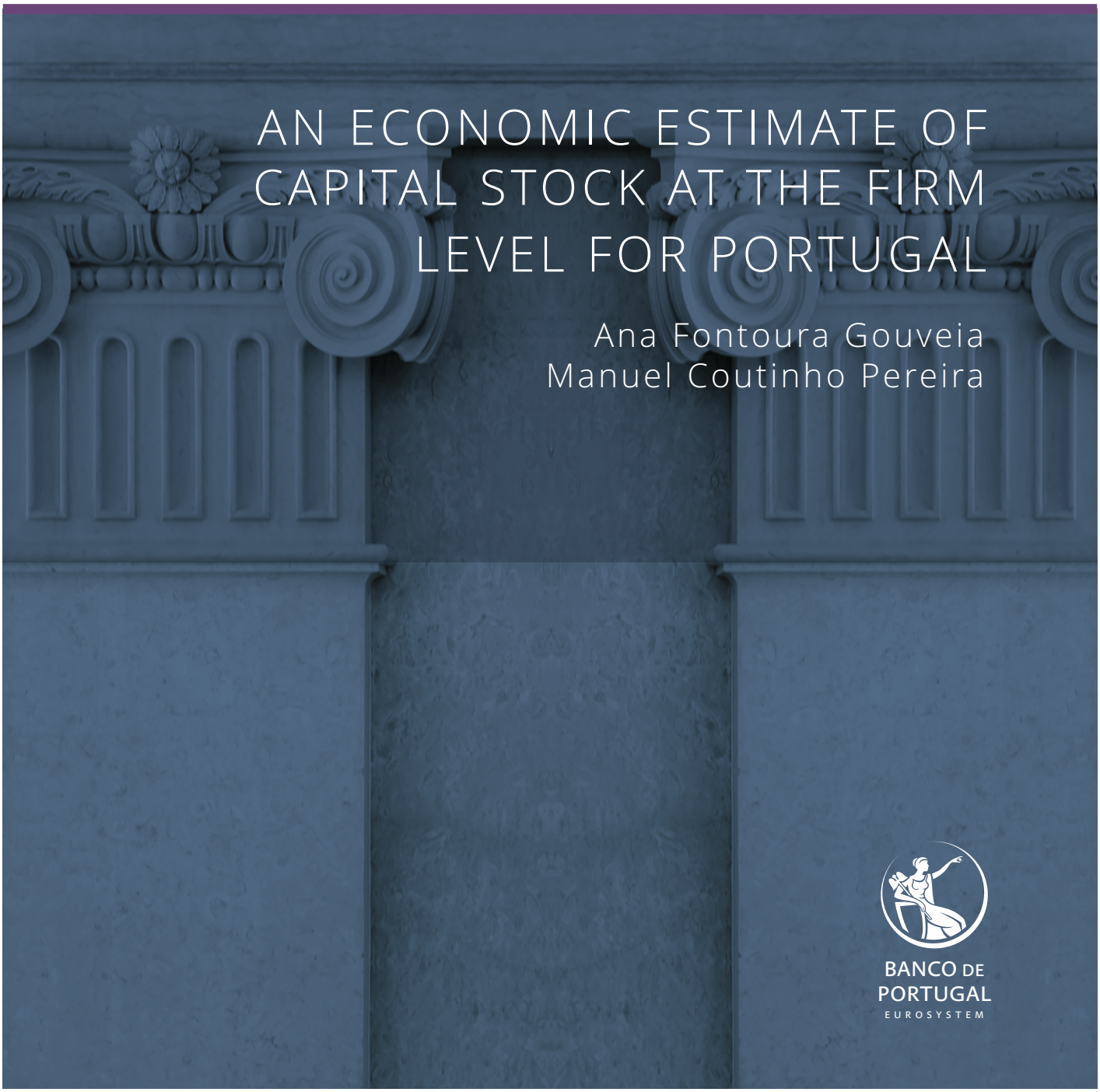
04

OCCASIONAL PAPERS 2022

AN ECONOMIC ESTIMATE OF CAPITAL STOCK AT THE FIRM LEVEL FOR PORTUGAL

Ana Fontoura Gouveia
Manuel Coutinho Pereira



BANCO DE PORTUGAL
EUROSYSTEM

04

OCCASIONAL PAPERS 2022

AN ECONOMIC ESTIMATE OF CAPITAL STOCK AT THE FIRM LEVEL FOR PORTUGAL

Ana Fontoura Gouveia | Manuel Coutinho Pereira

SEPTEMBER 2022

Please address correspondence to
Banco de Portugal
Rua do Comércio 148, 1100-150 Lisboa, Portugal
Tel.: +351 213 130 000, email: info@bportugal.pt

BANCO DE PORTUGAL
EUROSYSTEM

Lisboa, 2022 • www.bportugal.pt

Occasional Papers | Lisboa 2022 • **Banco de Portugal** Rua do Comércio, 148 | 1100-150 Lisboa • www.bportugal.pt •
Edition Banco de Portugal • **ISBN (online)** 978-989-678-838-4 • **ISSN (online)** 2182-1798

An economic estimate of capital stock at the firm level for Portugal

Ana Fontoura Gouveia
Banco de Portugal
Nova SBE

Manuel Coutinho Pereira
Banco de Portugal

September 2022

Abstract
In this paper, we propose a methodology to compute series for the tangible capital stock of Portuguese firms along with consistent flows in the period 2006-2020. We benefit from the richness of the accounting data at the micro level, which encompass detailed information about flows and stocks by asset category, making use of a modified version of the *Perpetual Inventory Method* to take into account the specificities of the data. In particular, given the change in the accounting standards in 2010 with the switchover from POC to SNC, we develop a strategy to overcome this break in the balance sheet data. We conclude with a comparison of our derived measure with the accounting series, and provide a brief overview of the evolution of capital stocks and flows of Portuguese firms over the period covered.

Keywords: capital stock, tangible assets, investment, firm-level data.

Acknowledgements: Ana Fontoura Gouveia worked on this project up to November 2019, when she entered on leave from Banco de Portugal. The authors are thankful to Idílio Freire (Statistics Portugal), Carlos Robalo Marques (formerly Research and Economics Department - Banco de Portugal), Fábio Albuquerque (formerly Statistics Department - Banco de Portugal), Adelaide Araújo and Carla Ferreira (Statistics Department - Banco de Portugal) for helpful discussions, the BPlim team for swift access to the data and Nuno Alves and João Amador for valuable comments. The opinions expressed in the article are those of the authors and do not necessarily coincide with those of Banco de Portugal or the Eurosystem.

E-mail: mpereira@bportugal.pt; corresponding author.

The measurement of capital is one of the nastiest jobs that economists have set to statisticians.

Hicks, Wealth and Welfare: Collected Essays in Economic Theory

1. Introduction

Micro-level research on the evolution of productive capital stock is of critical relevance to understand long-term economic dynamics within a country and its future growth prospects. Indeed, availability of firm-level data extends considerably the analytical methods that can be employed and allows to shed light on the considerable heterogeneity that hides behind aggregate developments. This paper develops a methodology to derive capital stock and investment series for the Portuguese firms from accounting data. We compile series by asset category from 2006 to 2020, using asset-specific economic depreciation rates and deflators. The availability of asset-type breakdowns of capital is important in order to better understand firms' production functions and gain additional insights into the evolution of productive capital. So far this project has encompassed tangible assets. The treatment of intangible assets poses specific issues in terms of measurement, valuation and coverage (see, for instance, Crouzet *et al.* 2022), which are left to future work.

Developing a firm-level measure of fixed capital stock from accounting data is a challenging task. A key issue is that balance sheet stocks depend on tax depreciation rates that do not necessarily reflect the economic use of the good. As long as there are differences between the two types of depreciation - which is actually the case - the accounting stocks will not be a good measure of the economic capital stock. The approach here followed, the *Perpetual Inventory Method* (PIM), borrowed from national accounts and commonly used by statistical agencies, but also employed in micro-level research (see, for instance, Gilhooly 2009,Ylmaz and Kiliç 2021 and Gal 2013), overcomes the issue by cumulating investment and other flows, corrected by a measure of economic depreciation. The starting point of the method, whenever the creation of firms is not observed, is an estimate of the initial capital. The application of the PIM, including the estimation of an initial value for capital, requires that a number of assumptions are made, particularly as regards the valuation of assets in the accounting statements and depreciation methods. The economic capital series here computed should be regarded as *conditional* on such assumptions, notwithstanding the robustness exercises carried out.

The period covered by this work is marked by the adoption of the new Accounting Standards System in 2010, leading to the switchover from the *Plano Oficial de Contas* (POC) to the *Sistema de Normalização Contabilística* (SNC). This change in accounting standards, while improving the quality of the reported information, harms comparability over time and jeopardises the economic reading

of the capital series directly taken from balance sheets. We implemented various corrections to cope with such a break. Nevertheless, for the sectors most affected by it, namely utilities, construction and transports, it has not been possible to fully harmonize the series. The whole exercise benefited from availability of detailed accounting information on capital inflows (additions and positive changes in volume) and outflows (sales and negative changes in volume). In particular, this made it possible to correct outflows, to harmonise their measurement in the SNC and POC periods. Many applications of the PIM are not able to implement this sort of corrections, as individual data on accounting additions, sales and other changes in volume are often lacking.

The paper is organized as follows. Sections 2 and 3 introduce the accounting series, depreciation rates and deflators, and deal with sector and firm coverage. Section 4 addresses the methodological break brought about by the change in the accounting standards in 2010. Sections 5 and 6 describe the estimation of the initial capital and negative capital flows to be embedded into the PIM. Section 7 explains the details of the application of the PIM to the framework under analysis. Section 8 compares the economic series with the underlying accounting data. Finally, section 9 outlines future work that could complement the approach developed in this paper.

2. Accounting data, sector and firm coverage

The series of capital stocks and flows developed in this paper are based on detailed firm-level accounting data for Portugal from 2006 to 2020, reported in the so-called *Informação Empresarial Simplificada* (IES), and made available by BPLIM, the microdata lab of Banco de Portugal.[1] We took from the accounting statements the gross and net beginning-of-period stocks and net end-of-period stocks. Moreover, we created flow variables from detailed accounting flow data. Specifically additions to the capital stock have been obtained as the sum of acquisitions in first-hand and own work, and sales of assets as the sum of actual sales and transfers to assets held for sale. Changes in volume (i.e. changes affecting the quantity of the asset that are not economic transactions) include in particular transfers between work in progress and other categories and write-offs. As we shall see, accounting stocks are not directly embedded into the PIM, but instead used especially to estimate the initial capital stocks. Positive accounting flows generally go directly into the PIM, while negative flows are used to compute their economic counterparts which then

1. Specifically we take the detailed information on tangible fixed assets by category appearing on Table 0510 (*Nota 10 ao Anexo ao Balanço e Demostração de Resultados*) for the years up to 2009 and Table 05081-A from 2010 onwards, due to the change in accounting standards. The exact series and calculations thus differ for these two periods.

are the input for the method.

The exercise covers non-financial corporations producing goods and market services. This has led to the exclusion of firms in CAE codes K (financial services) and O to U (comprising mainly public administration, education and health services). Firms in real estate sector have been similarly excluded, given the specificities of the capital stock they hold, as well as holding firms and those operating in the free zone of Madeira. Note that the coverage of some market sectors, particularly agriculture, is limited in IES.

Given that the PIM relies on the cumulation of flows - investment and changes in volume - it is necessary that firms report data for all periods in which they were active. In the dataset after sector exclusions, 97% of firms fulfil this condition i.e. they do not have any reporting gaps. For the remaining firms, one drops (i) those with more than one break in the reporting (0.2% of total); and (ii) those with only one break but with two or more consecutive years missing (1% of total). For the remaining firms (1.7% of total), new observations completing the spells have been imputed using general procedures for missing imputation (shortly described). The exercise covers 617,029 firms.

While there are missing observations in the accounting data, after running control checks on them, one realises that such missings correspond mostly to zeros i.e. firms do not report instead of reporting zero. Moreover, the distribution of capital variables has a great deal of zeros anyway, not displaying stable time patterns. This reflects in particular the spiky nature of investment, which is even more marked for the other flow variables. Therefore, missing accounting flow data have been assumed to be zeros. In contrast, gaps in stocks have been interpolated, but only if the firm had a positive stock before and after the year missing; otherwise such gaps have been also assumed to be zeros.[2]

3. Asset categories, depreciation rates and price indices

Fixed assets are broken down in the accounting statements in a similar - though not identical - manner in POC and SNC. For the purpose of computing economic capital we have considered seven asset categories, namely, land, buildings and structures, machinery, transport equipment, other equipment, other assets (including cultivated assets) and work in progress. Table 1 shows the mapping between these categories and the POC and SNC classes, and their importance in

2. The described procedure may give rise to a few inconsistencies between *accounting* flows and stocks, but this is a minor issue for the computation of the economic series, as the accounting stocks and negative flows enter the PIM indirectly.

absolute and relative terms by sector during the SNC period (as for some sectors there are important differences in asset level and composition in SNC vs. POC).

