey on DEA applications). Several studies used DEA to address the measurement of efficiency in the health sector, both from a micro perspective, which often focuses on hospitals within a country, and from a macro perspective, addressing general health efficiency across countries (see Hollingsworth (2008) for a meta-analysis of this literature). DEA estimates provide a useful ranking of how countries perform in terms of technical health efficiency, but due to its several limitations results should not be taken at face value.

Focusing on European Union (EU) countries, Medeiros and Schwierz (2015) provide evidence of widespread inefficiency in health systems, using a broad set of models with various combinations of input and output variables. Cetin and Bahce (2016) assess the efficiency of health sectors of OECD countries using input-oriented DEA and find that there is room for improvement in around 60% of the countries. Dutu and Sicari (2020) use a DEA model with a 2 inputs-1 output structure, with one of the variables representing a composite indicator of country-specific non-discretionary factors. The authors find wide dispersion of efficiency scores across OECD countries and significant potential gains on both output and input sides. The DEA estimates of Garcia-Escribano *et al.* (2022) reveal sizeable differences in health spending efficiency among countries, particularly between emerging economies and developed countries. The evolution of their efficiency scores indicates that there were important gains in most countries from 2007 to 2017.

The results obtained in this study are in line with previous empirical research, pointing to substantial health inefficiencies across euro area countries. Estimated potential gains in the input dimension tend to be much larger than those in the output dimension. This suggests that there is a significant scope for a decline in total health expenditure, which might be of at least 20% for the euro area average in 2019. In the output dimension, potential efficiency gains are larger for healthy life expectancy than for life expectancy. Our findings reveal a considerable dispersion in efficiency scores across the euro area. Approximately half of the countries, including Portugal, experienced improvements between 2014 and 2019. In terms of rankings, Portugal tends to fall in the middle range among euro area countries.

The study is organised as follows. Section 2 provides a detailed description of the Portuguese health system, focusing on its structure and organisation, reforms implemented in the last two decades, and the evolution of financial, physical and human resources. Section 3 applies DEA to evaluate the relative health efficiency across euro area countries. Section 4 presents some concluding remarks.

2. The Portuguese National Health Service

2.1. Organisation

The publicly-funded healthcare system in Portugal, known as the National Health Service (*Serviço Nacional de Saúde, SNS*), was created in 1979. It offers universal coverage and access to health services for all residents, regardless of nationality or legal status.

The organisation of SNS is depicted schematically in Figure 1. SNS is under the supervision of the Ministry of Health. In 2022, an executive director of the SNS was nominated. The Central Administration of the Health System (*Administração Central do Sistema de Saúde, ACSS*) was established in 2007 with the aim of managing the financial and human resources, facilities, and equipment of SNS, in addition to developing and implementing health policies, regulations, and plans. Its mission is to ensure effective management of resources and standardisation of healthcare services. At the regional level, Regional Health Administrations (*Administrações Regionais de Saúde, ARS*) are responsible for managing and coordinating healthcare services. Health regulatory entities, such as the National Authority for Medicines and Health Products (INFARMED) and the Health Regulatory Entity (*Entidade Reguladora da Saúde, ERS*), oversee and regulate health-related activities in Portugal. Additionally, there are public institutes that serve as specialised organisations or entities, established to fulfil specific roles within the healthcare system, like the National Medical Emergency Institute (*Instituto Nacional de Emergência Médica, INEM*) or the Portuguese Institute of Blood (*Instituto Português do Sangue e da Transplantação, IPST*), among others. Health services are mainly delivered to the population through[1]:

- **Health Centres** (*Centros de Saúde*): These are the primary care facilities responsible for providing general medical services, preventive care, family planning and health education. Since 2008, they are grouped in *Agrupamentos de Centros de Saúde* with the mission to guarantee the provision of primary healthcare to the population of a certain geographic area. Within some health centres, there are independent units known as Family Health Units (*Unidades de Saúde Familiar, USF*), which have implemented performance-based payment systems to incentivise and reward healthcare providers, and Personalised Healthcare Units (*Unidades de Cuidados de Saúde Personalizados, UCSP*) without performance-based incentives.
- **Hospitals**: These are secondary and tertiary care facilities that provide specialised medical care, surgical procedures, diagnostic imaging, laboratory services, and other advanced medical treatments. They are often associated with medical schools and research centres. Most public hospitals are now part of hospital centres (*centros hospitalares*), which bring together and manage several hospital units located in the same city or region. Hospitals may have organisational units within, called Integrated Responsibility Centres (*Centros de Responsabilidade Integrados, CRI*), which are built around specific medical specialities, clinical services, or administrative functions. They operate with a degree of autonomy, making decisions about resource distribution, budget management, and operational strategies within their designated areas.

  Vertical integration among entities within the Portuguese SNS is also possible. One example is the *Unidades Locais de Saúde, ULS* model, in which a unified entity supervises the delivery of comprehensive healthcare services across different levels of care, such as primary, hospital, and long-term care. The ULS model is currently being generalised across the country.

1. The SNS also incorporates a network for the provision of long-term care, although this aspect is not explicitly addressed in the analysis.

- **Private providers of health goods and services**: The provision of health goods and services by the government extends beyond what is directly supplied by public units, encompassing agreements with private providers. These providers include hospitals, clinics, laboratories, pharmacies, medical supply companies, and medical equipment manufacturers. Financing for these services is facilitated by contracts established with the government, but also through insurance contracts and out-of-pocket payments by households. Pharmacies in Portugal serve as a primary point of contact between patients and healthcare professionals.

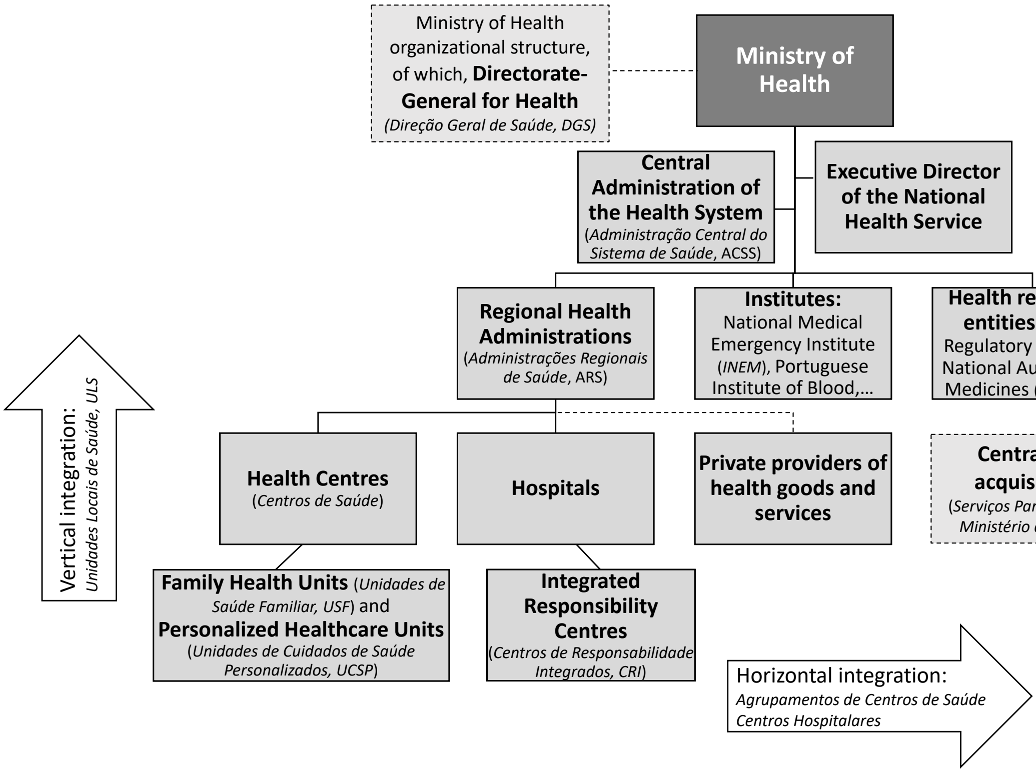


FIGURE 1: Organisation of the National Health Service in Portugal
Source: Authors.

