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Estimating non-financial assets by institutional sector for the euro area

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Contents

Abstract

Official euro area-wide statistics on the capital stock and its breakdowns by asset type and sector are not yet available, but would be very useful for economic and financial stability analysis. This paper proposes a constrained optimisation model with the help of which a full cross-sector classification of the capital stock by non-financial asset type can be estimated. The model is applied for the estimation of the capital stock by institutional sector, including households' non-financial asset types and housing wealth, both for the euro area as a whole and for euro area countries currently not estimating and/or publishing such data.

JEL classification: C33, C82, E02, E22.

Keywords: capital stock, households' housing wealth, Perpetual Inventory Method, constrained optimisation, euro area, institutional sector.

Non-technical summary

In response to a request by the G20 in April 2009 to pinpoint data gaps and suggest improvements to data collection, the Financial Stability Board and the International Monetary Fund formulated 20 recommendations – one of which tackled the subject of a better sector breakdown of economic data. In the same year, the Commission on the Measurement of Economic Performance and Social Progress included in its report a recommendation that directly addressed the sector compilation of balance sheets including non-financial assets. More recently, the results of the first and second waves of the Household Finance and Consumption Survey published by the European Central Bank have contributed to renewed interest in household wealth data and estimates of households' non-financial wealth, for the purposes of economic and financial stability analysis.

The cross-classifications in the national accounts of fixed assets (capital stock) and gross fixed capital formation (investment) by industry and by asset type are reported by most euro area countries as part of the European System of Accounts transmission programme. For the few euro area countries that do not report capital stock, it can be estimated by applying the Perpetual Inventory Method. However, the compilation of euro area balance sheets for non-financial assets by institutional sector is challenging, since most euro area countries do not provide a detailed sector breakdown for each of the different asset types.

In order to obtain the sector breakdown for non-financial assets, we propose an optimisation model that cross-classifies capital stock by industry into institutional sectors. In particular, the model uses available capital stock data reported by euro area countries and links the investment structures of these countries to the investment structures of euro area countries for which capital stock data are not reported. The proposed model assumes that where there is similarity of investment structures between the countries, there is also similarity of asset structures. On the basis of the model, a full cross-classification of euro area capital stock by institutional sector and by asset type can be obtained. The results can also be used to compile data on households' housing wealth.

1 Introduction

This paper proposes a constrained optimisation model with the help of which a full cross-sector classification of the capital stock can be estimated. The model is applied for the estimation of the capital stock by institutional sector, including households' non-financial asset types and housing wealth, both for the euro area as a whole and for euro area countries (hereafter referred to as Monetary Union Member States or MUMS) currently not estimating and/or publishing such data.

In response to the recent financial crisis, there have been numerous efforts to strengthen data collection. More detailed and complete financial and economic data, in particular on households and non-financial corporations, would give policymakers a broader view of the structure of the economy. Such data are needed in order to understand the relationships between the different institutional sectors of the economy. More detailed sector data would give information that could identify in a timely manner the vulnerability of the different domestic sectors to external shocks. Capital stock figures are essential for economists as they are a component of housing wealth. Being able to differentiate the capital stock at a sectoral level allows us to compile sector-specific wealth series.

Wealth data are important economic variables in many respects, one of them being the possible link to household consumption (see for example Baker, 2011, Kerdrain, 2011, Sousa, 2009, and Skudelny, 2009). First, economic agents could use part of their accumulated assets to finance current consumption expenditure. Second, wealth could be used as collateral for borrowing. In particular, households can offer non-financial wealth (e.g. housing) as collateral, which would ease their access to credit in the event that credit supply is constrained.

Households' net worth (the national accounts term for household wealth) is calculated as the sum of financial assets (+), non-financial assets (+) and financial liabilities (-), and thus measures the excess of households' assets over households' liabilities. A time-series presentation of households' net worth gives an insight into the balance sheet strengths (or weaknesses) of households at given points in time. In turn, it shows the impact of transactions and price changes on the stocks of households' assets and liabilities.

According to the European System of Accounts (ESA 95) (Eurostat, 1996), assets are "entities that must be owned by some unit, or units, and from which economic benefits are derived by their owner(s) by holding or using them over a period of time". Economic assets may be either financial assets or non-financial assets. Non-financial assets are grouped into two broad categories: produced and non-produced assets. Produced assets are non-financial assets that have come into existence as outputs from production processes. Non-produced assets are non-financial assets that have come into existence in ways other than through processes of production. Non-financial assets, or capital, have a dual role in an economy as a source of capital services in production and as a store of wealth. "Measuring Capital" (OECD, 2009) discusses the concepts and provides practical guidelines for measuring stocks

and flows related to (primarily) produced non-financial assets. However, it does not elaborate on the different approaches that can be used in order to obtain the sectoral breakdown of the capital stock. This makes the classification of the capital stock by institutional sector a challenge for many national compilers. The compilation of euro area balance sheets for non-financial assets by institutional sector is even more difficult since most of the MUMS do not provide detailed sector breakdowns for the different asset types. Since end-2009 quarterly euro area non-financial assets (gross and net) have been compiled for the total economy by asset type and for total fixed assets by institutional sector. At present, there is no compilation of the different non-financial assets into institutional sectors.