	Land	**Build. Struc.**	**Mach.**	**Trans. equip.**	**Other equip.**	**Other ass.**	**Work prog.**	**Total (abs.)**
SNC category	1	2	3	4	5	6,7	8	
POC category	1	2	3,5,7	4	6	8	9	
Agriculture	0.394	0.225	0.186	0.031	0.003	0.058	0.104	7.3
Mining and quarrying	0.270	0.132	0.459	0.023	0.003	0.013	0.100	1.4
Manufacturing	0.118	0.313	0.410	0.025	0.009	0.027	0.098	31.1
Electricity, gas	0.011	0.063	0.736	0.007	0.006	0.019	0.158	14.8
Water	0.082	0.383	0.422	0.023	0.005	0.011	0.073	3.6
Construction	0.143	0.273	0.403	0.061	0.006	0.014	0.101	12.5
Trade, repair	0.159	0.472	0.168	0.078	0.022	0.042	0.058	19.9
Transport., storage	0.081	0.368	0.381	0.083	0.008	0.018	0.060	8.0
Accomodation, food	0.180	0.534	0.099	0.014	0.007	0.020	0.146	15.8
Information, communic.	0.041	0.165	0.660	0.022	0.040	0.012	0.061	6.9
Scientific, technical serv.	0.062	0.266	0.415	0.069	0.027	0.023	0.138	6.6
Admin., support serv.	0.046	0.164	0.546	0.168	0.016	0.017	0.042	4.9
Total (abs.)	16.8	41.8	50.1	5.9	1.6	3.4	13.3	132.8

Table 1. Weights of asset categories within sectors and totals by asset category and sector (in billion euro)

Notes: Computations based on averages by firm of end-of-period accounting net stocks during the SNC period (2010-2020).

The economic rates of depreciation by asset type - at the two-digit sector level - needed for the implementation of the PIM, have been taken from the EUKLEMS database, and mapped into the categories on Table 1. Table 2 shows the minimum, median and maximum of the actual depreciation rates (which are generally sector-specific) for the firms in the database. The PIM - applied separately by asset type - assumes a geometric depreciation pattern, which is very convenient as depreciation in the current period depends only on the stock of the previous period.

Capital stock is the cumulation of flows incurred in different years, which thus must be inflated or deflated to the prices of a year taken as a reference, prior to the computation of capital. The last year of the period, 2020, has been chosen as the reference. We relied on the annual asset price indices (total industries), by asset

Asset type	EUKLEMS series	Depreciation rates Min	P50	Max
Land	-	0.000	0.000	0.000
Buildings and structures	dpr_OCon	0.024	0.031	0.044
Machinery	dpr_OMach	0.104	0.139	0.144
Transport equipment	dpr_TraEq	0.092	0.195	0.229
Other equipment*	dpr_IT, dpr_CT	0.215	0.215	0.215
Other assets (agriculture)**	dpr_Cult	0.151	0.151	0.151
Other assets (other sectors)**	unavailable	0.100	0.100	0.100
Work in progress	-	0.000	0.000	0.000

Table 2. Depreciation rates

Notes: *The depreciation rate for other equipment is the simple average of EUKLEMS series for computing equipment and communication equipment. **Cultivated assets are part of other assets in the typology here adopted, because - in contrast to SNC - in POC they are not singled out. In EUKLEMS there is a specific rate for cultivated assets, but not for other assets. For firms belonging to the agriculture sector, such EUKLEMS series has been used to depreciate other assets as a whole, given the weight of cultivated assets, while for the firms in the remaining sectors a conventional rate equal to 0.10 has been taken.

category, included in EUKLEMS.[3]

4. Switchover of accounting standards from POC to SNC

As mentioned above, there was an important change in accounting standards during the period covered, with the switchover from POC to SNC in 2009. The methodological break with the largest impact on capital variables was the delimitation of tangible vs. intangible assets (see, for instance, Franco 2010 and Serrenho 2012, for an overview of the impact of SNC adoption on the treatment of fixed assets). The recognition of *acquired* intangible assets in SNC led to a change in the recording of concession contracts. While in POC firms were recording the concession assets as tangible in their balance sheet, they are now recording the exploitation rights as intangibles. Another methodological break impacting fixed assets was the creation in SNC of the item assets held for sale. SNC recommends that firms transfer assets into this item once a decision to sell has been taken and the transaction is likely to happen in the short run. Given that we are interested in the economic substance, such transfers have been accounted for as sales, not as

3. For land and work in progress, given the absence of a specific index, the all-assets price index has been taken. EUKLEMS indices are available up to 2016 only and have been complemented with National Accounts data thereafter. The National Accounts price indices used were those for non-residential buildings, machinery and transport equipment, as well as the overall index.

changes in volume.

Table 3 shows a comparison of stocks of tangible assets at the beginning 2010 (already compiled under SNC) and at the end of 2009 (still compiled under POC), which should approximately coincide absent from methodological changes. The sectors electricity and gas, water and transportation and storage recorded falls around 50%, and construction around 25%, which should mainly relate to the mentioned reclassification of tangible assets as intangible. The remaining sectors were clearly less affected by the switchover, particularly when overall capital is taken (as it appears that some reclassification among asset categories took place in some sectors). The gaps between the two standards could also reflect in particular the implementation in SNC of revaluation procedures to approximate market valuation, but the fact that stocks are close in a number of sectors actually suggests that such revaluation effects may have had less of an importance than one would expect.

	Land	**Build. Struc.**	**Mach.**	**Transp. equip.**	**Other equip.**	**Other assets**	**Work in prog.**	**Total**
Agriculture	0.890	0.989	0.975	1.045	1.115	0.716	0.796	0.917
Mining	1.011	0.983	1.002	1.023	0.997	2.106	0.953	1.003
Manufacturing	1.010	0.998	0.984	1.061	0.968	1.041	0.945	0.991
Electricity, gas	0.806	0.669	0.491	0.906	0.826	1.033	0.899	0.540
Water	0.970	0.478	0.581	0.897	0.772	0.299	0.207	0.497
Construction	0.875	0.634	0.968	1.055	1.025	1.261	0.624	0.768
Trade, repair	0.944	0.978	0.946	1.069	0.960	0.983	0.860	0.968
Transport., storage	0.888	0.469	0.390	0.968	0.876	0.016	0.331	0.436
Accomodation, food	0.965	0.976	0.960	1.038	1.016	0.746	0.891	0.959
Inform., communic.	0.988	1.020	0.944	1.019	0.695	0.951	0.821	0.931
Scientific, techn. serv.	0.783	0.929	0.981	1.032	1.015	1.077	0.969	0.963
Admin., support serv.	0.959	0.967	0.956	0.906	0.933	0.780	0.859	0.945

Table 3. Value of tangible assets at the beginning of 2010 as a fraction of the value at the end of 2009

Note: Includes only firms that were active in the two periods.

Unfortunately we are not in a position to directly correct for the POC-SNC switchover, particularly regarding the treatment of concessions. This would require detailed firm-level data on the items affected by the breaks. Nevertheless, an indirect correction of stocks has been undertaken for the firms reporting both under POC and SNC, by using the SNC figures at the beginning of 2010 as a basis to estimate the PIM initial capital and applying the PIM backwards over the POC period (see Section 7). For the firms reporting solely under POC, however, it is not possible to undertake any correction. Indeed, one could not establish a clear pattern for the firms reporting under the two accounting standards that could be extrapolated to adjust the capital of the firms with activity confined to the POC

period. Moreover, even for the firms active in both periods, investment prior to 2010 on the assets later reclassified, which is based on POC data, will not be fully consistent with a stock estimated on the basis of the SNC level. In Section 7.4 we show that this is likely to have happened precisely for the sectors appearing most affected by the switchover on Table 3. Therefore, analytical work based on our series, particularly of a descriptive nature, should rely on the entire time-span only for the less affected sectors; for the most affected ones - electricity and gas, water, construction and transportation and storage - it should start in 2010.

	Number of firms	**Accounting net stock**						
		Land	**Build.**	**Mach.**	**Transp. equip.**	**Other equip.**	**Other assets**	**Assets in prog.**
				period 2006-2009				
Firms rep. POC only	0.214	0.046	0.053	0.063	0.094	0.108	0.080	0.053
Firms rep. POC-SNC	0.786	0.954	0.947	0.937	0.906	0.892	0.920	0.947
				period 2010-2020				
Firms rep. POC-SNC	0.522	0.916	0.877	0.892	0.758	0.875	0.783	0.778
Firms rep. SNC only	0.478	0.084	0.123	0.108	0.242	0.125	0.217	0.222

Table 4. Weights of number of firms and tangible assets and reporting under POC vs. SNC

Note: Computations based on averages by firm of end-of-period accounting net stocks.

The break in the accounting standards affects only the firms that were created before 2010. Table 4 presents indicators of the importance of such firms vis-a-vis those born in or after 2010, for which all data have been consistently reported under SNC. For the firms created before 2010, it is useful to distinguish for the implementation of the PIM between those that ceased activity before 2010 - thus reporting only under POC - and the ones with activity after 2009 and reporting under both systems. While as far as the number of firms is concerned, a substantial portion - close to 50% - of the firms active in or after 2010 report the whole spell according to SNC, the accounting capital stock of these firms represents a much smaller share of total.

5. Estimation of the initial capital stock

5.1. Methodology

The initial capital stock is the starting point for the application of the PIM, pinning down the level of the series, while the cumulation of flows drives the dynamics. In the accounting statements, firms report both gross and net capital stocks, but follow depreciation rules for tax purposes which tend to overstate the depreciation

speed vis-a-vis economic rates, and thus to underestimate the net stock. Moreover, it can happen that accounting practices differ across firms within the limits set out in the tax law. A second reason for an underestimation of value of assets is the recording at historical cost - such an effect being stronger the higher the inflation rate since the purchase of the asset.

The estimation of the initial value of capital stocks - when long series for backwards investment are unavailable - has been addressed in the literature - see, for instance, Ylmaz and Kiliç (2021) and Chen and Plotnikova (2018). Apart from book values, other methods have been put forward such as using variables strongly correlated with the capital stock, or making assumptions about the parameters measuring the growth rate of past investment and depreciation, which render the initial stock a simple function of current investment and such parameters. The method here devised puts together the information about the accounting *gross* capital stocks reported by firms and depreciation rates from EUKLEMS used in the PIM (Section 3), so that the computation of the initial stock is fully consistent - as far as depreciation rules are concerned - with the subsequent (de)cumulation of flows.

One needs to estimate the PIM initial capital of both the firms reporting under POC-SNC and the firms reporting solely under POC whose creation is not observed, because it happened before 2006. The PIM initial capital of the remaining firms - those reporting solely under POC whose creation is observed and those reporting under SNC only (whose creation is always observed) - coincides with the capital at inception which as explained below is assumed to be zero. The general idea is as follows. One obtains firstly an estimate of a firm-age profile of investment in the period prior to the moment the PIM initial capital is pinned down, which is the end of 2009 for the POC-SNC firms and the end of 2005 for the POC firms. This matches the times - respectively, beginning of 2010 and 2006 - the accounting SNC and POC stocks are observed for the first time (note that by convention PIM capital is measured at the end of the year). The sequence of investments over that period is cumulated, in order to calculate two implied stock measures: a gross one matching the valuation rules in the balance sheet of firms and a net one measured in real terms (at prices of 2009 or 2005, as applicable). A scale factor for the size of the firm is then calculated as the ratio between the implied and the actual accounting *gross* stocks. Such a scale factor is then applied to the implied real *net* stock to estimate the initial PIM capital. Other variables that could have had an impact on the capital stock, notably, sales of assets and other changes in volume, have been disregarded in this exercise given the difficulties in predicting a profile for them.

In order to implement this procedure, three sets of assumptions must be made. The first one is about the lifespan of assets, which is set to the number of years making up 3/4 of asset life, taking the depreciation rates and the geometric pattern

of depreciation assumed in the PIM.[4]

The second set of assumptions concerns the valuation of fixed assets in the balance sheet of firms. As a benchmark, one assumes that machinery, transport and other equipment and other assets are valued at historical cost, while for land and buildings and structures it is assumed that some degree of revaluation took place over time, albeit to a lesser extent than full market value. Such a *partial revaluation* in the latter case has been implemented by cutting down the respective deflator by $1/2$.[5] These calculations require the availability of long time series of asset-specific price indices, particularly for land and buildings and structures (which have been taken from national accounts). A sensitivity analysis of estimated initial stocks to a change in these benchmark assumptions is presented below along with the main results.