2.2. *Reforms*

Since 2000, several measures have been adopted in Portugal to enhance healthcare accessibility, quality, and efficiency. However, it is challenging to link their implementation to developments in the health sector, particularly regarding expenditure. These measures include the establishment of private sector practices and partnerships between different healthcare providers (hospital reforms, public-private partnerships and centralised acquisitions), a shift towards more integrated and patient-centred care (the creation of *USF* and *ULS*, as well as the promotion of generics) and the development of digital health tools (the electronic health record and the health hotline, app and portal). The following is a brief overview of these initiatives.

- **Public-Private Partnerships** (PPPs): The development of the hospital network using PPPs began in 2001. The program aimed to construct and manage 11 hospitals under this model, but only four were successfully completed between 2008 and 2010. The PPP model in Portugal involved the construction and maintenance of the hospital infrastructure and management of the building for 30 years, as well as the equipping and management of the hospital establishment for 10 years. Despite being managed by private entities, PPP hospitals are fully integrated into SNS and have the same obligation as publicly managed hospitals to provide the constitutionally guaranteed right to health. In recent years, the Court of Audit has been producing performance audit reports of the four PPP hospitals. The report released in April 2021 indicated that these hospitals demonstrated greater efficiency compared to publicly managed hospitals, and their performance in terms of quality, effectiveness, and access indicators was consistent with the average of the respective reference group. However, in recent years, the model has been discontinued, and at present, there is only a single hospital functioning under the PPP framework.
- **Hospital Reforms**: In 2002, the hospital management law underwent a revision that allowed for business-type models to be implemented within hospitals. This resulted in the creation of corporate hospitals, namely *Hospitais EPE* and *Hospitais SA*, which have autonomy in financial, administrative, and human resource matters. To further separate the State as a funder from hospitals as providers, programme-contracts were introduced in 2003 to govern the management of the SNS. These contracts involve negotiation between hospitals and the Ministry of Health, are typically valid for one year, and can be renewed by mutual agreement between the parties. The introduction of these contracts aimed to increase the transparency and rigour of hospital production classification and to implement prospective funding. Despite this, Portugal has experienced a persistent underfunding for the SNS, hindering its capacity to provide effective and high-quality healthcare services.
- **Generics**: In 2002, a law was passed to promote the use of generics, which established a legal framework for the approval, pricing, and reimbursement of generic drugs. Under this law, generic drugs are required to meet the same quality, safety, and efficacy standards as brand-name drugs, and are subject to the same regulatory approval process. Once approved, generics are assigned a reference price, which is usually lower than the price of the corresponding brand-name drug. The reference pricing system encourages not only the adoption of generics by consumers, but also the reduction of prices for corresponding branded drugs, since the SNS reimbursement is the same regardless of the products and of its price (see Costa and Santos (2022) for a discussion). Overall, the introduction of generics in Portugal has been successful. According to the OECD, the current share of generics in the whole pharmaceutical market is around 50%, similar to that observed in Finland and significantly higher than in Austria and Belgium (around 35%).
- **Family Health Units**: USF were established in 2005 with the aim of contributing to improving the quality and efficiency of the SNS. Operating on a capitation-based

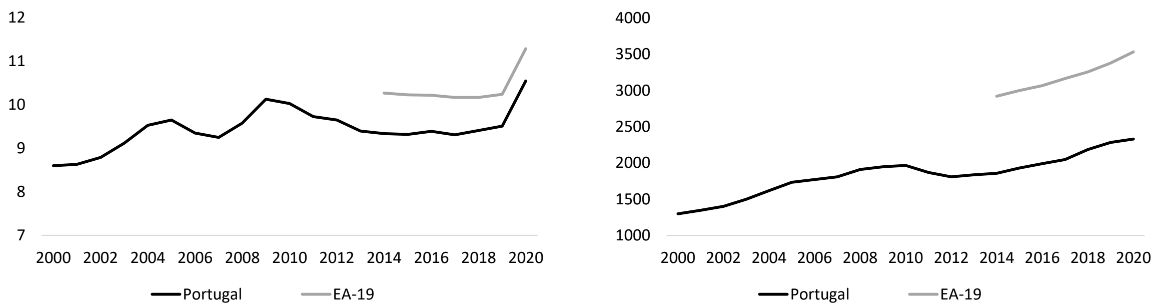
funding model, these facilities receive a fixed amount of funding per registered patient, irrespective of the number of consultations or services provided. This model aims to incentivise preventive care, health promotion, and the management of chronic conditions, rather than the traditional fee-for-service model, which often led to overuse of services and fragmentation of care. The first USF was founded in 2006, and presently Portugal has around 600 USFs covering about 65% of the population.

- **Local Health Units**: The inception of the first ULS dates back to 1999, but it was only a pilot project. Between 2007 and 2012, 7 ULS were established. Currently, plans are underway to introduce 12 more ULS, building on the expansion momentum. As mentioned before, these vertically integrated units combine various healthcare services, including hospitals and primary care facilities, into a cohesive network aimed at providing more efficient and patient-centred care.
- **Health Hotline, App and Portal** (*Linha Saúde 24/SNS 24*): *Linha Saúde 24* was launched in Portugal in 2007 as a health service that operates via telephone and offers round-the-clock medical advice and assistance to the Portuguese population. Its primary objective is to decrease the number of avoidable emergency room visits and enhance the availability of primary healthcare services. In 2017, it was broadened to SNS 24, which delivers various digital and telehealth services across different channels like phone, in-person, and online platforms such as the SNS 24 app and web portal. According to the Ministry of Health, the SNS 24 telephone line answered more than 9 million calls in 2022, the highest number ever.
- **Electronic Health Record**: To be implemented as part of a national initiative called *Registo de Saúde Eletrónico*. The project was launched in 2009 with the goal of creating a national health information system. However, the initiative is still undergoing due to challenges such as ensuring data privacy and security, and encouraging widespread adoption of electronic health records among healthcare providers. Despite these challenges, the electronic prescription management system component (*receita sem papel*) has been successfully introduced and is currently fully operational.
- **Centralised acquisitions**: The *Serviços Partilhados do Ministério da Saúde, SPMS* was created in 2010, having as one of its main tasks the provision of shared services in the areas of purchasing and logistics, financial services, human resources and information and communication systems and technologies. Over the recent period, the centralised acquisitions of medicines has generated a saving of around 50 million euros per year, according to available official data.

2.3. *Financial, physical and human resources*

SNS is funded through taxes and social security contributions and is designed to be accessible and affordable to all residents of Portugal. It operates on the principles of universality and equity, with the goal of ensuring that all citizens have access to the healthcare they need, regardless of their financial means. While the SNS is the main healthcare provider, the private sector complements its services, providing quicker access and more convenience for patients (Gouveia 2023). Additionally, some private hospitals have agreements with the SNS, augmenting the public health system's resources and capacity. Private health insurance also plays a crucial role, covering medical expenses not included in the SNS.

Total current health expenditure in Portugal is lower than in the euro area, measured either as a ratio to GDP or in PPS per inhabitant (Figure 2). Since the beginning of the century until 2019, the ratio of health expenditure to GDP in Portugal was relatively stable, ranging between 8.5% and 10%. During the Economic and Financial Assistance Programme period, from 2011 to 2014, health expenditure experienced a decline. By the end of the Programme, spending had returned to the level seen in 2007 and remained relatively stable up to the pandemic surge. In 2019, health spending as a percentage of GDP was 9.5%, increasing to 10.6% in 2020 due to the pandemic. These ratios to GDP compare to 10.2% and 11.3% for the euro area in 2019 and 2020, respectively.