The theory underlying capital stock measurement was introduced in the 1960s by Jorgenson (1963). Later on, Hall and Jorgenson (1967) worked on the estimation of the cost of capital. Jorgenson and Griliches (1967) and Jorgenson and Christensen (1969) modelled a measure of capital using service prices. After the 1960s a large number of economists worked on capital theory (see Jorgenson, 1969, Hulten, 1990, and Diewert et al., 2006).

In addition to the academic research done in this field, central banks and statistical institutes worldwide work on estimating non-financial assets to complete national balance sheets. The most widely used manual on capital stock estimation was published by the Organisation for Economic Co-operation and Development (OECD) in 2001 (see OECD, 2001) and a revised edition, taking into account more recent developments and the 1993 revision of the System of National Accounts (SNA), appeared in 2009 (see OECD, 2009).

The available approaches to calculate the capital stock can be separated into two groups depending on the information that they use. The first group of methods mainly uses data relevant to the level of the capital stock and does not consider investment information, whereas the second group of models uses information both on the level of the capital stock and gross investment flows. Current studies applying the first group of methods are Bughin (1993) and Wolfson (1993) who use companies' book values taken from annual financial reports in order to proxy the capital stock. Other economists use output capacity measures to obtain capital stock series, e.g. Lindquist (1995, 2000), Ohanian (1994), Reynolds (1986) and Lock (1985). Biorn et al. (1998) use stock exchange values as proxies for the capital stock.

The major drawbacks of the first group of models relate to the high costs of the estimations, and the limited availability and adequacy of the data. The most widely used approach in the empirical literature belongs to the second group of models and is called the Perpetual Inventory Method (PIM). This method is much less costly than the directly observed methods since it only takes into account investment data, which have to be combined with the corresponding retirement and depreciation rates and some initial stock. Some examples are Hahn et al. (1984), Boehm et al. (2002) and Costa et al. (1995). Little has been done to assess the effects of the a priori assumptions on the initial stock and retirement rates in the PIM. There are only a few studies, among which Usher (1980), Miller et al. (1983), Barnhart et al. (1990) and Biorn et al. (1999).

In this paper, we propose a new estimation method following a bottom-up approach and try to model country-specific non-financial asset estimates, and then compile the euro area (EA) balance sheets. The paper is organised in the following way. Section 2 gives an overview of data availability for the different MUMS. Section 3 introduces the enhanced methodology used to estimate the institutional sector breakdown of each non-financial asset type for the euro area. The results are included in Section 4. Section 5 concludes.

2 Data availability

In general, statistics on stocks of financial assets and liabilities are more common than those on non-financial assets, in particular statistics on housing wealth, mainly because they are reported on a voluntary basis or with a generous timeliness. There have been many requests for more detailed data collection. For example, in April 2009 the G20 requested that the Financial Stability Board (FSB) and the International Monetary Fund (IMF) pinpoint data gaps and suggest improvements to data collection. The response of the FSB and the IMF included 20 recommendations, one of which tackled the subject of a better sector breakdown of economic data. The Commission on the Measurement of Economic Performance and Social Progress (Stiglitz et al., 2009) included in its report a recommendation that directly addressed the sector compilation of balance sheets including non-financial assets. In August 2010 the Bank for International Settlements (BIS) organised a special conference on initiatives to address data gaps revealed by the financial crisis.

Only eight MUMS report a complete cross-classification of the annual net capital stock by asset type and institutional sector (composing Table 26[1]) representing 64%[2] of gross fixed capital formation (GFCF). These are Germany, France, Latvia, Luxembourg, the Netherlands, Austria, Slovenia and Finland.[3] In addition, Estonia, Italy, Cyprus and Slovakia (17% of GFCF) publish an institutional sector breakdown just for dwellings. Data for most MUMS cover the period between 1998 and 2012; however, some breakdowns for Latvia are available for 2007 to 2010 only. A detailed description of data coverage as well as the classifications of non-financial assets and institutional sectors can be found in Annexes A.1 to A.3.

Moreover, 14 MUMS (all except Greece, Spain, Malta and Portugal) publish capital stock figures for the total economy broken down by asset type and economic activity (composing Table 20).[4] This corresponds to around 87% of euro area GFCF. Note that the timeliness of Tables 20 and 26 under the ESA transmission programme is 24 months after the end of the reference year and these tables are available on an annual basis only.

Gross fixed capital formation is reported by all 18 MUMS for the total economy broken down by asset type and economic activity (composing Table 22). The valuation reported for GFCF is in constant prices and current prices, and the time series are available at an annual and a quarterly frequency.

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1 The main data source used in the presented estimations is the data collected under the European System of Accounts transmission programme (ESA TP). These data are collected by Eurostat and cover: (i) the annual balance sheet for non-financial assets (Table 26 of the ESA TP); (ii) the cross-classification of fixed assets by industry and assets (annual data) (Table 20 of the ESA TP); and (iii) the cross-classification of gross fixed capital formation by industry and assets (annual data) (Table 22 of the ESA TP).

2 Figure for 2013.

3 Based on figures available in February 2015.

4 A detailed classification of economic activities is given in Annex A.4.

There is very sparse data on land (underlying dwellings) and households' housing wealth (HHW) for MUMS. National HHW data are available only for Germany, Spain, France, Italy and the Netherlands. These data are national central bank (NCB) estimates, except for France and the Netherlands where the data come from the respective national statistical offices.