Finally, an assumption must be made concerning which portion of the assets acquired over time is not be available for production any more (say, due to accidental damage or obsolescence), not being part of the balance sheet stock in the year taken as a reference for the calculation of the initial capital. One assumes that such a portion, denominated as *asset retirement*, is a «small» fraction - α_a - of the full depreciation rate, while the remaining part accounts for the usual physical deterioration of assets,[6] except for land and buildings and structures, for which asset retirement is not allowed. The depreciation factor $(1-\delta_{a,s})$, when applicable, is thus divided into two parts:

$$(1-\delta_{a,s}) = (1-\delta_{a,s})^{\alpha_a}(1-\delta_{a,s})^{(1-\alpha_a)}. \quad (1)$$

The benchmark assumption is that $\alpha_a = 1/8$, while the remaining $(1-\alpha_a) = 7/8$ account for physical deterioration. These assumptions are also subject to a

4. This yields 9.8 years, on average, for machinery, 7.0 for transport equipment, 6.0 for other equipment and 9.0 for other assets. Buildings and structures' lifespan was set to 40 years, which is less than 3/4 of the asset life, because the estimates of the firm-age profile of investment are not reliable for spells over 40 years. This same lifespan was assumed for land - which by convention does not depreciate.

5. The valuation at market prices - at least for these two types of assets - could conceivably have become more widespread in the wake of the adoption of SNA. However, a comparison of accounting stocks in the two systems at the same point in time (Table 3), for the sectors less affected by methodological breaks (e.g. manufacturing), does not suggest the increase in book values that should have ensued. Therefore, no differentiation has been introduced in the assumptions about the valuation of SNC vis-a-vis POC stocks.

6. The OECD Manual *Measuring Capital* (OECD 2009, Chapter 5) distinguishes between three sorts of asset retirement encompassing normal accidental damage (e.g. an accident with a car or a machine), economic or technological obsolescence (e.g. scrapping of typewriters with the introduction of computers) and extraordinary losses of assets, for instance, due to wars and natural disasters. This manual considers that only the first sort should be included in depreciation. Here one assumes for simplicity that asset retirement over time as a whole is part of depreciation.

sensitivity analysis.

The whole procedure starts by estimating a firm age-profile of investment, which is obtained by regressing real additions (taken as a proxy of investment) on a cubic polynomial of firms' age, allowing a nonlinear profile of investment over the life-cycle, and the growth rate of real aggregate investment in the economy, separately by asset type and sector:[7]

$$ad^a_{i,t} = \beta^{a,s}_0 + \beta^{a,s}_1 age_{i,t} + \beta^{a,s}_2 age^2_{i,t} + \beta^{a,s}_3 age^3_{i,t} + \beta^{a,s}_4 \Delta \ln(ainv^a_t) + \varepsilon^a_{i,t}, \quad (2)$$

where i denotes firms, t years, a asset types and s industries. ad stands for additions to capital in real terms, age for firms' age and $\Delta \ln(ainv)$ for the growth rate of aggregate investment in the economy. Equation (2) is estimated over the full sample available - 2006-2020 using a two-part model (see Mihaylova *et al.* 2011 and Belotti *et al.* 2015), given that additions have a large number of zeros which tend to bias the estimates if OLS is directly applied. The two-part model encompasses firstly the estimation of a logit model for the probability of positive additions, followed by fitting an OLS model to the log of positive values.

The first step is to obtain an average investment profile backwards over the period limited by the lifespan of assets or, if smaller, firm's age, for the time being considering only the firms created before 2006. Such a profile is given by the fit of the model.[8] This is at 2005 prices and must be transformed to proxy the two stock measures outlined above, using the assumptions about valuation of assets in the balance sheet and asset retirement. Formally, the implied 2006 beginning-of-period gross balance sheet measure is given by:

$$\widehat{gst}^a_{i,2006} = \sum_t \{\widehat{ad}^a_{i,t} \pi_{a,t} (1 - \delta_{a,s})^{\alpha_a (2005 - t)}\}^{2005}_{t=2005-min(life_a, age_{i,2005})+1}, \quad (3)$$

where $\widehat{ad}$ is the fit of equation (2), π is the base 2005 price index, $life_a$ is the lifespan assumed for asset a and $age_{i,2005}$ is the age of firm i in 2005. Throughout the paper, by convention the accounting variables are written lowercase, while the PIM or economic variables are written uppercase. The corresponding net real measure (at 2005 prices) is given by

7. The breakdown of aggregate investment by asset type approximately matches the corresponding one at the firm level, except for land and other assets (overall investment has been used in these cases) and other equipment (machinery has been used). The 12-sector CAE breakdown - as appearing in Table 2 - has been used.

8. The expression is $\widehat{ad}|\mathbf{x} = (\hat{p}|\mathbf{x})(\widehat{ad}|ad > 0, \mathbf{x})$, where $\mathbf{x}$ are the regressors in equation (2) and $\hat{p}|\mathbf{x}$ is the predicted probability that $ad > 0$.

$$\widehat{nst}^{a}_{i,2006} = \sum_{t} \{\widehat{ad}^{a}_{i,t}(1-\delta_{a,s})^{(2005-t)}\}_{t=2005-min(life_a, age_{i,2005})+1}^{2005}. \quad (4)$$

The PIM initial capital, which is measured net, at the end of 2005 for the POC firms created before 2006 is given by

$$K^{a}_{i,2005} = \kappa'_{a,i}\widehat{nst}^{a}_{i,2006}, \quad (5)$$

where, denoting by $gst^{a}_{i,2006}$ the actual beginning-of-period 2006 POC gross stock, the firm-size scale factor κ' is calculated as

$$\kappa'_{a,i} = gst^{a}_{i,2006}/\widehat{gst}^{a}_{i,2006}. \quad (6)$$

For the POC-SNC firms, this procedure must be complemented with a further step, because the PIM initial capital is estimated on the basis of the additions up to 2009 and the SNC first-observed stock. In this case, the scale factor κ' is used to scale the pre-2006 estimates for additions on the right-hand side of (3) and (4). The observed additions over the period 2006-2009 are duly adjusted to match both gross balance sheet valuation and net real valuation. Figures for $\widehat{gst}^{a}_{i,2010}$ and $\widehat{nst}^{a}_{i,2010}$ are computed employing expressions analogous to (3) and (4), but now with t ranging from $2009 - min(life_a, age_{i,2009}) + 1$ to 2009 and using the base 2009 price index. The PIM initial net capital at the end of 2009 for the POC-SNC firms (created before 2006) is given by expressions analogous to (5) and (6):

$$K^{a}_{i,2009} = \kappa''_{a,i}\widehat{nst}^{a}_{i,2010} \quad (7)$$

and

$$\kappa''_{a,i} = gst^{a}_{i,2010}/\widehat{gst}^{a}_{i,2010}, \quad (8)$$

where $gst^{a}_{i,2010}$ is the beginning-of-period 2010 SNC gross stock.[9]

In the case of the firms POC-SNC whose creation happened in 2006 of thereafter, one observes the full sequence of additions up to 2009. Maintaining the assumptions above about valuation of fixed assets in the balance sheet and asset retirement, such a sequence is used to estimate the two relevant stock measures. These two stock measures and the beginning-of-period 2010 SNC gross stock along with expressions analogous to (7) and (8) are used to obtain the PIM initial capital at the end of 2009.

9. For some firms and certain asset categories, it may not be possible to implement this procedure, because both the POC 2006 initial gross stock (and thus κ') and investment in the subsequent years up to 2009 are zero. In such cases, one takes directly the SNC 2010 net stock (which is often - though not always - equal to zero) as the PIM initial capital.

5.2. Benchmark estimates and robustness

This section presents the initial capital values in the benchmark and robustness exercises, comparing them with the corresponding accounting stocks. The first and second robustness exercises experiment with changing the assumptions about the valuation of accounting stocks to valuing all assets either at market prices (i.e. full revaluation) or at historical cost. The second exercise affects only land and buildings and structures as, for the remaining assets, this is the benchmark assumption. The third and fourth exercises look at the sensitivity of the estimates to considering different asset retirement factors over time, namely, setting this factor either to 0 (i.e. $\alpha_a = 0$) for all categories of assets or to $1/4$ (twice the benchmark figure). Recall that asset retirement does not apply to land and buildings and structures. Table 5 summarises the assumptions in the benchmark and robustness exercises.

	Valuation in the balance sheet		Asset retirement	
	Land and buildings	Remaining assets	Land and buildings	Remaining assets
Benchmark	«half» revaluation	historical cost	no retirement	1/8 of dep. rate
Robustness				
Exercise 1	full revaluation		= benchmark	
Exercise 2	historical cost		= benchmark	
Exercise 3	= benchmark		no retirement	no retirement
Exercise 4	= benchmark		no retirement	1/4 of dep. rate

Table 5. Assumptions in the benchmark and robustness exercises

The benchmark estimate for the initial stock, adding up over all firms in the two sets considered (Figure 1), is larger than the corresponding net accounting figure for every asset category. This reflects the combined effects of assuming that valuation of assets is below market value in the balance sheets and a PIM depreciation speed slower than tax depreciation (for land this second effect is absent).[10] Measured relative to the net accounting stock, the benchmark estimate for the PIM initial stock is largest for other equipment (around 2.5 times for the POC-SNC firms), followed by transport equipment and other assets (around 2 times), machinery and buildings and structures (over 1.5 times) and land (1.2 times).

The assumptions about valuation of assets play a particularly important role in the case of buildings and structures, as shown by the difference between the

10. Machinery and other equipment are exceptions in that the valuation effect goes in the opposite direction, as there was a decrease in prices in the years up to 2005 and 2009 (the price index for these two asset categories is the same).

estimates assuming full revaluation and historical cost, due to their long lifespan coupled with a pronounced price increase over time. This is much less so for land, which has an equally long lifespan but a less steep price index. In contrast, in the case of machinery, transport and other equipment and other assets the depreciation effect clearly predominates due to the much shorter lifespan: the difference between full revaluation and historical cost (which is the benchmark assumption) is small. Moreover, Figure 2 shows that the estimated initial stock of such assets is larger the greater the fraction of asset retirement is assumed. Nevertheless, the impact of the latter assumption is relatively moderate compared to that of taking economic (vis-a-vis tax) depreciation. Figure 3 depicts the distributions of the benchmark initial stocks and gross and net accounting stocks - given the large quantity of zeros, only values above percentiles 85, for land, and 50, for the remaining assets, are shown. The distributions of the benchmark initial stocks feature a shift in the original accounting distributions (standing in-between the two), rather than a change in shape.

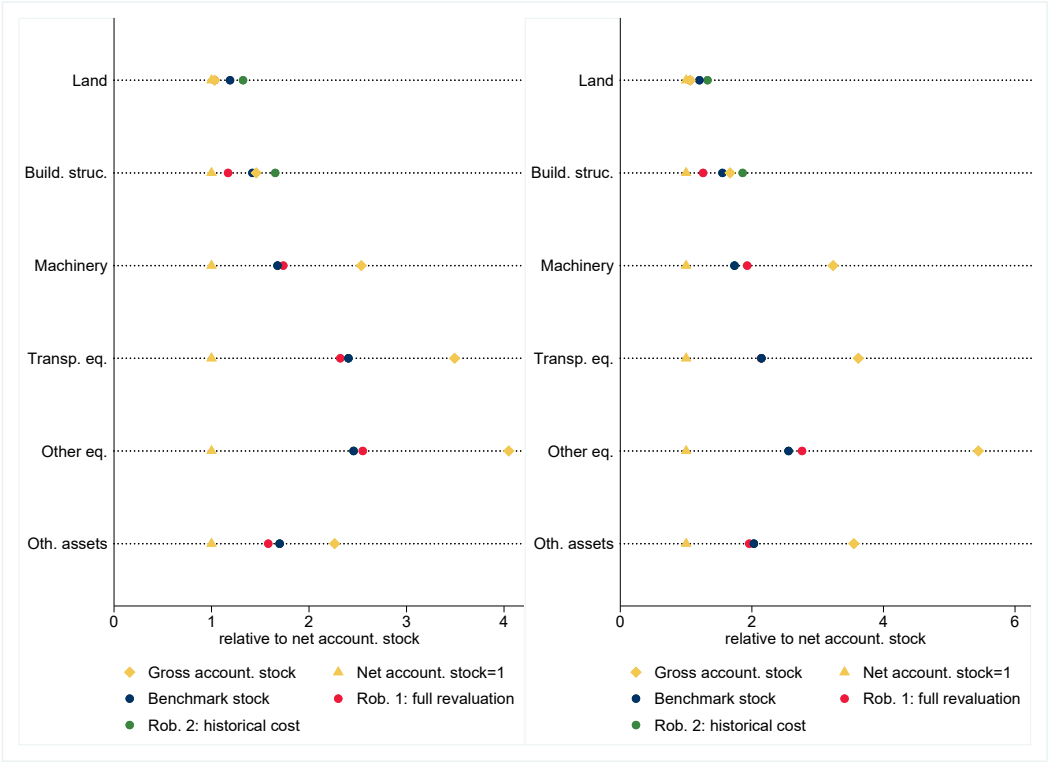


Figure 1: Overall initial capital: accounting vs estimated stocks, normalized by the net accounting stock (firms reporting POC only on LHS and firms reporting POC-SNC on RHS)

Note: The chart presents the initial capital estimates in the benchmark and robustness exercises 1 and 2 (see Table 5) and the corresponding gross and net accounting stocks.