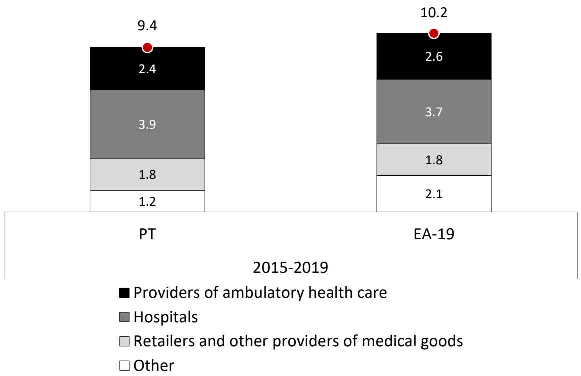
(A) As a percentage of GDP

(B) In euros expressed in purchasing power standards (PPS) per inhabitant

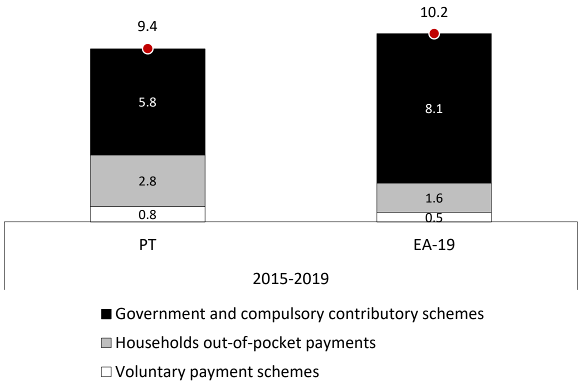
FIGURE 2: Total current health expenditure in Portugal and the euro area (EA-19)
Source: Eurostat (System of Health Accounts - SHA).

Measured in PPS per inhabitant, total current health expenditure in Portugal has been on a consistent upward trajectory, with interruptions occurring solely in 2011 and 2012. On average, spending grew by 3% per year between 2000 and 2019 and reached €2283 PPS per inhabitant in 2019. This level was lower than that of the euro area in 2019 (€3378). From 2014 to 2019, per capita health spending in Portugal grew faster than in the euro area, at 4.2% and 2.9% on average per year, respectively, allowing the broad maintenance of the difference in levels.

Figure 3 displays total current health expenditure in Portugal and the euro area during the period of 2015-2019, focusing on the categorisation by provider and financing scheme. When examining the breakdown by provider, it becomes evident that hospitals play a predominant role in Portugal, accounting for around 40% of the total expenditure, slightly surpassing the euro area average. According to OECD (2023), public hospitals, which are fewer in number but larger in size than private hospitals, constitute more than 70% of Portuguese hospital expenditure in 2019. The higher hospital spending is balanced out by lower expenditure for ambulatory healthcare providers. In terms of expenses related to retailers and other medical goods providers, Portugal and the euro area exhibit similar levels, although it should be noted that in Portugal, these expenses have declined since the early 2000s by approximately 0.6 p.p. of GDP. Consequently, the primary distinction between Portugal and the euro area arises from other expenditures not encompassed within the aforementioned categories, primarily associated with residential long-term care facilities.



(A) By provider



(B) By financing scheme

FIGURE 3: Total current health expenditure in Portugal and the euro area | As a percentage of GDP

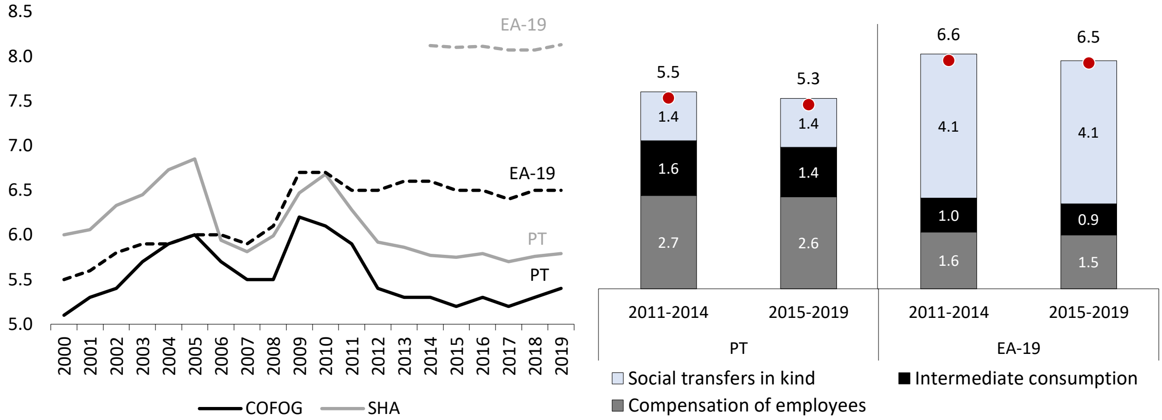
Source: Eurostat (System of Health Accounts - SHA).

In terms of financing, the public component, which includes government and compulsory contributory healthcare financing schemes, accounts for about 60% of total spending in Portugal (70% in the early 2000s), compared with around 80% in the euro area. Accordingly, the relevance of households' out-of-pocket payments in the financing of the health system is much higher in Portugal than in the euro area. In 2015-2019, around 30% of health expenditure is financed directly by resources of Portuguese households at the time of healthcare provision (about half in the euro area). The majority of these direct payments in Portugal is associated with the use of private outpatient healthcare and the purchase of medicines at pharmacies (Barros and Costa 2023).

To enhance the understanding of public health expenditure in Portugal and its comparison with the euro area average, national accounts data that have been compiled based on the Classification of Functions of Government (COFOG) can be used. It should be noted, however, that the scope and definitions used in COFOG differ somewhat from those of the System of Health Accounts (SHA), as illustrated in panel A of Figure 4.[2] According to COFOG data, health final consumption expenditure by general government as percentage of GDP rose in Portugal and the euro area until 2009.

2. For example, in the case of Portugal, long-term care spending is included in the SHA but not in health COFOG data (it is recorded in the social protection COFOG). The same happens with spending on health-related tax deductions, which in COFOG (as well as in national accounts) are deducted to tax revenue. The opposite occurs in the case of the public employees health system - ADSE - which was included in COFOG expenditure up to 2009. The SHA includes, since 2006, this subsystem in the voluntary payment schemes.

However, in Portugal, it has decreased since then, while it has remained relatively stable in the euro area. On average in the 2015-2019 period it reached 5.3% of GDP in Portugal and 6.5% in the euro area (Figure 4, panel B). The main spending categories are also shown but caution is warranted in these comparisons. This is because governments have the flexibility to either produce healthcare services for the population or contract and purchase them from market producers. In the former scenario, the associated costs appear primarily in categories like compensation of employees and intermediate consumption. Conversely, in the latter case, when the government pays for or co-finances healthcare services delivered by the private sector, this expense is categorised as social transfers in kind. This category also encompasses the co-financing of medicines by the government. The data point to a higher proportion of healthcare services being directly produced by the government in Portugal compared to the euro area average. Additionally, the larger value of social transfers in kind in the euro area could suggest a more substantial co-financing of medical acts and medicines compared to Portugal. However, drawing a robust conclusion would require more detailed data which is not available.