3 Methodology

The most widely used estimation method for non-financial assets is based on the capital accumulation equation, also known as the Perpetual Inventory Method (PIM). The capital accumulation equation can be written as:

$$NCS_t = [1 - (r_t + d_t)]NCS_{t-1} + GFCF_t \quad (1)$$

where r_t is the retirement rate and d_t is depreciation for $t = 1 \ldots T$. Here NCS and $GFCF$ stand for net capital stock and gross fixed capital formation, respectively.

We can express (1) as a function of the stock in the initial period $t = 1$ in the following way:

$$NCS_t = \big(1 - (r_t + d_t)\big)NCS_{t-1} + GFCF_t$$
$$= \sum_{j=2}^{T} GFCF_j \left[\prod_{s=j+1}^{T}\big(1 - (r_s + d_s)\big)\right] + NCS_1 \prod_{i=2}^{T}\big(1 - (r_i + d_i)\big) \quad (2)$$

In order to calculate the EA capital stock series from equation (2), we have to estimate r_t, d_t and NCS_1 for the EA aggregate. The EA GFCF series are available at quarterly and annual frequency. There are two approaches that can be taken in order to estimate the EA capital stock: an "aggregate" approach (which was used in the past by the ECB to estimate the euro area capital stock) and a "bottom-up" approach (which is the enhancement of the estimation of the euro area capital stock that this paper introduces). We will present the two approaches in the following sections.

3.1 The "aggregate" approach for the estimation of the euro area capital stock

The first approach tackles the estimation as an "aggregation" problem, thus trying to estimate EA figures directly without using granularity at a MUMS level. The ECB implemented a similar approach in 2008 and used it until 2013 to estimate the euro area capital stock for the total economy, including a breakdown by main asset type. The "aggregate" approach has several limiting assumptions. In order to estimate EA retirement and depreciation rates, equation (1) is solved using the aggregated capital stock and gross fixed capital formation series from the MUMS reporting them. The estimated retirement and depreciation rates are assumed to hold for the capital stock aggregates for the euro area. In order to calculate the initial net capital stock at $t = 1$, it is assumed that for the block of reporting MUMS the GDP-to-capital stock ratio at $t = 1$ is equal to the aggregate GDP-to-capital stock ratio at $t = 1$ for the euro area. In addition, the sector breakdown of the EA fixed asset series is done using the shares reported by the eight reporting MUMS.

The shaded areas in Table 1 show the institutional sectors and non-financial assets for which EA estimates can be obtained based on the "aggregate" method under the

assumptions described above. As can be seen, there is not a breakdown by institutional sector for all fixed assets.

Table 1

Estimates of euro area non-financial assets by asset type and institutional sector using the "aggregate" method

Institutional Sector / Produced Non-Financial Assets (NFA)	Total economy (S1)	Non-financial corporations (S11)	Financial corporations (S12)	General government
Fixed assets (AN.11)				
Dwellings (AN.1111)				
Other buildings and structures (AN.1112)				
Machinery and equipment (AN.1113)				
Other produced assets (AN.111N)				

The shaded areas represent the available estimates for the euro area.

The "aggregation" approach is not optimal since MUMS have very heterogeneous non-financial asset allocations and corresponding depreciations. The two most important enhancements of the "aggregate" method are the sectorisation of all produced assets using all available country data and the estimation of the granular capital stock data at country level which could then be used for the compilation of the EA figures.

3.2 The bottom-up approach for the estimation of the euro area capital stock

In the bottom-up approach proposed below, we consider each of the 18 MUMS separately and thus work at country level. In this way, the non-financial balance sheet for each individual MUMS is obtained and the euro area figures are compiled based on the country data (reported or estimated).

It is important to emphasise that this paper concentrates on the methodology used to establish the euro area capital stock estimates. The methodology presented here takes into account published country data or estimates any missing country data. It should be noted that the estimated country HHW figures were presented to the members of the ECB's Working Group on Euro Area Accounts and validated by the data compilers. The country estimates are currently published as part of the ECB's Household Sector Report[5].

[5] http://sdw.ecb.europa.eu/reports

3.3 Optimisation model to obtain a full sector breakdown by asset type

As noted previously, the main goal of this paper is to obtain a non-financial asset type classification by sector and such a breakdown of annual non-financial assets is reported by only eight MUMS.

Let us call all MUMS that report the capital stock by asset type and institutional sector the available countries. The missing countries do not report such cross-classifications, but only the total capital stock by asset type. In addition, for all 18 MUMS we have GFCF by asset type and industry. The model presented below is a two-step procedure, which compiles a full institutional sector breakdown for each asset type for each of the MUMS. The main assumption is that countries that have very similar industry breakdowns would also have similar sector breakdowns.

In the first step of the estimation, we use data from the cross-classification of GFCF by industry and by asset type from the ESA transmission programme (Table 22) to estimate a measure that indicates how close the industry breakdown of each missing country is to the industry breakdown of each of the available countries.