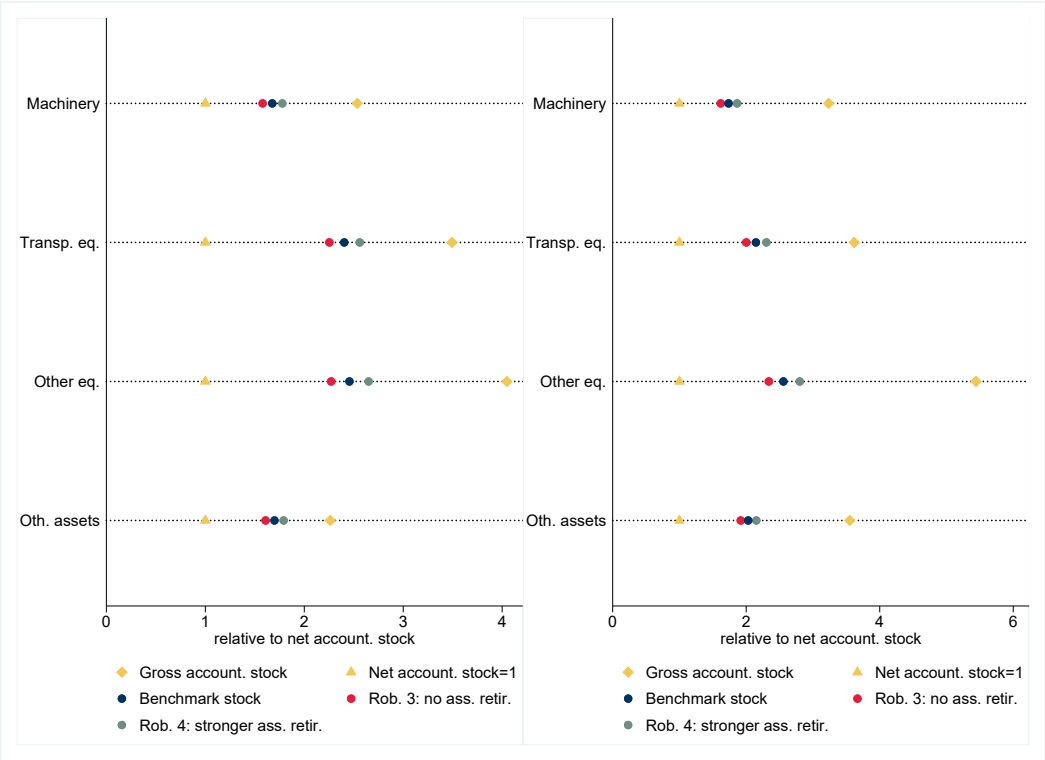


Figure 2: Overall initial capital: accounting vs estimated stocks, normalized by the net accounting stock (firms reporting POC only on LHS and firms reporting POC-SNC on RHS)

Note: The chart presents the initial capital estimates in the benchmark and robustness exercises 3 and 4 (see Table 5) and the corresponding gross and net accounting stocks.

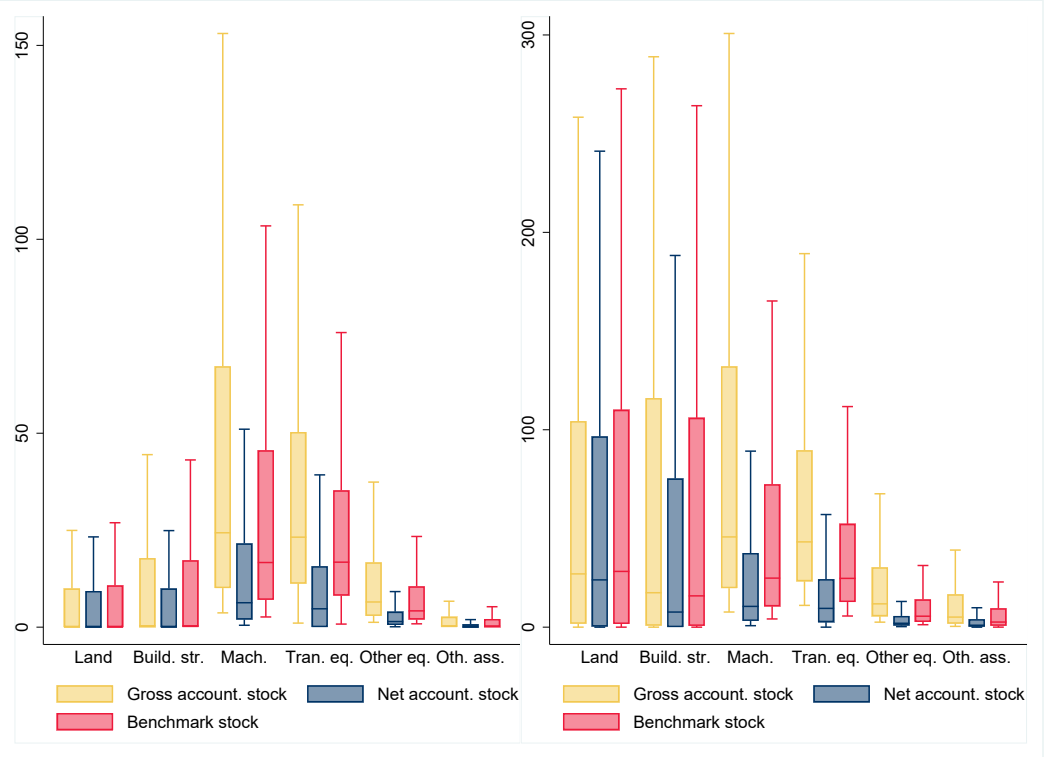


Figure 3: Distribution of initial capital: accounting vs estimated figures, in thousand euro (firms reporting POC only on LHS and firms reporting POC-SNC on RHS)

Note: The chart shows box plots for the values above percentiles 85 for land and 50 for the remaining assets.

6. Estimation of negative capital flows

The switchover from POC to SNC had also implications for the recording of negative capital flows i.e. sales of assets and negative changes in volume. While such flows were reported gross of depreciation under POC, they are reported net of depreciation under SNC. Obviously gross flows cannot be directly used to compute figures for economic capital which is measured net. Moreover, even in the SNC period, accounting data on disposals of assets are recorded in accordance with the rules applying to balance sheet stocks, both as far as depreciation and valuation are concerned, which as seen do not coincide with economic ones.

Figures 4 and 5 show the accounting annual totals by category of assets for sales and negative other changes in volume. For most asset categories, it is visible

Figure 4: Assets sales in the accounting data, totals in billion euro

a break around the switchover from POC to SNC due to the change from gross to net in the recording of asset disposals. Note that acquisitions of capital goods or positive changes in volume[11] (including notably transfers from assets in progress) are largely unaffected by such issues, as they have been subject to very little or no depreciation and should be recorded at approximately market prices. We now describe the procedure employed to estimate figures for negative flows suitable to be used within the PIM framework.

11. The assumption about the sign of changes in volume is a simplification as the overall sign - positive or negative - may result from a combination of positive and negative operations and thus encompass an effect of depreciations. In any case, being changes in volume rare events, this assumption should not deviate significantly from reality.

Figure 5: Negative other changes volume in the accounting data, totals in billion euro

6.1. POC period (2006-2009)

The working assumption during the POC period is that if the firm sells, say, 15% of its accounting gross stock, there is a 15% reduction in the economic net stock. One thus computes, for asset a, firm i, and year t, a *sales ratio* (sr) and a *changes in volume ratio* (vr), in this latter case only for negative changes in volume:

$$sr^a_{i,t} = \frac{sal^a_{i,t}}{gst^a_{i,t}} \ (t \leq 2009) \tag{9}$$

$$vr^a_{i,t} = -\frac{\Delta v^a_{i,t}}{gst^a_{i,t}} \text{ if } \Delta v^a_{i,t} < 0 \ (t \leq 2009), \tag{10}$$

where sal, Δv and $gsti$ are, respectively, the *gross* values of sales, changes in volume and beginning-of-period stock reported in POC statements.

The use of these ratios implicitly assumes that the pattern of depreciations embedded in the particular capital good being sold is the same as that embedded in the overall stock for that type of asset, which is a simplifying assumption. Indeed,

the goods being sold are likely to be, in general, older than average, thus having a higher share of cumulated depreciations. If this is the case, the procedure may overestimate to some extent the value of economic net flows. In the computation of the economic measure, the above ratios are applied to the PIM net capital stock at the end of the previous year, to derive consistent flows using the firm-specific accounting information - see Section 6. When $gst^a_{i,1} = 0$, the ratios (9) and (10) cannot be computed and sales and changes in volume of assets are assumed to be zero in the PIM computations.

6.2. SNC period (2010 and after)

During the SNC period, one follows an approach similar to that used with POC data, computing a sales ratio (sr) and a changes in volume ratio (vr), but now relying on the available net stock accounting figures. As both the numerator and denominator are affected by the same type of depreciations, this should provide a good approximation of the proportional reduction in the stock, in spite of the fact that goods being sold are likely to be older than average and thus have a higher share of cumulated depreciations.

$$sr^a_{i,t} = \frac{sal^a_{i,t}}{nst^a_{i,t}} \ (t \geq 2010) \tag{11}$$

$$vr^a_{i,t} = -\frac{\Delta v^a_{i,t}}{nst^a_{i,t}} \text{ if } \Delta v^a_{a,t} < 0 \ (t \geq 2010), \tag{12}$$

where sal, Δv and $nsti$ are, respectively, the *net* values of sales, changes in volume and beginning-of-period stock as reported in SNC statements. One applies these ratios to the previous year PIM capital stock, in order to derive consistent outflows. When $nst^a_{i,t} = 0$, the ratios (11) and (12) cannot be computed. In such cases, the accounting figures for sales and changes in volume are directly used in the PIM as, being net figures, they are a reasonable approximation (in contrast to the gross figures reported prior to 2010).

7. Application of the Perpetual Inventory Method

Our application of the Perpetual Inventory Method must take into account the break in the reporting of the accounting data brought about by the switchover from POC to SNC. The method has been adapted to cope with such a break, by distinguishing among three groups of firms: (i) firms only active before 2010, reporting solely under POC; (ii) firms active before and from 2010 on, reporting under POC and SNC and (iii) firms only active from 2010 on, reporting solely under SNC. Table 4 above presents data on the relative importance of these groups.

7.1. Firms only active before 2010

The standard recursive PIM formulation applies. The detailed formulas for the iterative computation of capital stock are as follows:

$$K^a_{i,t} = (1 - \delta_{a,s})K^a_{i,t-1} + I^a_{i,t} + \Delta V^a_{i,t} \tag{13}$$

where

$$I^a_{i,t} = (ad^a_{i,t}/\pi_{a,t} - sr^a_{i,t}K^a_{i,t-1}) \tag{14}$$

and

$$\begin{cases} \Delta V^a_{i,t} = -vr^a_{i,t}K^a_{i,t-1} \text{ if } \Delta v^a_{i,t} < 0 \\ \\ \Delta V^a_{i,t} = \Delta v^a_{i,t}/\pi_{a,t} \text{ if } \Delta v^a_{i,t} \geq 0, \end{cases} \tag{15}$$

and K is the PIM capital stock of asset a for firm i in year t, δ is the asset-sector depreciation rate, and I and ΔV are the PIM investment and other changes in volume. ad and Δv are balance sheet additions and other changes in volume, respectively, and vr and sr are the ratios defined in (9) and (10) above. The capital stock and remaining PIM series are computed at prices of 2020; π is the asset-specific base 2020 price index.

Replacing (14) and (15) into (13) yields a summary formula for the iterative computation of the PIM capital from the previous year figure (omitting the subscripts for δ, sr and vr, to save space):

$$\begin{cases} K^a_{i,t} = (1 - \delta - sr - vr)K^a_{i,t-1} + ad^a_{i,t}/\pi_{a,t} \text{ if } \Delta v^a_{i,t} < 0, \\ \\ K^a_{i,t} = (1 - \delta - sr)K^a_{i,t-1} + (ad^a_{i,t} + \Delta v^a_{i,t})/\pi_{a,t} \text{ if } \Delta v^a_{i,t} \geq 0. \end{cases} \tag{16}$$

Flows are cumulated according to (16), starting from a PIM initial capital in the first year the firm is observed. If the firm was born before 2006, this is the net stock at the end of 2005, as given by expression (5), valued at 2020 prices. As explained in Section 4, the estimated initial capital stock of such firms, being derived from POC data, may be biased upwards. If the firm was born in or after 2006, the PIM initial capital is the capital at inception which is assumed to be zero. The assumption that the capital of firms is zero at the moment of creation implies that if the firm reports a positive initial capital in the year of creation, this amount is assigned to additions (and thus to investment). As the PIM is applied separately by asset type, the total tangible capital stock of firm i is given by the

sum across all types:

$$K_{i,t} = \sum_a K^a_{i,t}. \tag{17}$$

7.2. Firms active before and from 2010 on

The PIM initial capital - at the end of 2009 - for this group of firms is derived from the SNC figure, in order to ensure consistency with the most up-to-date accounting standards, being given by expression (7), valued at 2020 prices. For the period after 2009, the annual flows are cumulated forward much in the same way as for the firms in the first group. The formulas (13)-(15) apply, except that the sales and changes in volume ratios (vr and sr) are the now defined by (11) and (12). For the period 2006-2009, one must de-cumulate flows. The backwards version of the PIM formula can be obtained by solving (16) for $K^a_{i,t-1}$:

$$\begin{cases} K^a_{i,t-1} = (1-\delta-sr-vr)^{-1}(K^a_{i,t} - ad^a_{i,t}/\pi_{a,t}) \text{ if } \Delta v^a_{i,t} < 0, \\ \\ K_{i,t-1} = (1-\delta-sr)^{-1}(K_{i,t} - (ad^a_{i,t} + \Delta v^a_{i,t})/\pi_{a,t}) \text{ if } \Delta v^a_{i,t} \geq 0, \end{cases} \tag{18}$$

while investment and changes in volume (I and ΔV) are given, as before, by expressions (14) and (15). For the firms in this group created in 2006 or thereafter, when going backwards, if a positive «initial capital» remains in the year of creation, this is treated as a positive volume variation, in keeping with the assumption of a zero capital at firm inception. We do not assign this amount to additions, in order not to change this variable as reported by the firms in the balance sheets by an amount that is highly dependent on assumptions. The PIM initial capital is derived from the SNC figure, which is the highest quality one available, but flows originating in the period from 2006 to 2009 may not be fully encompassed in such figure, as explained in Section 4. We take up this issue shortly.