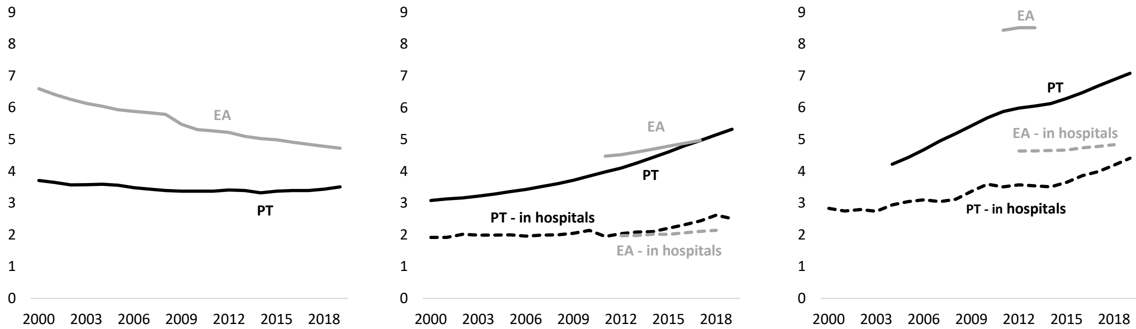
(A) Comparison between SHA and COFOG accounts (B) Main items - COFOG

FIGURE 4: Public health expenditure | As a percentage of GDP

Source: Eurostat (System of Health Accounts and COFOG data).
Notes: In panel A, SHA data refer to current expenditure by government and compulsory contributory healthcare financing schemes; for the COFOG final consumption expenditure is considered.

When analysing healthcare provision, it is also important to consider physical and human inputs, such as buildings, equipment, and personnel, in addition to expenditure. Physical and human resources are essential determinants of healthcare delivery, as they directly influence the availability, accessibility, and effectiveness of services. Figure 5 presents three types of healthcare physical and human resources - hospital beds, doctors and nurses - for which data are available.

The number of hospital beds per (1000) inhabitant in Portugal has been below the euro area average, although quite constant in the last two decades, contrasting with the declining trend at the euro area level (Panel A). When considering doctors and nurses, it is worth noting that the availability and definition of the data can impact the comparison between Portugal and the euro area average. The number of licensed doctors to practice per inhabitant in Portugal shows an increasing trend and is similar to that of the euro area in 2017, although in the construction of the aggregate practicing doctors are used for some countries (Panel B). In the case of Portugal, the value includes all doctors registered with the Portuguese Medical Association (*Ordem dos Médicos*), whether active or not, and according to OECD (2023), about 20% are aged 67 or older. The number of doctors in hospitals is close to that of the euro area, but it is not possible to extract conclusions on the allocation between public and private sectors on the basis of available information. In the case of nurses, the values per inhabitant in Portugal are much lower than those of the euro area but an increasing trend is observed (Panel C).



(A) Hospital beds (B) Doctors (C) Nurses

FIGURE 5: Healthcare physical and human resources in Portugal and the euro area | Per 1000 population

Source: OECD (Health statistics).
Notes: EA is the simple average of euro area countries for which data are available. It excludes: Cyprus and Malta in the case of hospital beds; Cyprus, Latvia, Malta and Slovakia in total doctors; Cyprus, Luxembourg, Malta and Slovakia in hospital doctors; Cyprus and Malta in total nurses, plus Luxembourg and Slovakia in hospital nurses. Total doctors correspond to doctors licensed to practice, with the exception of Austria, France and Slovenia for which the practising doctors definition was used. Total nurses correspond to professionally active nurses, with the exception of Austria, Estonia and Greece for which the practising nurses definition was used. In both cases, euro area averages would be higher if all information was available.

3. Data envelopment analysis (DEA)

DEA is a mathematical technique for the non-parametric estimation of production frontiers using linear programming methods (Charnes *et al.* 1978, Banker *et al.* 1984). DEA derives a linear frontier using the most efficient decision-making units (DMUs), countries in our case. It then assesses each country's performance relative to the frontier, assuming the same production function for all. DEA allows the computation of technical efficiency measures that can be input-oriented or output-oriented. Input-oriented measures determine the extent to which inputs can be reduced without altering output levels, while output-oriented metrics determine the extent to which outputs can be increased without altering input levels. The results of the input/output orientation may vary depending on the assumed production function.[3] Appendix A presents the mathematical formulation of the DEA models used in this study: radial Debreu–Farrell measures of technical efficiency assuming variable returns to scale (VRS), both input-based and output-based.

DEA's attractiveness stems from its ability to benchmark multiple inputs and outputs without requiring the specification of a functional form. It also works with a relatively limited number of observations and allows the derivation of both input-based and output-based metrics. The simplicity of expressing DEA as a linear program contributes to its widespread popularity. Nonetheless, DEA models also have several limitations. Each unit's distance to the frontier is totally accounted as technical inefficiency. Consequently, the results are critically influenced by the composition and size of the sample, the selection of input and output variables, and the presence of outliers, measurement errors and statistical noise. In addition, the inclusion of exogenous factors in the analysis is not straightforward and heavily relies on the choice of variables, often difficult to quantify, as well as on the aggregation and weighting methods. Moreover, when the DEA method is applied to a large number of inputs/outputs relative to the number of DMUs, the count of efficient units is overstated. In summary, it is important to regard DEA estimates not as absolute measures, but rather as relative metrics that rank the performance of various units in terms of overall input or output technical efficiency.

3.1. *Empirical application*

3.1.1. Baseline specification

Our analysis includes the 19 euro area countries at two specific points in time: 2014 and 2019. The selection of these countries is intended to reduce the risk of defining the frontier based on healthcare systems that are not comparable to Portugal. Due to the limited number of observations in our sample, the baseline results are derived using a DEA structure with one input and one output. All the data used in the analysis are obtained from Eurostat, and the DEA calculations are performed using the Stata commands developed by Badunenko and Mozharovskyi (2016).

We use two distinct output variables separately. The first is life expectancy at birth, measured in years. Life expectancy has the advantage of being a broad measure of population health that is correlated with other indicators of health status. This variable also tends to have a high level of reliability and international comparability. The second is healthy life expectancy at birth, which combines information on mortality and disability and measures the average number of years that an individual is expected to live in a healthy condition.[4] Indicators on healthy life years introduce the concept of the quality of life, by focusing on those years that may be enjoyed by individuals free

3. Input-oriented and output-oriented DEA models give the same results only under constant returns to scale. Under variable returns to scale, both models identify the same set of efficient DMUs, but the scores of inefficient DMUs may be different between the two models.

4. Healthy life expectancy is also called health-adjusted life expectancy (HALE) or disability-free life expectancy (DFLE). Eurostat calculates this indicator using mortality statistics and data on self-perceived

from the limitations of illness or disability. These indicators also monitor health as a productive or economic factor, and an increase in healthy life years is one of the main goals of the EU's health policy.

The main input variable is total health expenditure, measured in PPS per inhabitant and averaged over a 5-year period.[5] This expenditure encompasses both public and private current health spending, excluding any capital investment. To calculate the moving average, the data from the current year and the preceding four years are utilised. The decision to employ a backward-looking moving average is motivated by several factors. Firstly, it helps smoothing any significant fluctuations that may occur in a particular year, ensuring a more consistent representation. Secondly, it accommodates instances of missing data by considering previous values. Lastly, it acknowledges the fact that health spending impacts health outcomes with a time lag.

The relationship between input and output variables, which forms the basis of the construction of the efficiency frontier, is depicted in Figure 6. The horizontal axis represents per capita health expenditures of the different countries, while the vertical axis displays life expectancy (Panel A) and healthy life expectancy (Panel B). In 2019, Spain, Italy, and France showed the highest life expectancies, whereas Latvia, Lithuania, and Slovakia had the lowest values. However, most countries displayed relatively high levels of life expectancy, surpassing 80 years, and the disparity between the maximum (Spain) and minimum (Latvia) was less than ten years.

In terms of healthy life expectancy, there were larger differences between countries, with a 20-year gap observed between the maximum (Malta) and minimum (Latvia). The top three countries in terms of healthy life expectancy were Malta, Spain, and Ireland, while the bottom three were Latvia, Estonia, and Slovakia. Compared to life expectancy, the indicator of healthy life expectancy typically exhibits greater variability for the same level of expenditure, probably because it is more influenced by factors beyond the direct control of health systems. This cross-country variation in outcomes is sometimes viewed as a sign of potential healthcare inefficiencies. Regarding per capita health expenditure, the top spenders were Germany, Austria and the Netherlands, while Latvia, Slovakia, Estonia were the countries that spent the least.