Let us denote the different asset types as $AN = \{AN11, AN1111, AN1112, AN1113, AN111N\}$.[6] Each asset type is decomposed into industries denoted as $V = \{VA, VB, VC, \dots, VU\}$.[7] We denote the data from the available countries with X_j where $j \in J$ indicates the reporting countries, and the data from the missing countries with Z_i where $i \in I$ indicates the missing countries. The set of all reporting countries is denoted with J and the set of all missing countries is denoted with I. Then, for each missing country i, the following constrained linear least-squares problem is defined:

$$\min_{\alpha_{ij}^{AN}} \frac{1}{2} \left\| \alpha_{ij}^{AN} \sum_j^J (X_j)_V^{AN} - (Z_i)_V^{AN} \right\|_2^2 \tag{3}$$

$$\forall i \in I \quad \sum_j \alpha_{ij}^{AN} = 1 \tag{4}$$

$$subject\ to \quad \forall i \in I, \forall j \in J \quad 0 \leq \alpha_{ij}^{AN} \leq 1 \tag{5}$$

The two constraints that are imposed are needed so that the estimated $\hat{\alpha}_{ij}^{AN}$ s serve as a weighting measure that shows the similarities of the activity classification between any available country j and missing country i. Note that equation (3) holds for each missing country i and asset type AN. Once the $\hat{\alpha}_{ij}^{AN}$ s are estimated, we can use them as a universe measure that relates also to the similarities of the institutional sector breakdown of the different countries. Knowing the breakdown for the assets of the available countries j, we can estimate the institutional sector breakdown of the missing countries i. Note that the capital stock for the total

6 The notation that follows will be expressed in a matrix form, which is why the time dimension t will be dropped.

7 The lists with all possible asset, sector and industry breakdowns are included Annexes A.2, A.3 and A.4.

economy by asset type is known for most of the MUMS and is obtained from the cross-classification of fixed assets by industry and asset type from the ESA TP (Table 20). The total economy capital stock by asset type for the few MUMS not reporting these data is estimated and will be discussed later on.

Let us denote the set of institutional sectors as $S = \{S_1, S_{11}, S_{12}, S_{13}, S_{1M}\}$[8]. Then, for each $j \in J$ and AN, we know the shares $\left\{ \left(\frac{S_{11}}{S_1}\right)_j^{AN}, \left(\frac{S_{12}}{S_1}\right)_j^{AN}, \left(\frac{S_{13}}{S_1}\right)_j^{AN}, \left(\frac{S_{1M}}{S_1}\right)_j^{AN} \right\}$. This information is obtained from Table 26. For each i and AN, we know $(S_1)_i^{AN}$, which is retrieved from Table 20 or estimated. We assume that the similarities between the industry breakdowns also hold for the institutional sector breakdowns. In this way, we can estimate $\left\{ (\hat{S}_{11})_i^{AN}, (\hat{S}_{12})_i^{AN}, (\hat{S}_{13})_i^{AN}, (\hat{S}_{1M})_i^{AN} \right\}$ based on the similarities of the breakdowns by industry $\hat{\alpha}_{ij}^{AN}$. For each i and asset type AN, the following shares hold:

$$\left(\frac{\hat{S}_{11}}{S_1}\right)_i^{AN} = \left[\sum_j \hat{\alpha}_{ij}^{AN} \left(\frac{S_{11}}{S_1}\right)_j^{AN}\right] \quad (6)$$

$$\left(\frac{\hat{S}_{12}}{S_1}\right)_i^{AN} = \left[\sum_j \hat{\alpha}_{ij}^{AN} \left(\frac{S_{12}}{S_1}\right)_j^{AN}\right] \quad (7)$$

$$\left(\frac{\hat{S}_{13}}{S_1}\right)_i^{AN} = \left[\sum_j \hat{\alpha}_{ij}^{AN} \left(\frac{S_{13}}{S_1}\right)_j^{AN}\right] \quad (8)$$

$$\left(\frac{\hat{S}_{1M}}{S_1}\right)_i^{AN} = \left[\sum_j \hat{\alpha}_{ij}^{AN} \left(\frac{S_{1M}}{S_1}\right)_j^{AN}\right] \quad (9)$$

In this way, we obtain a weighting matrix that can break down asset types into different institutional sectors for all MUMS. Once the country breakdown is obtained, the EA asset type by institutional sector is calculated as the accumulation of all country-specific breakdowns. In order to obtain the quarterly estimates for the capital stock, we use quarterly series on investment (available for all EA countries) to perform Chow-Lin (1971) temporal disaggregation of the annual capital stock.

3.4 Estimating total economy fixed assets for the non-reporting MUMS

As mentioned earlier, there are four MUMS (Greece, Spain, Malta and Portugal) for which there are no data on the capital stock (these countries are neither present in Table 20 nor in Table 26). For such countries, we can obtain the similarity index as described above since it is based on the GFCF classification for which we have full data coverage. However, we do not have the total economy capital stock by asset type to be able to perform the breakdown into institutional sectors. In order to

[8] Note that S1 = S11 + S12 + S13 + S1M. A sector classification is included in Annex A.3.

estimate the completely missing series on the capital stock for the total economy, we use the initial “aggregate” PIM methodology, with several modifications, and apply it to the four MUMS listed above.