7.3. Firms only active from 2010 on

The standard PIM formulation in (13)-(15) applies to this group of firms as well, with the sales and changes in volume ratios being defined by (11) and (12). The creation of such firms is always observed and reporting is fully under SNC, not being affected by the change in standards. The PIM initial capital is the capital at inception which is assumed to be zero (same procedure as for the firms active before 2010).

7.4. Restrictions on the PIM and POC-SNC switchover

The practical application of the PIM requires that some restrictions are imposed. Firstly, one cannot rule out that either $1-\delta-sr<0$ or $1-\delta-sr-vr<0$ (as applicable) in (16) or in (18), which would mean that the firm is disposing of more capital as sales or other volume changes than the capital available after depreciation. In order to avoid this, one imposes the restriction that these quantities cannot be smaller than 0.1, or, equivalently, that after depreciation and disposal of assets, there should remain at least 10% of previous' year capital. This restriction is imposed in such a way that δ remains always unchanged, and whenever the restriction is active, it is firstly accommodated by vr and then by sr.[12]

Secondly, as is costumary in the application of the PIM, a non-negativity condition is imposed, meaning that whenever the computed PIM capital stock is negative, it is replaced by zero. This restriction is almost never active when the PIM is applied forward - affecting 0.1% or less observations, depending on the type of assets, because it is indirectly enforced by the abovementioned condition that firms should retain at least 10% of previous' year capital.[13] When the PIM is applied backwards, however, negative capital figures may arise if either $K_{i,t}-ad^a_{i,t}$ or $K_{i,t}-(ad^a_{i,t}+\Delta v^a_{i,t})$ in (18), as applicable, are negative. In this instance, more observations are affected - from 1% to 2% for the various types of assets, except for machinery, where the figure is around 5%. There could be several reasons for the violation of the non-negativity condition when the PIM is applied backwards. For instance, our initial capital estimate may underestimate the «true» economic capital at that point in time, if the unobserved investment flows were actually younger (being less depreciated) than what is implied by the estimated firm-age profile. Nevertheless, in what follows we provide evidence that the main source of violation of the non-negativity condition appears to be the coupling of an economic stock based on the SNC level with POC additions and positive changes in volume.

The amounts imputed to enforce the non-negativity condition (positive, when the PIM is applied forward, negative, when the PIM is applied backwards) are included in a separate series that we name as *PIM other changes in volume*, to keep them isolated from the corresponding economic variable. Anticipating results,

12. In spite of this restriction, it happens very occasionally - for certain firms and years - that the estimated negative flows deviate substantially from the underlying balance sheet flows. This may happen in particular for POC-SNC firms when sr and vr, which up to 2010 are based on the POC stock, are applied to an economic stock (derived from SNC) of a very different size. In order to limit the gap between the balance sheet and corresponding economic figures, sr and vr have been further constrained upwards, in that the ratio between the PIM and the balance sheet negative flows across all firms and years are winsorized at the respective percentile 90.

13. Therefore the PIM capital can never be negative, except in the very few cases when the accounting figures for sales and changes is volume are being directly used - see the end of Section 6.

Figures A.4 and A.5 of the Appendix display these PIM volume variations, along with the respective accounting and economic series, by asset category and sector. The breakdown by sector shows large negative magnitudes for electricity and gas and water, transportation and storage and construction - precisely the sectors most impacted by the POC-SNC switchover (Table 3), which is evidence that the PIM investment prior to 2010 is overestimated. Consequently, the corresponding stocks should be underestimated, but this is then attenuated by the imposition of the non-negativity condition. The issue also occurs, albeit to a smaller degree, for communication, administration and consultancy services (affecting the sector communications).

Note that we also include in the PIM other changes in volume (with a positive sign) the «initial capital» remaining at the year of inception, when the PIM is applied backwards to the firms created in the period 2006-2009, as explained above. Therefore the series assumes occasionally positive overall values in sectors in which the violation of the non-negativity condition has relatively less of an impact, such as manufacturing and trade and repair.

7.5. Treatment of work in progress

Work in progress represents the costs incurred on a fixed asset that is still under construction, and has a different nature than the remaining assets. The staying of a given asset in work in progress is transitory, as once the work has been completed and the asset put to use, it is allocated to the appropriate category. Such a reclassification takes place via other changes in volume, which for this category of assets assume a disproportionate importance. We have decided not apply the PIM forward to work in progress, but instead to take directly the net accounting stock on two grounds. On the one hand, work in progress usually does not depreciate and the valuation issues discussed above hardly apply given its short-lived nature. On the other hand, if a firms fails to cancel a given asset out of work in progress, when it is moved to another category, this will give rise to a permanent (given the absence of depreciation) and cumulative overestimation of the PIM stock. When going backwards for the firms POC-SNC, however, we still employed the PIM, in order to overcome the gap between the SNC and POC levels, but the initial capital has been directly anchored on the 2010 SNC net figure.

Flows have been also taken from the accounting data, even for negative ones which are essentially changes in volume, as sales of such assets are rare. Note that accounting figures for additions and negative other changes in volume should approximately match with some delay for this category. Given that in keeping with previous practice we have not modified accounting additions, it seemed appropriate not to modify accounting other changes in volume as well.

8. Results: economic series vs. accounting series

This section presents the stock and investment series compiled in the paper, benchmarking them against the accounting data. The additional PIM series, namely, additions to capital stock, asset sales, depreciation and other changes in volume are shown in an appendix. Here we give just a general overview of the evolution of the economic series, emphasizing the differences vis-a-vis their accounting counterparts, while a deeper analysis is left for other outlets.[14] The analysis is carried out by asset type and sector of activity (based on an 8-sector classification, slightly more aggregated than the one used so far). The economic series - stocks and flows - are valued at prices of 2020, as discussed above. We inflate the accounting data by applying the base 2020 price index, in order to minimize differences to the economic series due to valuation.[15] The results in 2006-2009 for the sectors most affected by the break POC-SNC i.e. electricity and gas, water, construction and transportation and storage are presented but - given the issues discussed throughout the paper - one should bear in mind that they are not comparable with those for the subsequent period. This is taken up explicitly in the analysis, notably, by presenting additional charts excluding such sectors.

8.1. Capital stock

Figures 6 and 7 show the yearly totals for the economic and net accounting stocks by asset category, respectively, for all sectors and excluding the sectors most affected by the POC-SNC switchover. The level of the economic stocks is consistently higher throughout the period, reflecting the larger size of the initial capital anchoring the PIM, as described in Section 5.2. The two series also differ in terms of trajectory for certain assets categories and time periods. The break around the switchover from POC to SNC is clearly visible in Figure 6, particularly in the stocks of buildings and structures and machinery. The evolution of the economic measure by asset type is differentiated, but stocks generally show a downwards inflection following the contraction of investment in the post-2008 period (this variable is dealt with in the next section). This profile is more evident for the assets with higher depreciation rates such as transport and other equipment and, to a lesser degree, machinery. Actually, in the case of other equipment for which that rate is highest, the stock according to our measure has not resumed a growing trend until the end of the

14. A preliminary version of the investment series was the object of analysis in the special issue «A firm-level analysis of investment», published in the December 2019 Economic Bulletin of Banco de Portugal. A forthcoming special issue will deal with the stocks series.

15. This should be seen as an approximation to prices of 2020, although not a fully correct one in the case of stocks (and flows derived from them), whenever the balance sheet valuation of the firm is at historical cost.

period considered.

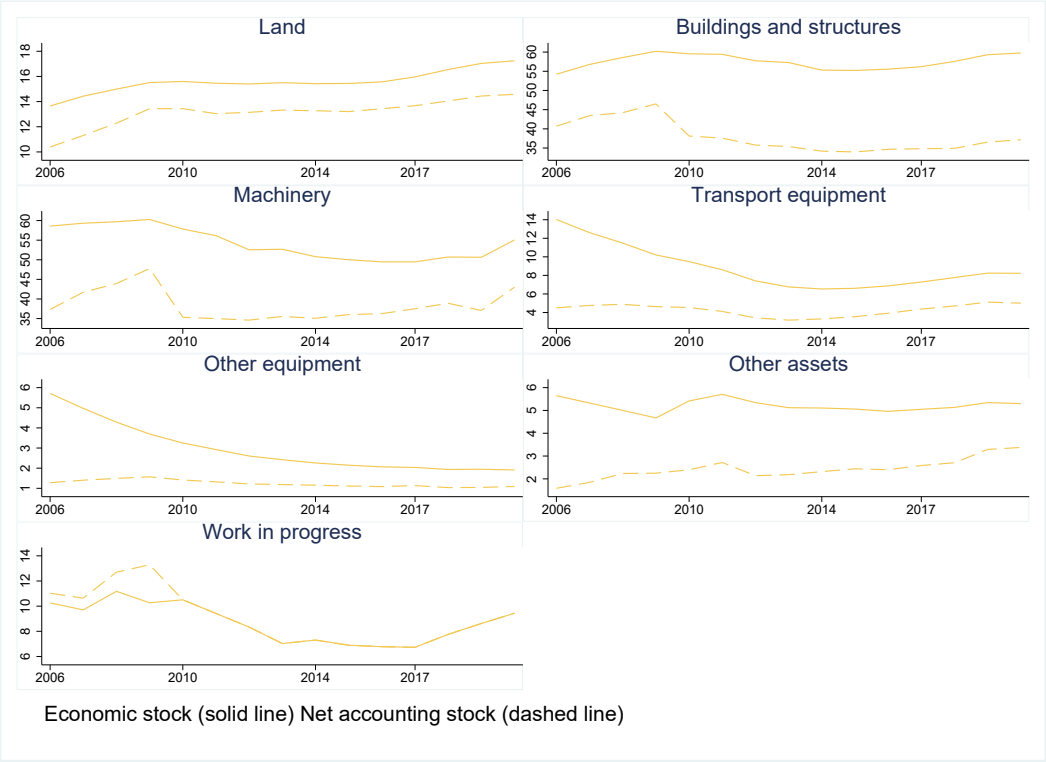


Figure 6: Economic stocks and net accounting stocks by asset category, totals in billion euro

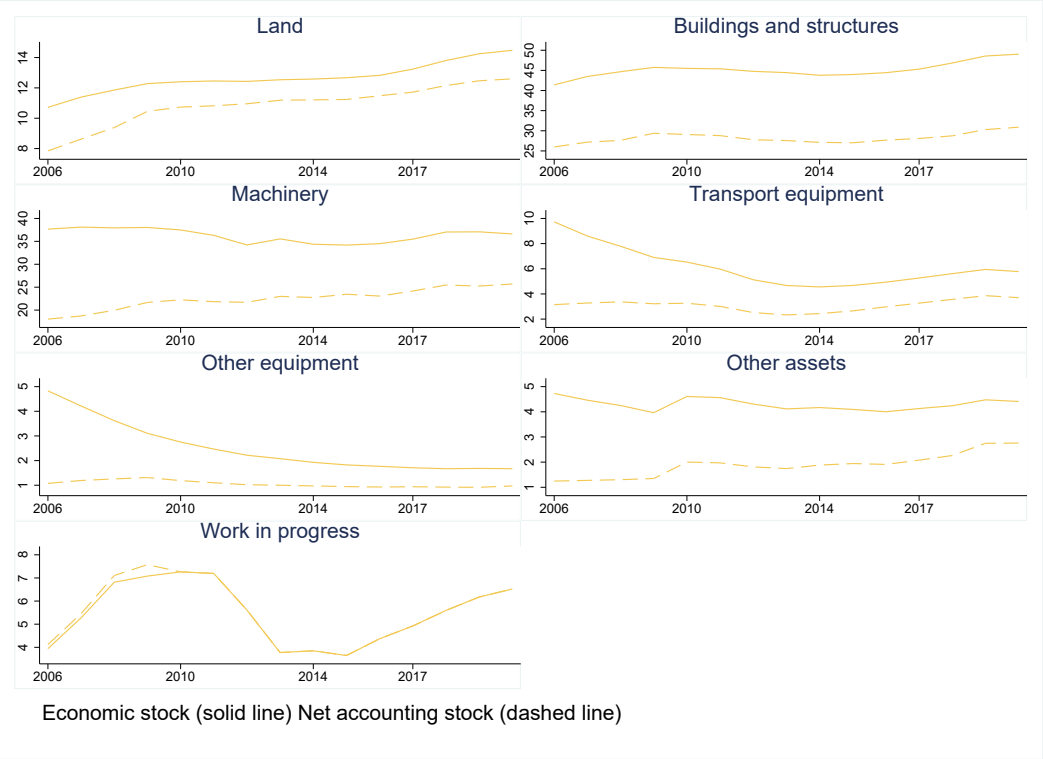


Figure 7: Economic stocks and net accounting stocks by asset category, excluding the sectors most impacted by the POC-SNC switchover, totals in billion euro