In Portugal, life expectancy at birth was about 82 years in 2019, while healthy life expectancy was nearly 60 years. Yet, these levels are lower than those of more than half of the other euro area countries, with Portugal ranking 12th in the first health outcome and 13th in the second. The ranking of Portugal on the input side is very similar: Portugal has below average total health spending per capita, ranking also 12th in terms of expenditure.

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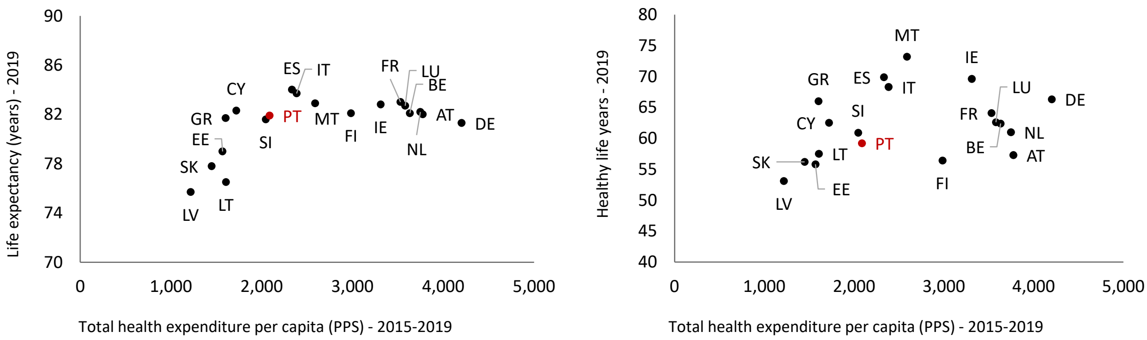
long-standing activity limitations. Mortality data come from Eurostat's demographic database, while self-perceived activity limitations data come from the health module integrated within the EU statistics on income and living conditions (EU-SILC). Following the Sullivan's method, the prevalence of disability at each age is used to divide the hypothetical years of life of people at different ages into years with and without disability.

5. As the main input variable is expenditure, potential differences in the cost of production factors are not considered in the analysis. Due to the lack of comparable data on physical inputs for all euro area countries, the separation of quantity and price effects is not possible.

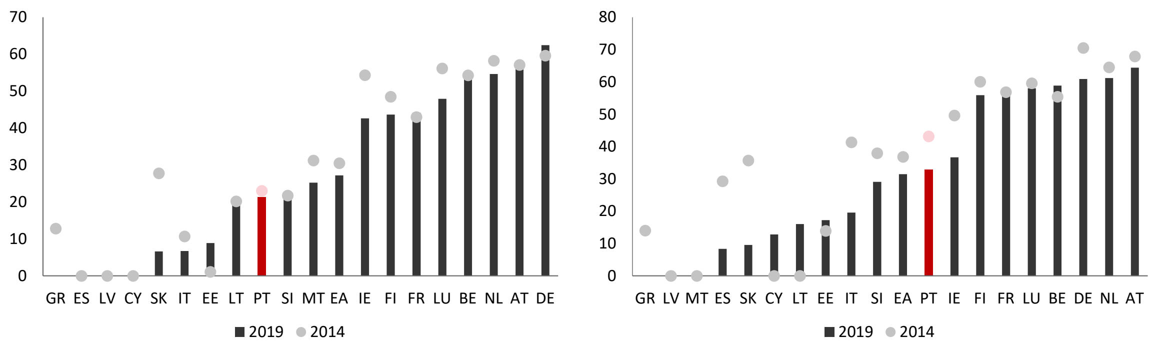


(A) Life expectancy at birth (B) Healthy life expectancy at birth

FIGURE 6: Life expectancy and health expenditure

Source: Eurostat.
Notes: The indicator of healthy life expectancy measures the number of years in good health that a person is expected to live. The indicator is also called disability-free life expectancy (DFLE) or health-adjusted life expectancy (HALE). It is a composite indicator calculated following the Sullivan's method. The method is mainly based in two pieces of information: a life table that enables the calculation of the life expectancy for each age; information on the prevalence of population in healthy or unhealthy conditions. The latter is used to divide the hypothetical years of life of people at different ages into years with and without disability.

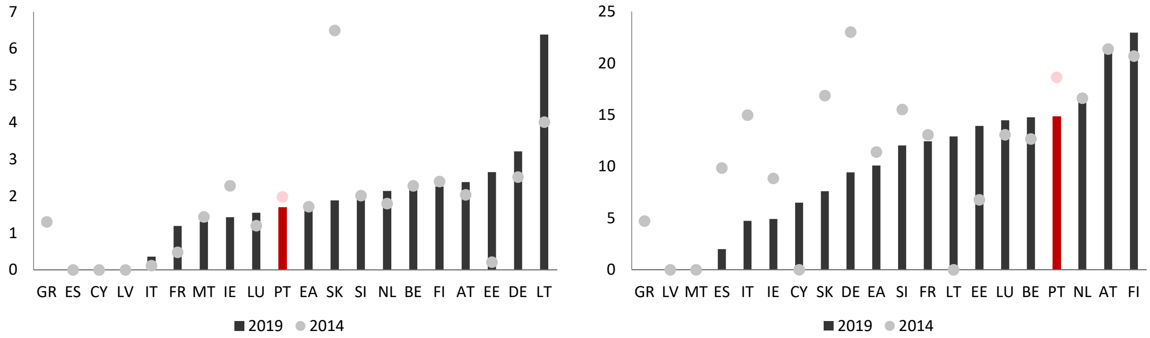
Figures 7 and 8 plot the potential health efficiency gains estimated by DEA in 2014 and 2019, using input-oriented or output-oriented models, respectively. The detailed efficiency scores are included in Appendix B. The results reveal important cross-country differences, as well as much higher inefficiency levels in input-oriented than in output-oriented models. Moreover, the efficiency scores for life expectancy also tend to be greater than those for healthy life expectancy, especially in output-oriented models. Overall, the striking feature relates to the potential reduction in total health expenditure, as more than half of the countries could achieve the same outcome while cutting their expenditure by at least 20%.



(A) Life expectancy as output (B) Healthy life expectancy as output

FIGURE 7: Input inefficiency – Potential reduction in total health expenditure, in %

Notes: DEA models with 1 input-1 output. The inefficiency of each country is measured as its distance to the technical efficiency frontier. In input-oriented models, this distance is measured in terms of inputs as the % decrease in input if the country moved to the frontier while maintaining its level of output. The countries in the x-axis are in ascending order of their inefficiency scores in 2019. A value of zero indicates that the country is in the efficiency frontier in that specific year.



(A) Life expectancy as output

(B) Healthy life expectancy as output

FIGURE 8: Output inefficiency – Potential increase in life expectancy, in %

Notes: DEA models with 1 input-1 output. The inefficiency of each country is measured as its distance to the technical efficiency frontier. In output-oriented models, this distance is measured in terms of outputs as the % increase in output if the country moved to the frontier while maintaining its level of input. The countries in the x-axis are in ascending order of their inefficiency scores in 2019. A value of zero indicates that the country is in the efficiency frontier in that specific year.

Starting with the average of the 19 euro area countries in 2019, health expenditure could decline by 27.2% by adopting the most efficient practices, while keeping the same life expectancy. However, the potential for similar improvements in terms of output is much smaller. Moving towards the efficiency frontier would result in a 1.7% increase in life expectancy at birth or an additional 1.4 years. This difference can be explained by the fact that many of these countries already have high levels of life expectancy, leaving less room for further enhancements. Considering healthy life expectancy as the outcome, input-oriented models suggest a potential gain of 31.5% in the euro area average, while output-oriented models indicate a 10.1% increase (equivalent to 6.1 years). The greater potential gains in healthy life expectancy align with the wider differences observed among countries in this variable.