For the calculation of the initial capital stock for the missing countries, we use the ratio of the accumulated consumption of fixed capital (K1) to the accumulated capital stock of the reporting countries. Knowing K1 for the missing countries and using the calculated ratio, we generate the initial capital stock for each of the missing countries. We choose 2005 as the starting year in our accumulation equation and we forecast and backcast the capital stock to cover the period from 1998 to 2013. For each of the reporting countries, the retirement and depreciation rates are calculated using the PIM equation. For the missing countries, the rates of the most “similar” reporting countries are taken into account. The similarity of gross fixed capital formation between countries is calculated using the Bray-Curtis distance.[9]

A detailed sensitivity analysis on the selection of the initial year of the capital stock and the use of different retirement and depreciation rates is presented in the next section.

[9] The index is composed based on country investment data for each non-financial asset. A detailed description is included in Annex A.6. The Bray-Curtis measure is usually used to compare countries based on their trade structure.

4 Results

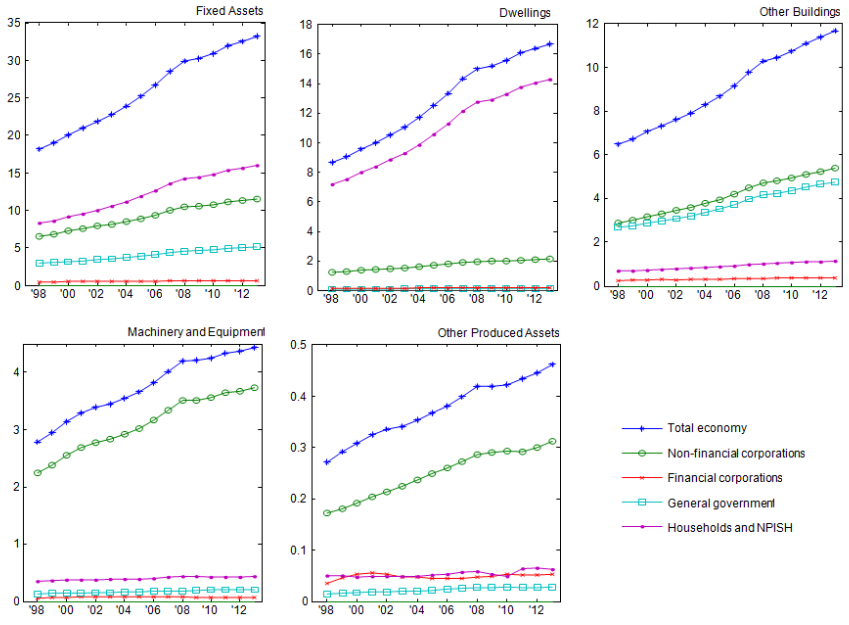
4.1 The enhanced capital stock estimates for the euro area

In this section, we present the results for the aggregated EA non-financial asset estimates. All of the series are at current prices. The results presented in this section cover the period from 1998 to 2013. Figure 1 displays the estimated capital stock by asset type broken down into institutional sectors. Figure 2 shows the asset composition for each sector. The new estimation allows for the calculation of the sector breakdown for all asset types. In addition, Figure 3 shows the share distribution of the institutional sectors for each of the asset types. As can be seen from Figures 1 to 3, the biggest portion of the fixed assets is owned by households and non-profit institutions serving households (NPISH) (on average around 42%), followed by non-financial corporations (NFCs) (on average around 39%). The same order of the institutional sector shares is observed for dwellings (on average around 85% for households and 13% for NFCs). As expected, the largest shares for other buildings are observed for NFCs and general government, followed by households and financial corporations. Machinery and equipment is mostly built up by NFCs, with very small portions attributed to the other three sectors. The allocation of sector shares for other produced assets is similar.

Figure 1

Net capital stock in current prices by asset type

(levels, EUR trillions)



The proposed estimation method allows us to analyse the sector allocation of the capital stock broken down into assets (see Figure 2). The largest portion of total

economy fixed assets is accounted for by dwellings, mainly owned by households. However, for the three remaining sectors (NFCs, general government and financial corporations), the biggest share of the capital stock is made up of other buildings, followed by dwellings, machinery and other produced assets.

Figure 2

Net capital stock in current prices by sector

(levels, EUR trillions)