The evolution by sector (Figure 8) is differentiated as well. Agriculture and fisheries and accommodation and food services saw a rise in the overall stock of tangibles during the pre-pandemic period of expansion of economic activity. The stocks of these two sectors in the recent period reached a level above the one in the initial years. The stocks of tangibles in manufacturing and mining and trade and repair have been broadly stabilized taking the period as a whole. The remaining sectors show a downward trend, even confining the analysis to the period from 2010 onwards, for the ones most affected by the POC-SNC switchover. In the case of construction, this trend has been reversed in 2020 due to a jump in the stock brought about by a very large firm appearing in the database for the first time. One should bear in mind that part of the capital goods that such sectors employ in production is currently assigned to intangibles, so the evolution of tangibles gives an incomplete picture of their capital stock.

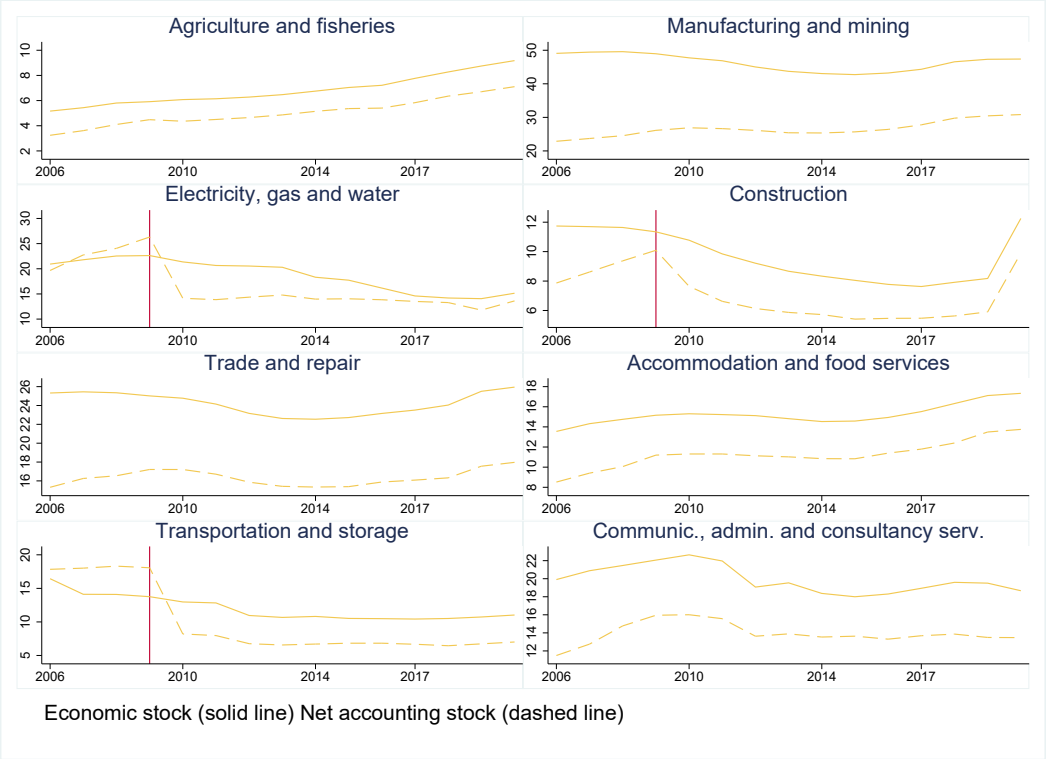


Figure 8: Economic stocks and net accounting stocks by sector, totals in billion euro

Note: The vertical lines mark the POC-SNC break for the most affected sectors.

The overall stocks for all firms presented in the previous charts are strongly influenced by the values for the very large ones, being appropriate to look at the distributions excluding them. Figure 9 shows box plots for the stocks by asset category confined to the values above percentile 90 for land and 50 for the remaining assets, and excluding the sectors most affected by the POC-SNC switchover. We complement this information with the evolution of the stock of tangibles by sector at percentiles 50, 75 and 99, but now considering only the firms that remain in the database from 2006 to 2020 («incumbent firms»), so that the percentiles are calculated over a constant set of firms.

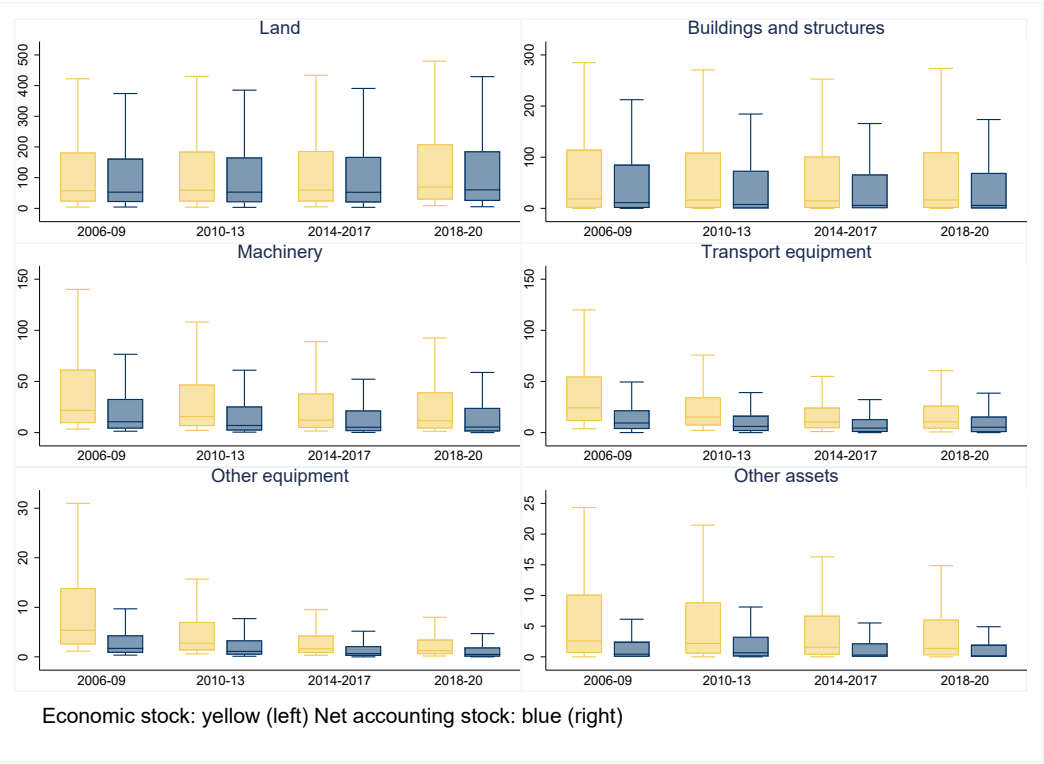


Figure 9: Distribution of economic and net accounting stocks excluding the sectors most impacted by the POC-SNC switchover, in thousand euro

Note: The box plot represents the values above percentile 90 for land and 50 for the remaining assets (excluding outliers), calculated on the basis of averages over the indicated time period.

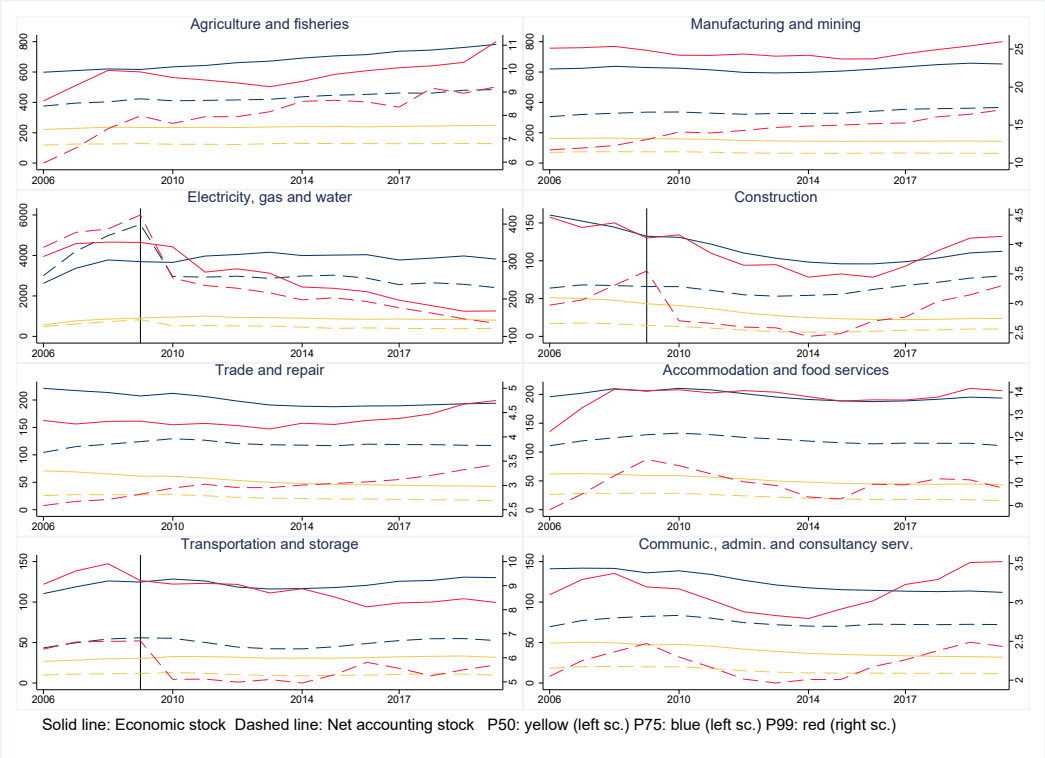


Figure 10: Economic stock and net accounting stock, percentiles 50 and 75 (left scale, in thousand euro) and 99 (right scale, in million euro)

Note: Quantiles calculated over the set of firms present in the database throughout the whole period 2006-2020. The vertical lines mark the POC-SNC break for the most affected sectors.

The box plots in Figure 9 indicate that the differences in the levels of economic vs. accounting stocks - holding for the totals - hold as well across the distribution as a whole. Such differences in levels also show up for the specific percentiles depicted in Figure 10. Moreover, the rises (falls) in overall economic stocks by asset type in Figure 7 above generally correspond to shifts in the distributions to the right (left), suggesting that the trends shown for totals are not confined to the largest companies. Note that given the zero lower-bound of the capital stock, shifts to the left in the distribution of stocks show up as a shrinkage of the box plot. The evolution of the economic stock of tangibles within sectors is heterogeneous across the distribution, as trends at the considered percentiles generally differ. Although these charts cover incumbent firms only, not being directly comparable with those in Figure 8, for the sectors construction and communication, administration and consultancy services they hint at a more positive evolution at specific points of the distribution, notably percentile 99, than as given by the overall total.

We finalize this section by examining possible heterogeneous differences across firms between accounting and economic capital. Table 6 shows averages by type of asset of the Spearman's rank correlation coefficients between the two capital measures (averages based on values computed by year and sector).

Asset type	**Spearman corr. coef.**
Land	0.903
Buildings	0.900
Machinery	0.793
Transport equipment	0.751
Office equipment	0.737
Other assets	0.705
Assets in progress	0.943

Table 6. Rank correlation between capital measures

The Spearman's rank correlation coefficients are high for all asset types, indicating a homogeneous impact of the transition from accounting to economic capital across firms - which is the expected outcome.

8.2. Investment

We now turn to the analysis of investment using charts corresponding to the ones presented for stocks. Figures 11 and 12 show the yearly totals by asset category, respectively, for all sectors and excluding the sectors most affected by the POC-SNC switchover.