Greece and Latvia are the two countries at the efficiency frontier in all four DEA models in 2019. The case of Latvia is a good example of how the evaluation of efficiency operates in DEA models, illustrating that efficient countries are not required to have the best output indicators: Latvia has the lowest levels of both input and output. In the case of Greece, the country has one the lowest levels of expenditure and ranks relatively well in terms of life expectancies. Countries like Spain, Cyprus and Malta are also estimated as efficient in more than one model: Spain and Cyprus in models that use life expectancy as output, and Malta in models that use healthy life expectancy as output.

Germany, the Netherlands, Austria and Belgium appear consistently among the worst performers in 2019, which reflects the fact that they are among the highest spenders but reach only average levels of health outcomes. In output-oriented models, Germany ranks much better in terms of healthy life expectancy than in terms of life expectancy, while the opposite occurs for the Netherlands. The results of these countries are particularly notable as regards input-efficiency: they could, in theory, achieve the same life expectancies by cutting their expenditure by more than 50%. Even if the magnitude of these potential gains appears excessive, it is not uncommon in this literature: for instance, Dutu and Sicari (2020) obtain comparable values for these countries and even higher for the USA. However, it should be emphasised that these estimates should not be taken at face value, but rather only as a ranking of how countries perform in terms of health spending efficiency.

Looking at the changes in efficiency from 2014 to 2019 in the four models considered, around half of the countries were able to improve their efficiency scores over this period. In general, there were more countries recording gains in terms of input efficiency than in output efficiency. Only two countries (Greece and Slovakia) managed to reduce health spending, which translated into substantial efficiency gains for them. The decrease in health expenditure was crucial in Greece's ability to move to the frontier of all DEA models in 2019, given its small change in health outcomes. Slovakia also shows efficiency gains in all models from 2014 to 2019, but never reaches the frontier. On the contrary, Cyprus and Latvia are in efficient frontier in DEA models with healthy life expectancy in 2014 but not in 2019: the rise in expenditure was accompanied by a reduction in this output variable. Other countries like Germany, Italy and Spain evince important output efficiency gains related to the strong rise in their healthy life expectancy from 2014 to 2019.

Portugal was one of the four countries, along with Greece, Slovakia and Ireland, which registered an increase in efficiency in the four models from 2014 to 2019. Nevertheless, the country still ranks in the middle of the range and has the potential for significant improvements through enhanced efficiency. Similar to other countries, the estimated gains are more substantial in the input dimension, implying that Portugal could potentially save up to 21.4% of its health expenditure while preserving life expectancy if it fully utilises the efficiency gains of frontier countries. If healthy life expectancy is considered as the output, the potential gains rise to 33%. Regarding output efficiency in 2019, Portugal could increase its life expectancy by 1.7% (1.4 years, from 81.9 years to 83.3 years) or its healthy life expectancy by 14.9% (8.8 years, from 59.2 years to 68 years) by maintaining its health expenditure constant but using it more efficiently.

3.1.2. An extension with socioeconomic and life-style variables

As discussed in the literature, countries' life expectancies depends also on socioeconomic and life-style factors that do not have a direct link with health spending and are, at least in the short to medium term, beyond the control of governments. To capture these country-specific environmental aspects, we complement the previous DEA models with a composite input index of these factors. The composite indicator for 2014 includes the following six variables: real GDP per capita, chain linked volumes (2010 euros); educational attainment, as the share of the population aged 15-64 who has successfully completed tertiary studies; body mass index (BMI), as the share of population that is normal-weighted; smoking prevalence, as the share of population that is non-smoker; daily consumption of fruit and vegetables, as the share of population that consumes at least one portion per day; physical activity, as the share of population performing aerobic and muscle-strengthening activities.[6]

Prior to aggregation, all individual variables were standardised, given their very distinct scales, and then rescaled to obey the restriction of non-negativity of inputs in DEA models.[7] Due to the very small size of our sample, the options for combining the six individual variables into a single measure are limited. Hence, we resorted to a very simple method, the equal-weighting method, in which every variable is given the same weight.[8]

The box plots in Figure 9 depict the distributions of the different variables that constitute the composite indicator, as well as Portugal's relative position in each distribution. Portugal has relatively low values for the variables representing real income per capita and physical activity of the population, standing in the 25th percentile. Adult educational attainment is the variable in which Portugal performs the worst in comparison to the other euro area countries, with the fourth lowest value. On the contrary, Portugal has the second highest proportion of non-smokers and of people who daily eat fruit and vegetables. The share of the Portuguese population that is normal-weighted is around the median of these countries. The composite indicator, which is the simple average of these six variables, has a lower dispersion than its components, as indicated by the smaller size of its central box. Portugal has a value of the composite indicator equal to the median (and to the average) of euro area countries.

Due to data availability, all components of the composite indicator refer to 2014 and the 2 inputs–1 output DEA structure is exclusively computed for 2019, i.e., the life expectancies used as outcomes refer to 2019 and the 5-year average health expenditure variable refers to 2015-2019 as before. Given that we now have two inputs, we also estimated a distinct set of input-oriented frontiers using a non-radial measure of technical efficiency, the Russel measure introduced by Färe and Lovell (1978), to allow for a non-proportional change in inputs. The correlation between the radial and non-radial efficiency measures is greater than 97%. Thus, to maintain comparability with the previous models, we only display the traditional radial measures of efficiency in Figure 10. The detailed results of radial and non-radial measures are included in Appendix B.

The efficiency scores derived from the 2 inputs-1 output DEA models are either equal to or greater than those obtained from the 1 input-1 output models, suggesting some relevance in considering non-discretionary inputs when assessing health efficiency across countries. However, the overall assessment of how euro area countries' health

6. Data on physical activity for Belgium and the Netherlands refer to 2019, as there was no information for 2014 for these countries.

7. The rescale of each standardised variable was done by adding the absolute value of its minimum plus one.

8. As robustness, we also tried two other simple aggregation methods: the rank-sum method (where countries are sorted within each variable, ranks are computed, and then all ranks for each country are summed) and the median-weighting method (where each variable is weighted by its standardised and rescaled median). The linear correlation between the various composite indexes is always above 97%, and the same occurs with the resulting DEA efficiency scores obtained with the three aggregation alternatives.

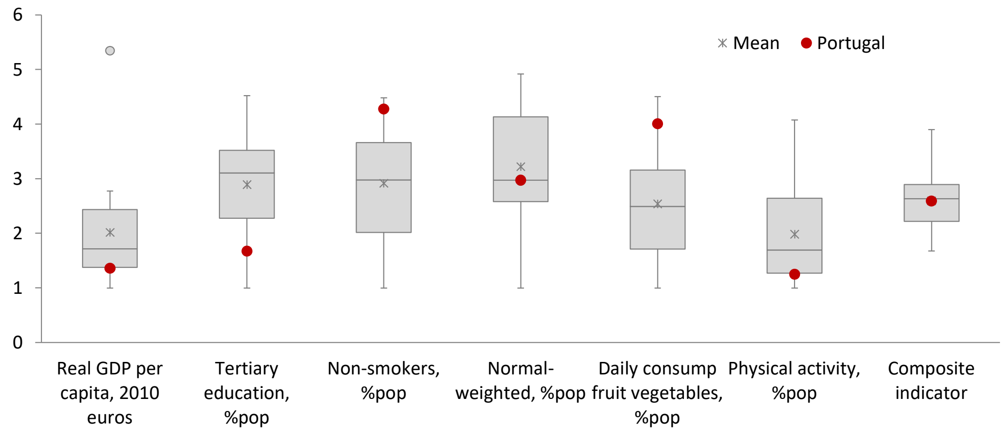


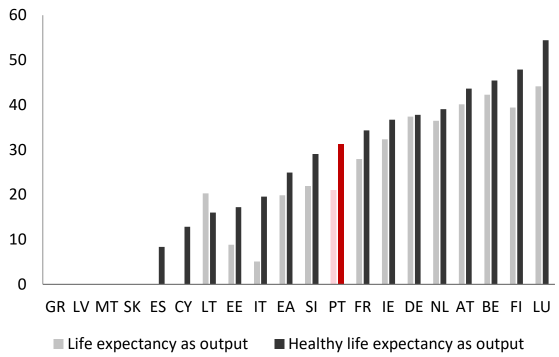
FIGURE 9: Composite indicator – distribution of the socioeconomic and life-style variables, 2014