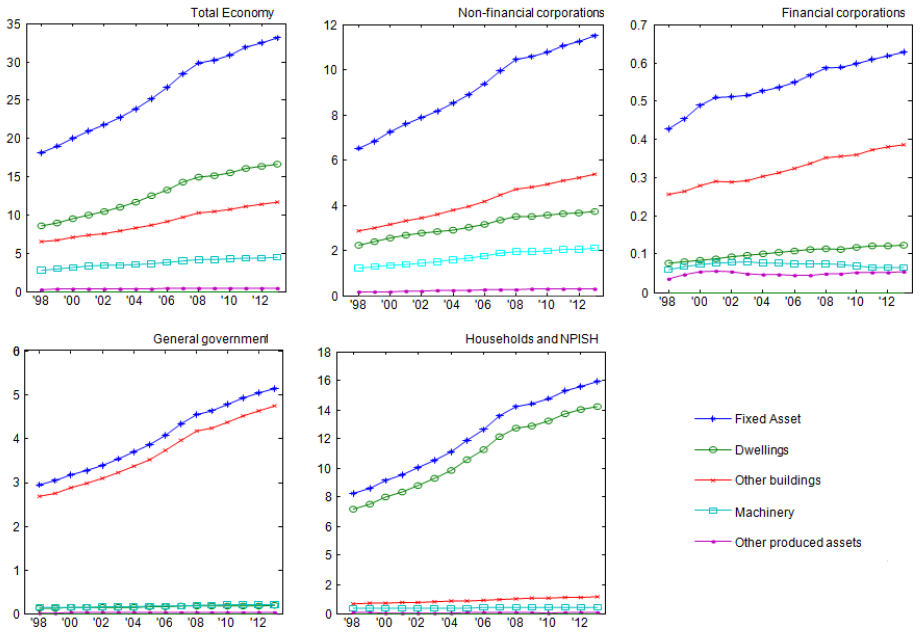
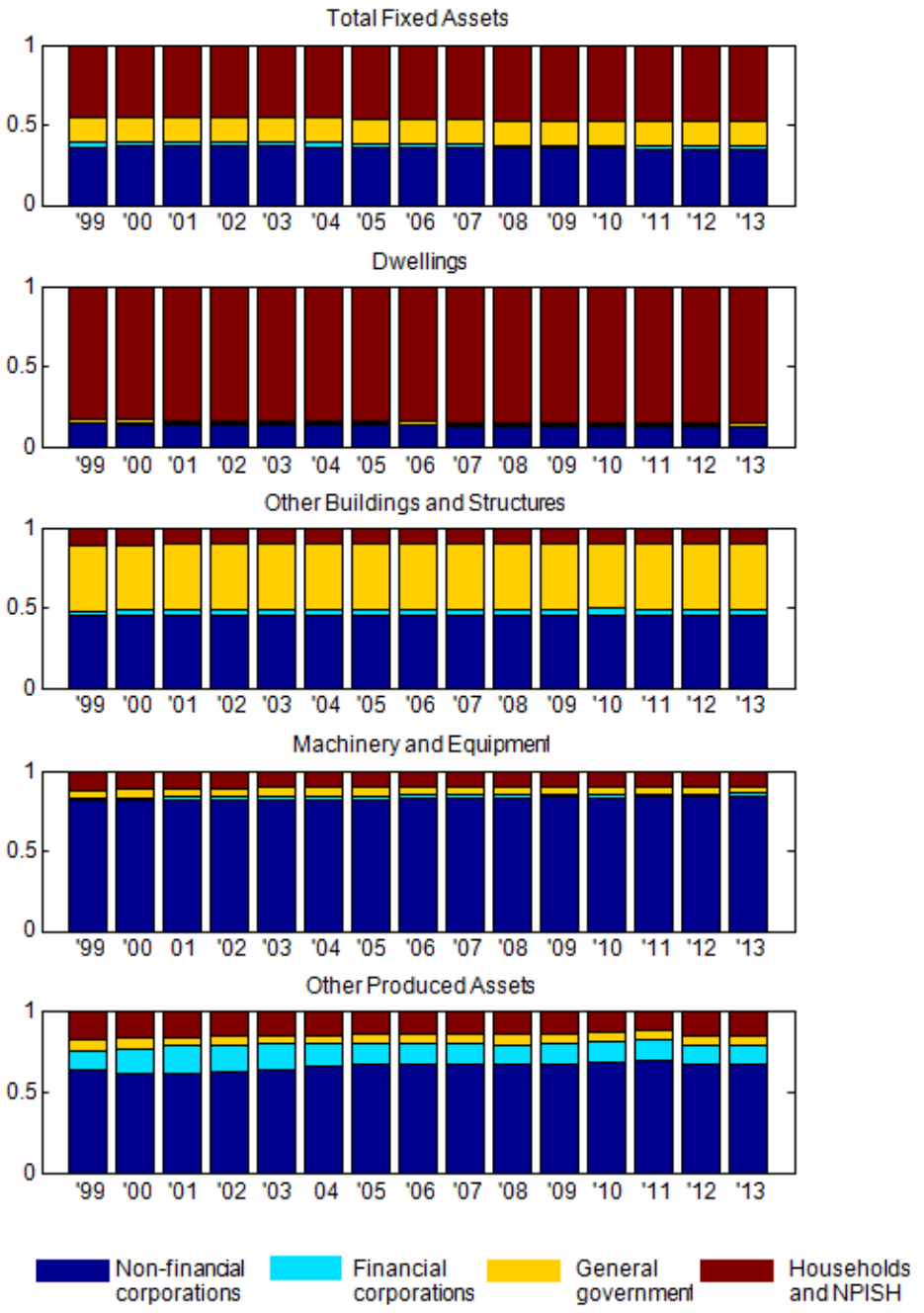