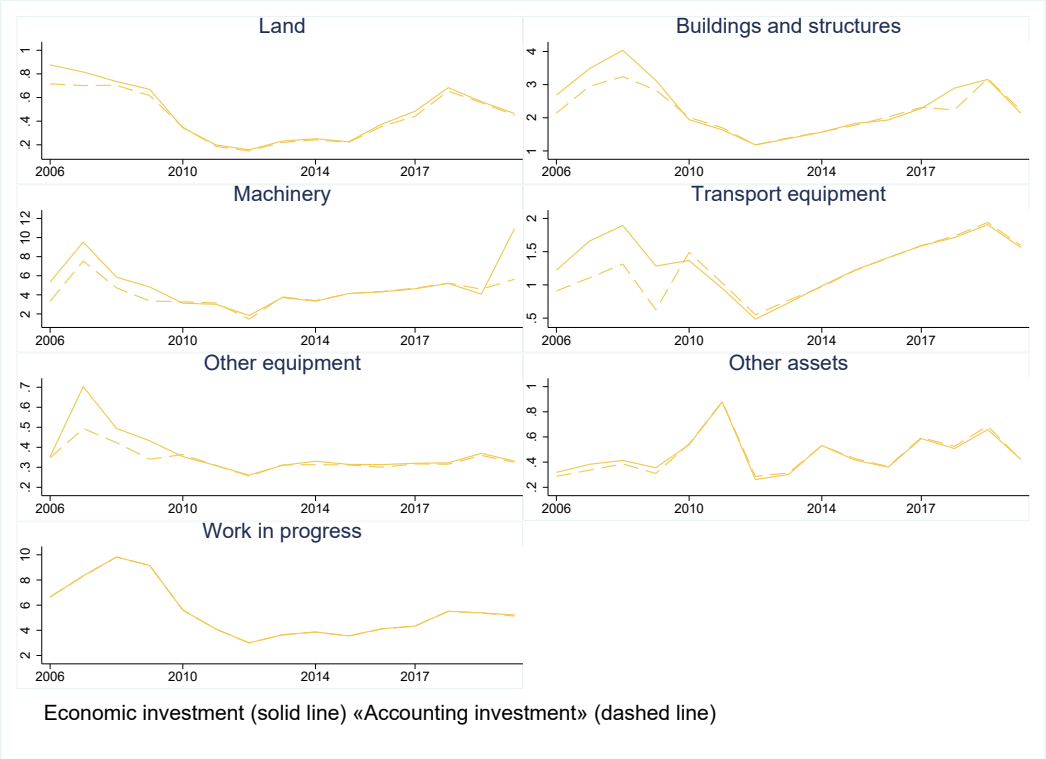


Figure 11: Economic investment and «accounting investment» by asset category, totals in billion euro

In contrast to stocks, the economic and accounting series for investment[16] are rather close to each other during the POC period and essentially coincide during the SNC period, as PIM additions to capital stock (Figure A.1 in the Appendix) are almost directly taken from the accounting data.[17] The series for assets sales (Figure A.2 in the Appendix) are rather different, particularly in the period 2006-2009, but sales weight much less than additions. Investment in the main asset categories displays a profile of fall during the recessionary episodes from 2008 on, which

16. There is no series for investment in the financial statements of firms, however, for the sake of comparison with the economic series, we created an «accounting investment» subtracting accounting sales from additions.

17. The difference to the accounting additions stems from the firms that have a positive initial capital at the moment creation (see Section 7.1). This is generally unimportant, however, there was one such case associated with a very large firm appearing in 2020, already mentioned for stocks, showing up prominently in the investment on machinery of sector construction.

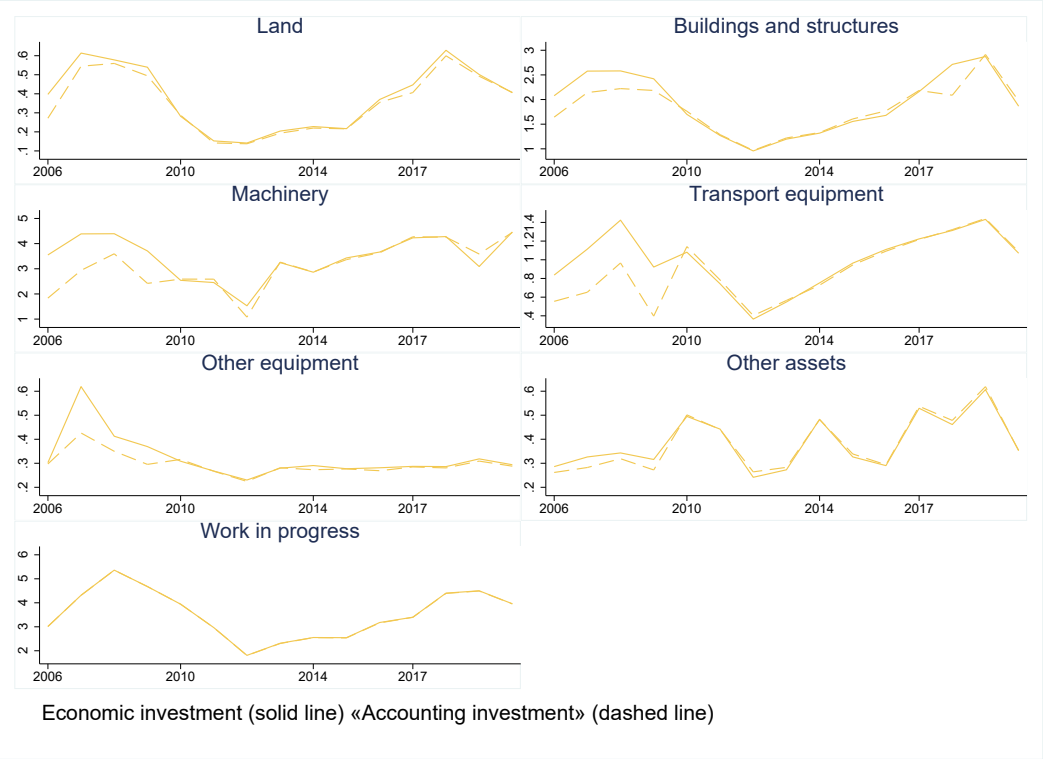


Figure 12: Economic investment and «accounting investment» by asset category, excluding the sectors most affected by the POC-SNC switchover, totals in billion euro

in Figure 11 appears overstated by the POC-SNC switchover, but is still clearly visible in Figure 12. The rebound in the subsequent period has been differentiated and weaker for machinery and, even more so, for other equipment. In the last case, this fact coupled with high depreciation rates, brings about the absence of recovery of the capital stock (Figures 6 and 7). By sector, such rebound was confined to agriculture and fisheries, manufacturing and mining, trade and repair and accommodation and food services (Figure 13). For the remaining sectors, the pick up of investment in tangibles during the expansion stage was rather subdued. Similarly as for stocks, this evolution should be read bearing in mind that part of productive investment in some of those sectors currently appears under intangibles.

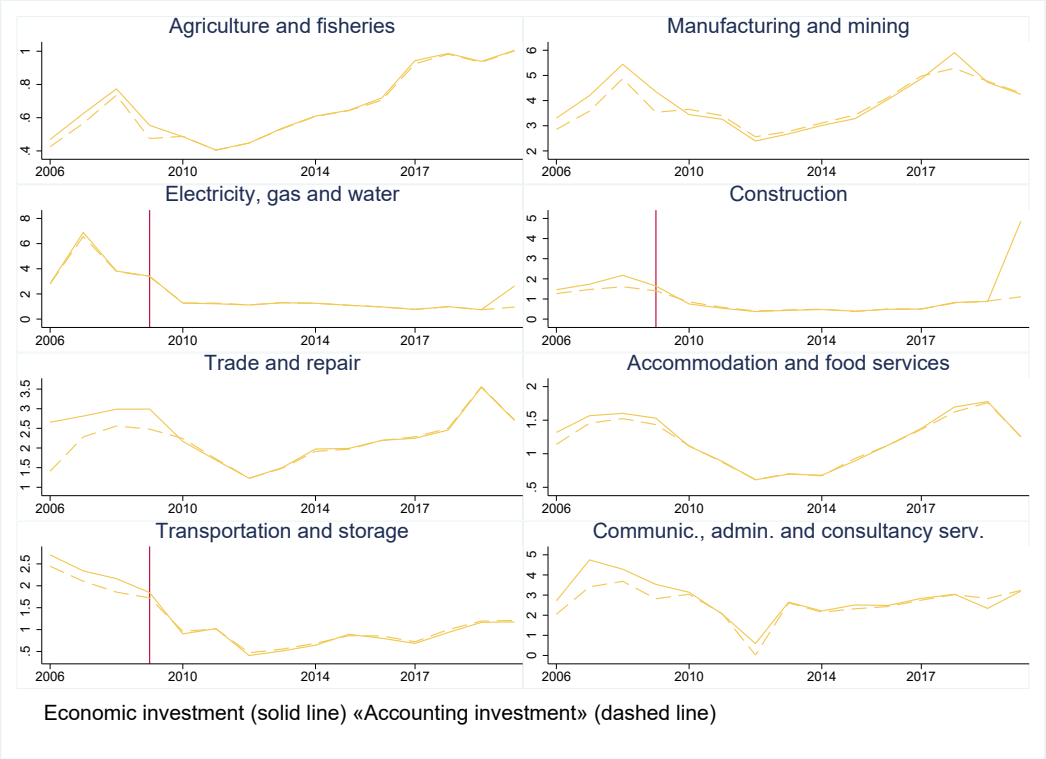


Figure 13: Economic investment and «accounting investment» by sector, totals in billion euro

Note: The vertical lines mark the POC-SNC break for the most affected sectors.

Figure 14 displays box plots for investment by asset category, confined to the values above percentiles 95, for land, and 75, for the remaining assets, and excluding the sectors most affected by the POC-SNC switchover. Figure 15 displays the evolution of this variable at percentiles 50, 75 and 99 by sector (restricting the sample to incumbent firms, as before). The evolution of the distributions as given in the box plots generally matches that of overall investment in Figure 12. Figure 15 shows at percentile 99 of incumbent firms more clear rebounds of investment than indicated by the overall figure for some of the sectors with weaker behaviour during the recovery stage, suggesting a particularly sluggish pick-up for top firms.

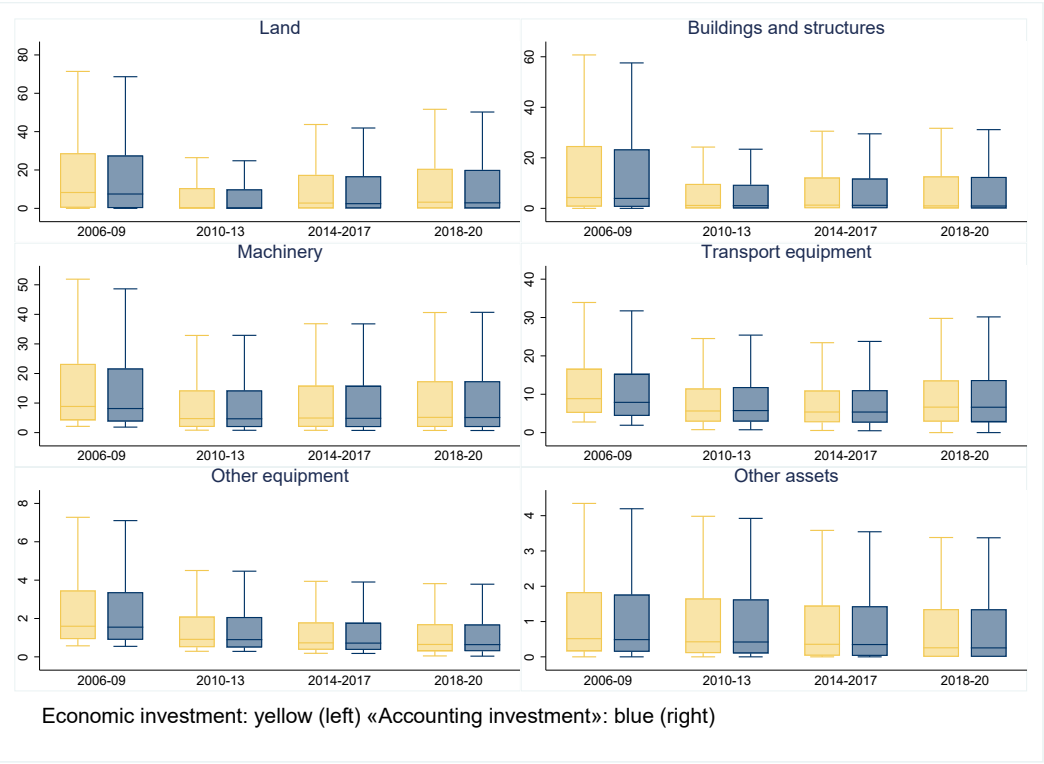


Figure 14: Distribution of economic and accounting investment by asset category excluding the sectors most affected by the POC-SNC switchover, in thousand euro

Note: The box plot represents the values above percentiles 95 for land 75 for the remaining assets (excluding outliers), calculated on the basis of averages over each time period.