Notes: Data on physical activity for Belgium and the Netherlands refer to 2019. Individual variables were standardised and rescaled so that all observations are stricly positive. The composite indicator is computed as the simple average of the six individual variables. In each box plot, the central box shows the values from the 25th percentile to the 75th percentile (interquartile range) and the horizontal line corresponds to the median of the distribution (50th percentile). The box plot of the variable real GDP per capita includes one outlier (Luxembourg), with a value higher than the sum of the 75th percentile and 1.5 times the interquartile range.

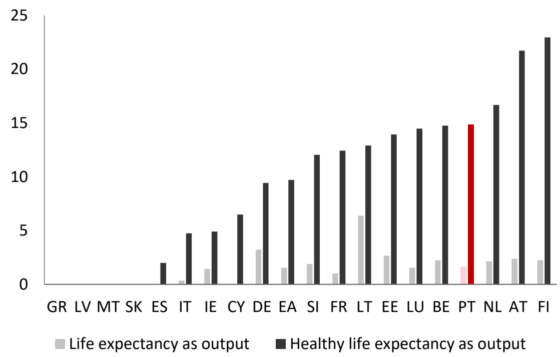
systems perform remains largely unchanged with the inclusion of the composite index. While there may be some variations in country positions, the rankings remain consistent between the two types of DEA models. The DEA estimates consistently highlight significant disparities among countries in terms of efficiency, with much greater potential gains achievable in input efficiency compared to output efficiency. Furthermore, the estimated potential efficiency gains are more substantial for healthy life expectancy than for life expectancy, particularly in output-based structures.

Four countries are found to be efficient in all 2 inputs-1 output models: Greece and Latvia, as previously, and Malta and Slovakia. One of the main changes in individual rankings when comparing the results of the two types of model refers to Slovakia, which was never in the technical efficiency frontier in the previous models. In terms of potential efficiency gains for the euro area average, input inefficiency is 19.9% when using life expectancy as the relevant output and 24.9% with healthy life expectancy. Output inefficiency scores are much smaller: 1.5% for life expectancy and 9.7% for healthy life expectancy.

In DEA models with 2 inputs-1 output, Portugal consistently performs marginally worse than the average of the euro area. The difference in terms of ranking, relative to the euro area, is larger in output-oriented models with healthy life expectancy. Potential estimated gains in health outcomes in Portugal reach 14.9% for healthy life expectancy and 1.7% for life expectancy, the same values obtained with 1 input-1 output models. Regarding input inefficiency, the scores of Portugal are 31.3% and 21%, respectively, using healthy life expectancy or life expectancy as the relevant outcome.



(A) Input inefficiency in 2019



(B) Output inefficiency in 2019

FIGURE 10: Inefficiency scores in % – DEA models with 2 inputs-1 output

Notes: DEA models with 2 inputs-1 output in 2019. The two inputs are total per capita health expenditure in PPS (average of the 2015-2019 period) and a composite index of non-discretionary inputs in 2014, which captures the effect of socioeconomic and life-style factors. The inefficiency of each country is measured as its distance to the technical efficiency frontier. In input-oriented models, this distance is measured in terms of inputs as the % decrease in inputs if the country moved to the frontier while maintaining its level of output. In output-oriented models, this distance is measured in terms of outputs as the % increase in output if the country moved to the frontier while maintaining its level of inputs. The countries in the x-axis are in ascending order of their inefficiency scores obtained using healthy life expectancy as output. A value of zero indicates that the country is in the efficiency frontier.

4. Concluding remarks

Portugal has made significant progress in enhancing its healthcare system over the last two decades by implementing organisational restructuring and enacting several reforms. These reforms aimed to introduce private sector practices, foster integrated and patient-centred care, and promote the use of digital health tools. Despite these efforts, concerns persist regarding the adequacy of health expenditure in the country.

From a macro perspective, Portugal's healthcare spending falls below the euro area average, and it possesses fewer physical and human resources per capita. While health expenditure as a percentage of GDP has remained relatively stable in recent years, there has been a significant decline in the public component since 2009. Public funding constitutes around 60% of total health spending in Portugal, in contrast to the 70% observed in the early 2000s, and it is lower than the 80% seen in the euro area in 2019.

To assess the effectiveness of resources and reforms on the actual health status of the Portuguese population, it is essential to use an appropriate methodology. This study examines the efficiency of health systems in euro area countries by employing input-oriented and output-oriented DEA models. By using DEA, our analysis focuses solely on measuring technical efficiency in production. This refers to the health system's capability to achieve the highest output with a given input set or to achieve a specific level of output using the minimum input set. Implicitly, it is assumed that the healthcare systems of the euro area countries share comparable structural features, along with similar population health-related needs. Regarding results, DEA estimates are highly sensitive to the selection of samples and indicators used. Therefore, instead of accepting

DEA scores at face value, they should be regarded as relative metrics that rank countries based on their overall health efficiency performance.

The findings in this study are consistent with previous empirical research. Technical efficiency varies substantially across health systems of euro area countries. Results derived from DEA suggest that there might be significant scope to increase efficiency across the euro area. Estimated potential efficiency gains are typically much larger in the input dimension that in the output dimension. In fact, the most remarkable aspect of these DEA estimates is the potential for reduction in total health expenditure, which could reach at least 20% for the euro area average. For around half of the countries, including Portugal, there was an improvement in efficiency from 2014 to 2019. Portugal's rankings generally place it in an intermediate position among euro area countries.

While DEA is a valuable tool for examining technical efficiency, it should be complemented with other studies that consider the broader aspects of healthcare system performance, such as the quality of treatment and equity in provision, as well as an analysis of the supply of health services by both the public and private sectors. While a macro analysis, like the one conducted in this study, provides a comprehensive understanding of the system's structure and functioning, policy recommendations for improving overall health system performance should also be informed by micro-level analysis. These are areas to be explored in future research.

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Appendix A: DEA analytical framework

In this study, efficiency is evaluated by the radial Debreu–Farrell measures of technical efficiency, output-oriented and input-oriented. The mathematical description of the linear programming problems to be solved assuming variable returns to scale (VRS) are presented below.

For the output-oriented radial DEA model, the objective function for a given DMU h is:

$$\max_{\lambda,\theta} \theta^{out}, \tag{A.1}$$

subject to:

$$\theta^{out} y_{hj} \leq \sum_{k=1}^{K} \lambda_k y_{kj}, \quad j = 1, 2, \ldots, N$$

$$x_{hi} \geq \sum_{k=1}^{K} \lambda_k x_{ki}, \quad i = 1, 2, \ldots, M$$

$$\lambda_k \geq 0, \quad k = 1, 2, \ldots, K$$

$$\sum_{k=1}^{K} \lambda_k = 1 \qquad ,$$

where M is the number of inputs, N is the number of outputs, K is the number of DMUs. y is a KxN matrix of available data on outputs, so y_{kj} is the amount of output j produced by DMU k; x is a K×M matrix of available data on inputs, so x_{ki} is the amount of input i used by DMU k. λ_k are the weights associated to each DMU k. The last constraint that these weights add up to 1 ensures a VRS model (Banker *et al.* 1984).