Figure 3

Breakdown of capital stock asset types by sector

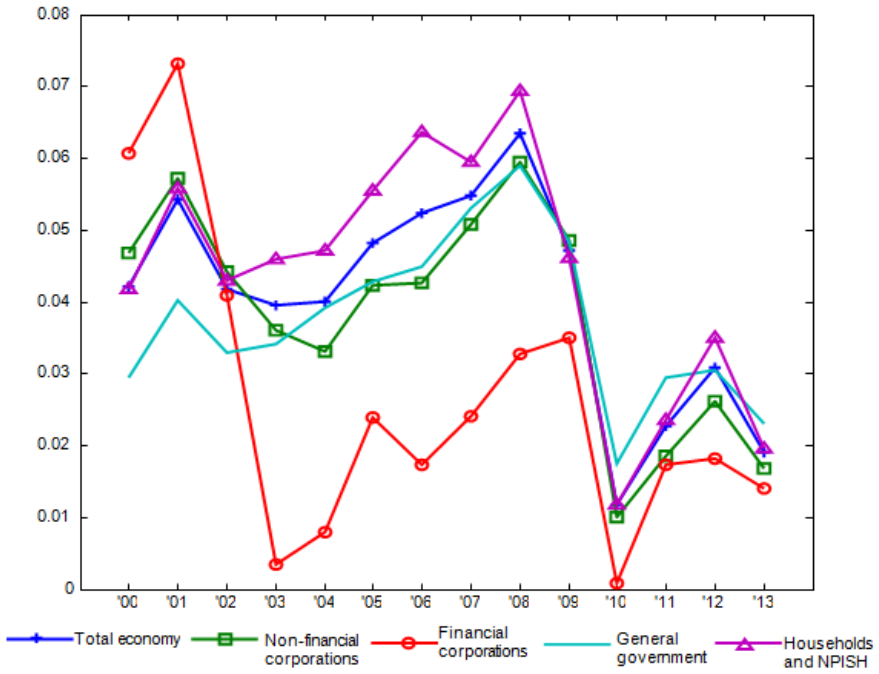


As can be seen from Figures 1 and 2, the time series are pretty stable with one exception. There is a slight fluctuation in the capital stock for almost all of the series after 2008 which is due to the effect of the financial crisis. This is confirmed by Figure 4, where the growth rates of the capital stock for the different sectors are displayed. The biggest drop in growth rates in 2009 relative to 2007 occurred for the household sector. The growth rate of this sector fell from 0.074% in 2007 to 0.012%

in 2009, i.e. by around 0.06 percentage point in absolute terms. In comparison, the growth rate of the capital stock for the financial corporation sector shrank from 0.035% in 2007 to 0.001% in 2009, which is a decrease of around 0.03 percentage point in absolute terms. The drop in the financial corporation sector between 2000 and 2002 is explained by the stock market downturn in 2002 when the dot-com bubble burst.[10]

Figure 4

Fixed asset net capital stock in current prices by sector (annual growth rates)



4.2 Robustness checks

In this section, we discuss some of the assumptions mentioned earlier. First, we test the robustness of the presented optimisation model, and then we examine the PIM assumptions introduced in Section 3.2.2.

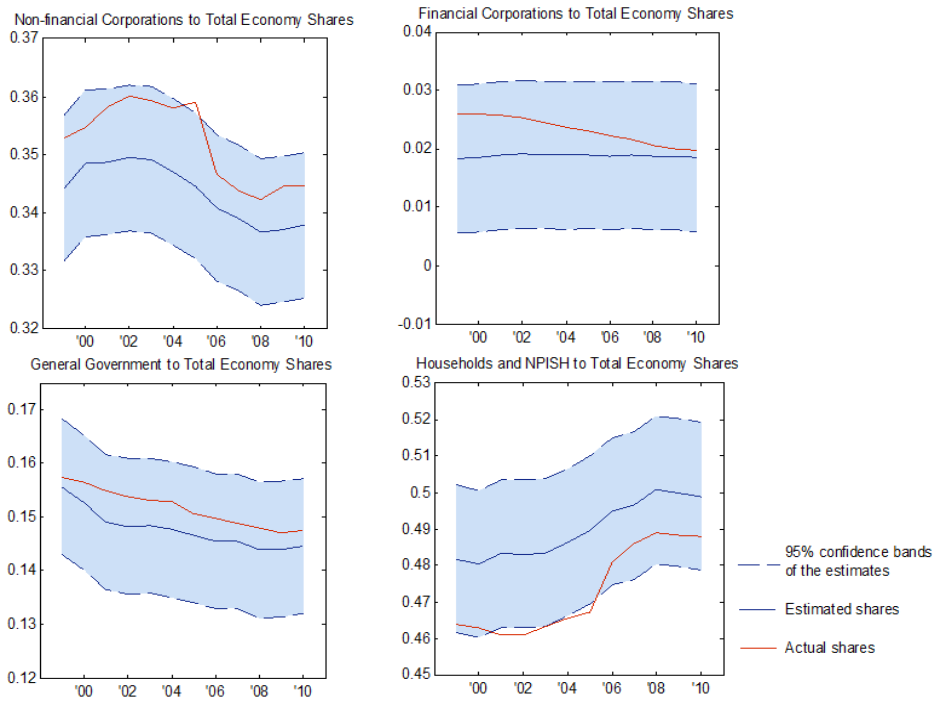
In order to make sure that the new model correctly estimates the shares of the different sectors in the total economy stock, we perform the following experiment. For each of the MUMS for which we have an institutional sector breakdown for fixed assets, we try to estimate this breakdown (the countries considered include Germany, France, Latvia, Luxembourg, the Netherlands, Austria, Slovenia and Finland). In a recursive exercise for each of the listed countries, we estimate institutional sector breakdowns based on the remaining seven countries using the

[10] The data on the euro area capital stock are released in the ECB's Statistical Data Warehouse (link). All euro area figures are estimates based on the presented methodology following the ESA 95.

model proposed in Section 3.2.1. Figure 5 displays the estimated and actual shares, along with the 95% confidence intervals of the accumulated estimates for the above countries. It can be seen that in the majority of cases, the actual shares lie within the confidence intervals of the estimates, which confirms that the proposed method can estimate a reliable institutional sector breakdown of the EA aggregate.