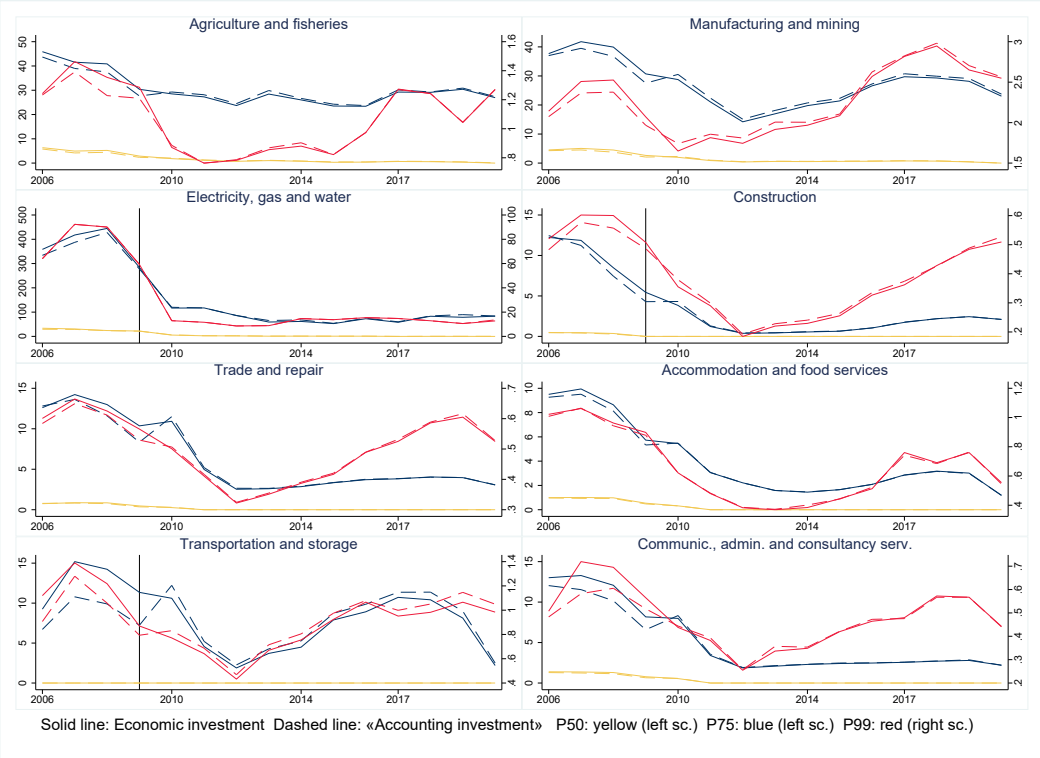


Figure 15: Economic investment and «accounting investment», percentiles 50 and 75 (left scale, in thousand euro) and 99 (right scale, in million euro)

Note: Quantiles calculated over the set of firms present in the database throughout the whole period 2006-2020. The vertical lines mark the POC-SNC break for the most affected sectors.

9. Future work

The work developed in this paper could be usefully complemented in two directions. The first one would be the inclusion of intangible assets. Indeed, literature (see e.g. Corrado *et al.* 2009 and Corrado *et al.* 2022) has stressed the importance of intangible inputs such as software and databases, R&D, market research and branding and employee training for the competitive advantage of firms and economic growth. There is information on some of these categories in the accounting statements. Moreover, as discussed, concession assets are recorded as intangibles in the firm's balance sheet in SNC, this would allow to enter into consideration with them as part of the firms' capital stock.

A second interesting extension would be to encompass capital goods which are available to firms under operating lease agreements, going beyond the more conventional approach (here followed) of considering only the assets in the balance sheet of firms, either directly owned by them or, indirectly, through financial leases. Such a broader measure would reflect better the amount of capital used by firms in the production process. This extension would be best introduced by bringing in the concept of capital services (see e.g. Oulton and Srinivasan 2003) - the flow of services generated by the assets used by firms during a period of time, irrespective of ownership.

References

Belotti, F., P. Deb, W. G. Manning, and E. C. Norton (2015). "twopm: Two-part models." *The Stata Journal*, 15, 3–20.

Chen, Xi and Tatiana Plotnikova (2018). "The measurement of capital: Retrieving initial values from panel data." *Review of Income and Wealth*, 64(3), 542–562.

Corrado, Carol, Jonathan Haskel, Cecilia Jona-Lasinio, and Massimiliano Iommi (2022). "Intangible Capital and Modern Economies." *Journal of Economic Perspectives*, 36(3), 3–28.

Corrado, Carol, Charles Hulten, and Daniel Sichel (2009). "Intangible Capital and US Economic Growth." *Review of Income and Wealth*, 55(3), 542–562.

Crouzet, Nicolas, Janice C. Eberly, Andrea L. Eisfeldt, and Dimitris Papanikolaou (2022). "The Economics of Intangible Capital." *Journal of Economic Perspectives*, 36(3), 29–52.

Franco, Paula (2010). "Noites SNC - primeira sessão - ativos não correntes." Ordem dos Técnicos Oficiais de Contas, apresentação disponível na internet.

Gal, Peter (2013). "Measuring Total Factor Productivity at the firm-level using OECD-ORBIS." OECD Economics Department Working Papers no. 1049.

Gilhooly, Robert (2009). "Firm-level estimates of capital stock and productivity." *ONS Economic and Labour Market Review*, 3(5), 36–41.

Mihaylova, B., A. Briggs, A. O'Hagan, and S. G. Thompson (2011). "Review of statistical methods for analysing healthcare resources and costs." *Health Economics*, 20, 897–916.

OECD (2009). *Measuring Capital - OECD Manual, second edition*. OECD Publishing, Paris.

Oulton, Nicholas and Sylaja Srinivasan (2003). "Capital stocks, capital services, and depreciation: an integrated framework." Bank of England Working Papers no. 192.

Serrenho, Carmen (2012). "O impacto da adoção do SNC nas empresas portuguesas de construção e de comércio por grosso." Dissertação para obtenção do Grau de Mestre em Contabilidade - Universidade do Algarve.

Ylmaz, Ensar and Ibrahim Kiliç (2021). "Estimating firm-level capital stock: The evidence from Turkey." *The Developing Economies*, 59(4), 371–404.

Appendix: Additional PIM series

Figure A.1: Economic and accounting additions by asset category, totals in billion euro

Figure A.2: Economic and accounting sales by asset category, totals in billion euro

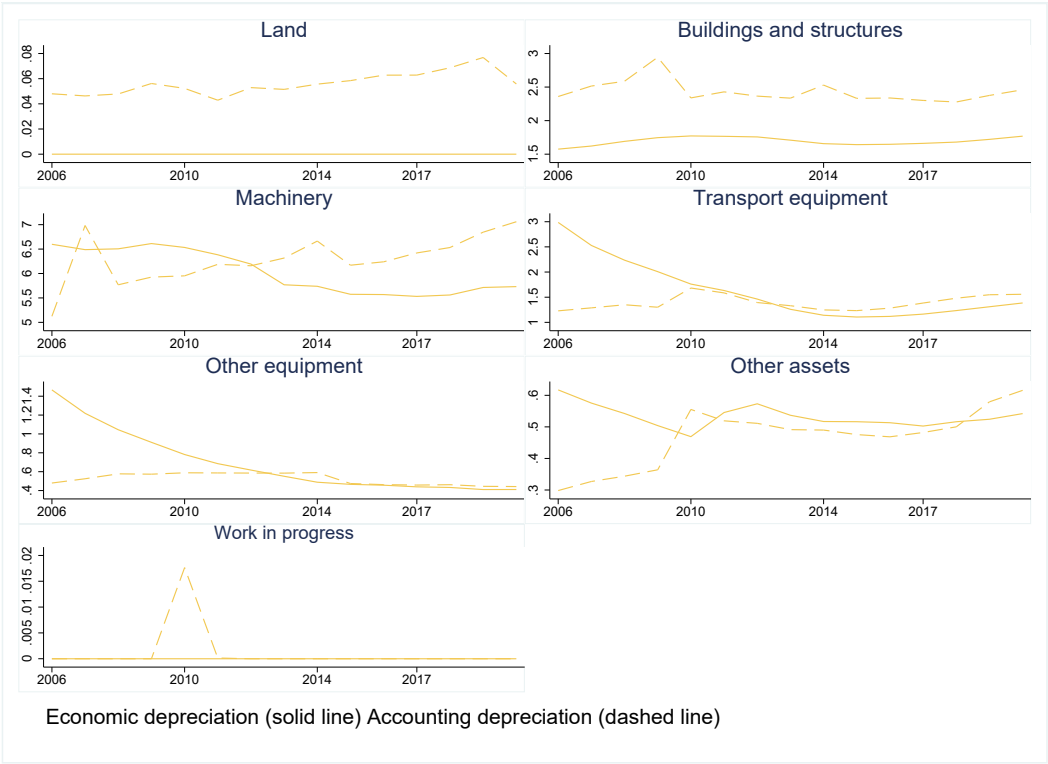


Figure A.3: Economic and accounting depreciation by asset category, totals in billion euro

Figure A.4: Economic, accounting and PIM volume variations by asset category, totals in billion euro

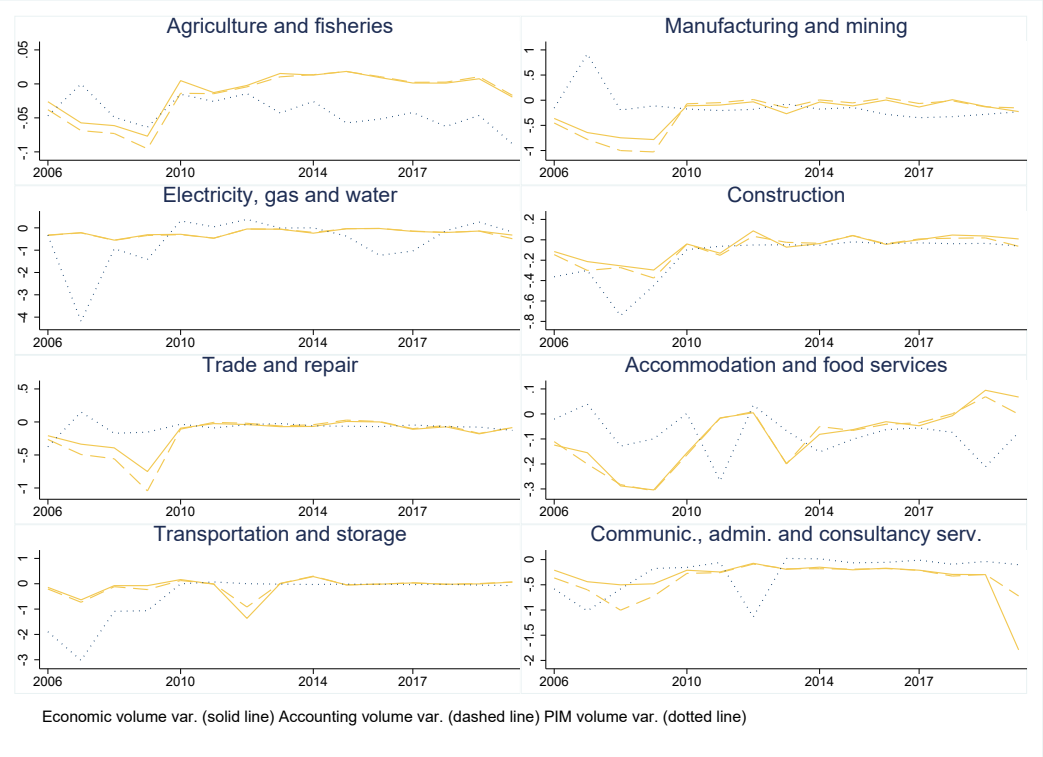


Figure A.5: Economic, accounting and PIM volume variations by sector, totals in billion euro

Occasional Papers

2019

1|19 The Deepening of the Economic and Monetary Union
João Amador | João Valle e Azevedo
Cláudia Braz

2|19 A tentative exploration of the effects of Brexit on foreign direct investment *vis-à-vis* the United Kingdom
Ana de Almeida | Duncan Van Limbergen
Marco Hoeberichts | Teresa Sastre

3|19 Sovereign exposures in the Portuguese banking system: evidence from an original dataset
Maria Manuel Campos | Ana Rita Mateus
Álvaro Pina

4|19 Economic consequences of high public debt and challenges ahead for the euro area
Cristina Checherita-Westphal | Pascal Jacquinot | Pablo Burriel | Maria Manuel Campos | Francesco Caprioli | Pietro Rizza

2020

1|20 Banco de Portugal TARGET balance: evolution and main drivers
Rita Soares | Joana Sousa-Leite | João Filipe | Nuno Nóbrega

2|20 Imputation of the Portuguese Household Finance and Consumption Survey
Luís Martins

3|20 The short-term impact of the COVID-19 pandemic on portuguese companies
Cristina Manteu | Nuno Monteiro
Ana Sequeira

4|20 Occasional paper on crypto-assets
Banco de Portugal working group on crypto-assets

2021

1|21 Assessment of the exposure of the portuguese banking system to non-financial corporations sensitive to climate transition risks
Ricardo Marques | Ana Margarida Carvalho

2022