The objective here is to find, for each DMU k $(k = 1, 2, h, \ldots, K)$, a linear combination of the other units that increases in proportional or radial terms the production of the

N outputs to the highest possible value given the consumption of the M inputs. The inverse of the maximised factor, i.e., $1/\theta^{out}$, is the technical output-efficiency score that ranges from 0 (fully inefficient) to 1 (fully efficient). The linear programming in Equation (A.1) has to be solved for each of the K DMUs, countries in our case, in order to obtain K efficiency scores.

In input-oriented DEA models, the objective is to find, for each DMU k $(k = 1, 2, h, \ldots, K)$, a linear combination of the other units that reduces in proportional or radial terms the consumption of the M inputs for the least possible value given the production of the N outputs. The input-oriented efficiency score of DMU h can be represented mathematically as:

$$\min_{\lambda,\theta} \theta^{in}, \tag{A.2}$$

subject to:

$$\begin{aligned} \theta^{in} x_{hi} &\geq \sum_{k=1}^{K} \lambda_k x_{ki}, \quad i = 1, 2, \ldots, M \\ y_{hj} &\leq \sum_{k=1}^{K} \lambda_k y_{kj}, \quad j = 1, 2, \ldots, N \\ \lambda_k &\geq 0, \quad k = 1, 2, \ldots, K \\ \sum_{k=1}^{K} \lambda_k &= 1 \qquad , \end{aligned}$$

with all variables defined as above and solved with an analogous linear programming process. The minimised objective function θ^{in} is the input-efficiency score of DMU h that ranges from 0 (fully inefficient) to 1 (fully efficient).

The inefficiency of each DMU is measured as its distance to the frontier. This distance can be measured in terms of inputs (% decrease in inputs for the same level of outputs) or of outputs (% increase in outputs for the given inputs). That is, the level of inefficiency of each DMU is $1 - \theta^{in}$ in the input-oriented model and $1 - 1/\theta^{out}$ in the output-oriented case.

For data point (x_k, y_k), output-oriented radial measure expands all N outputs $y_k = (y_{k1}, ..., y_{kN})$ proportionally until the frontier is reached. The input-oriented radial measure shrinks all M inputs $x_k = (x_{k1}, ..., x_{kM})$ proportionally until the frontier is reached. In a multidimensional case, the required distance is the radial path from a data point that is parallel to axes along which all outputs (inputs) are measured. At the reached frontier point, some but not all outputs (inputs) could still be expanded (shrunk) while remaining feasible. If such possibility exists for a given unit k, then the reference point is said to have slack in output (input). A non-radial measure of technical efficiency, the Russell measure (Färe and Lovell 1978), accommodates such slacks by allowing for non-proportional expansions (reductions) in each output (input). With just one output (input), the output-based (input-based) non-radial measure is equal to the Debreu–Farrell radial measure of technical efficiency.

Appendix B: DEA detailed results

		2014				2019			
		Input-oriented		Output-oriented		Input-oriented		Output-oriented	
		LE	HALE	LE	HALE	LE	HALE	LE	HALE
Belgium	BE	0.457	0.446	0.977	0.873	0.463	0.412	0.977	0.852
Germany	DE	0.403	0.295	0.975	0.770	0.375	0.391	0.968	0.906
Estonia	EE	0.989	0.861	0.998	0.932	0.911	0.828	0.973	0.861
Ireland	IE	0.456	0.503	0.977	0.911	0.574	0.633	0.986	0.951
Greece	GR	0.872	0.860	0.987	0.953	1	1	1	1
Spain	ES	1	0.707	1	0.901	1	0.916	1	0.980
France	FR	0.570	0.431	0.995	0.869	0.559	0.438	0.988	0.876
Italy	IT	0.893	0.587	0.999	0.850	0.933	0.805	0.996	0.953
Cyprus	CY	1	1	1	1	1	0.872	1	0.935
Latvia	LV	1	1	1	1	1	1	1	1
Lithuania	LT	0.798	1	0.960	1	0.790	0.840	0.936	0.871
Luxembourg	LU	0.438	0.404	0.988	0.869	0.520	0.419	0.985	0.855
Malta	MT	0.687	1	0.986	1	0.748	1	0.987	1
Netherlands	NL	0.417	0.355	0.982	0.834	0.454	0.388	0.979	0.833
Austria	AT	0.429	0.321	0.980	0.786	0.440	0.356	0.976	0.783
Portugal	PT	0.770	0.568	0.980	0.814	0.786	0.670	0.983	0.851
Slovenia	SI	0.782	0.620	0.980	0.845	0.781	0.709	0.981	0.880
Slovakia	SK	0.722	0.643	0.935	0.831	0.934	0.904	0.981	0.924
Finland	FI	0.515	0.399	0.976	0.793	0.563	0.441	0.977	0.770
Average	EA	0.695	0.632	0.983	0.886	0.728	0.685	0.983	0.899
Median		0.722	0.587	0.982	0.869	0.781	0.709	0.983	0.880

TABLE B.1. DEA radial efficiency measures, 1 input-1 output models, 2014 and 2019

Notes: LE denotes life expectancy and HALE denotes health-adjusted life expectancy. The DEA specifications use either current year LE or HALE as output and total health expenditure in per capita PPS as input (average of the last 5 years). All DEA models were estimated under the assumption of variable returns to scale (VRS) and the efficiency scores refer to radial efficiency.

		Non-radial measures				Radial measures			
		Input-oriented		Output-oriented		Input-oriented		Output-oriented	
		LE	HALE	LE	HALE	LE	HALE	LE	HALE
Belgium	BE	0.558	0.497	0.977	0.852	0.577	0.546	0.977	0.852
Germany	DE	0.518	0.528	0.968	0.906	0.626	0.622	0.968	0.906
Estonia	EE	0.862	0.812	0.973	0.861	0.911	0.828	0.973	0.861
Ireland	IE	0.676	0.620	0.986	0.951	0.676	0.633	0.986	0.951
Greece	GR	1	1	1	1	1	1	1	1
Spain	ES	1	0.789	1	0.980	1	0.916	1	0.980
France	FR	0.720	0.570	0.990	0.876	0.721	0.657	0.990	0.876
Italy	IT	0.948	0.737	0.996	0.953	0.950	0.805	0.996	0.953
Cyprus	CY	0.932	0.795	1	0.935	1	0.872	1	0.935
Latvia	LV	1	1	1	1	1	1	1	1
Lithuania	LT	0.797	0.827	0.936	0.871	0.797	0.840	0.936	0.871
Luxembourg	LU	0.556	0.445	0.985	0.855	0.559	0.456	0.985	0.855
Malta	MT	1	1	1	1	1	1	1	1
Netherlands	NL	0.596	0.519	0.979	0.833	0.635	0.609	0.979	0.833
Austria	AT	0.554	0.478	0.976	0.783	0.598	0.563	0.976	0.783
Portugal	PT	0.774	0.684	0.983	0.851	0.790	0.687	0.983	0.851
Slovenia	SI	0.746	0.702	0.981	0.880	0.781	0.709	0.981	0.880
Slovakia	SK	1	0.984	1	1	1	1	1	1
Finland	FI	0.603	0.498	0.977	0.770	0.606	0.521	0.977	0.770
Average	EA	0.781	0.710	0.985	0.903	0.801	0.751	0.985	0.903
Median		0.774	0.702	0.985	0.880	0.790	0.709	0.985	0.880

TABLE B.2. DEA radial and non-radial efficiency measures, 2 inputs-1 output models, 2019

Notes: LE denotes life expectancy and HALE denotes health-adjusted life expectancy. The DEA specifications use either LE or HALE as output. The two inputs are total health expenditure in per capita PPS as input (average of the period 2015-2019) and a composite index of socioeconomic and life-style factors in 2014. All DEA models were estimated under the assumption of variable returns to scale (VRS).

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