Figure 5

Sector shares relative to the total economy for the net capital stock of fixed assets



The PIM assumptions that were presented in the methodology in Section 3.2.2 are also tested in order to obtain the most accurate capital stock estimate. As stated earlier, the year 2005 is chosen as the initial year of the PIM from where we forecast and backcast the capital stock. Then, the ratio of consumption of fixed capital to fixed assets for reporting MUMS is used to estimate the initial capital stock for missing MUMS. In order to justify these assumptions, we evaluate different methods to generate the initial capital stock in different starting years. We consider the MUMS for which we have data and try to estimate the initial stock for each one of them on the basis of the rest of the available stock. We then generate the accumulated stock estimates for the available MUMS and calculate the Root Mean Square Error (RMSE) of the forecast for each initial year relative to the actual stock values. Table 2 presents the results. It can be concluded that the best method to generate the initial stock is to use the consumption of fixed capital-to-capital stock ratio for 2005. The poorly performing alternative methods considered different functions of investment or GDP-to-capital stock ratios.

Once the initial capital stock has been estimated for the non-reporting MUMS, we have to choose the retirement and depreciation rates that are entered into the accumulation equations. We use the Bray-Curtis distance measure to compare the

distribution of investment within industries across all countries. Table 3 presents the results. The lower score indicates stronger similarity, which means that the retirement and depreciation rates of the countries with low scores should be similar.

Table 2

RMSE of capital stock estimates of reporting countries

Year	Method				
	GDP/CS	I/CS	sum(I)/CS	sum(I-K1)/CS	K1/CS
1998	0.0380	0.0545	0.0205	0.0446	0.0572
1999	0.0389	0.0413	0.0364	0.0271	0.0367
2000	0.0034	0.0028	0.0065	0.0120	0.0029
2001	0.0029	0.0036	0.0056	0.0124	0.0025
2002	0.0027	0.0039	0.0048	0.0127	0.0023
2003	0.0025	0.0040	0.0041	0.0126	0.0022***
2004	0.0025	0.0034	0.0030	0.0136	0.0019**
2005	0.0025	0.0037	0.0026	0.0134	0.0018*
2006	0.0026	0.0037	0.0027	0.0131	0.0024
2007	0.0027	0.0041	0.0026	0.0127	0.0024
2008	0.0028	0.0043	0.0025	0.0129	0.0027
2009	0.0384	0.0270	0.0419	0.0096	0.0454
2010	0.0418	0.0371	0.0311	0.0129	0.0536
2011	0.0395	0.0285	0.0456	0.0426	0.0529
2012	0.4330	0.4810	0.1011	0.1218	0.0920

The three minimum values are indicated with stars. GDP=gross domestic product, CS=capital stock, I=GFCF, K1=consumption of fixed capital.

Table 3

Bray-Curtis similarity distance between missing countries and reporting countries

Reporting countries	Missing countries			
	Spain	Portugal	Greece	Malta
Italy	0.157	0.152*	0.202	0.143*
Slovakia	0.329	0.284	0.340	0.307
Estonia	0.179	0.166	0.196	0.164
Belgium	0.168	0.189	0.219	0.173
Cyprus	0.110*	0.158	0.140*	0.190
Austria	0.167	0.172	0.195	0.189
The Netherlands	0.143	0.161	0.142	0.211
Slovenia	0.221	0.164	0.242	0.201
Finland	0.202	0.210	0.224	0.230
Germany	0.201	0.223	0.271	0.177
France	0.161	0.185	0.209	0.214
Ireland	0.252	0.194	0.200	0.286

The distances with stars are the minimum distance measures indicating similarity between the missing and reporting countries.

5 The relevance of the enhanced capital stock estimates to monetary policy

As discussed in the introduction, the capital stock is an important component of housing wealth. Being able to differentiate the capital stock at a sectoral level helps us to compile sector-specific wealth series. For policymakers and economists, it is essential to be able to analyse the transmission of monetary policy within different institutional sectors. In this way, sector-specific vulnerabilities can be identified and addressed. Maintaining price stability is the main goal of monetary policy. This is achieved through the reactions of households and non-financial corporations to central banks' monetary policy initiatives (Bull, 2013). Monitoring developments in these sectors, and across MUMS, is therefore of key interest, and balance sheet information, including non-financial assets, contributes to the quality and range of sector analysis. Since the recent financial crisis, much effort has been made to understand the structure of the household sector and its exposure to financial shocks. Most of the time, economists analyse the resilience of household wealth during difficult financial times. One of the biggest contributors to household wealth is households' housing wealth (HHW).

To arrive at housing wealth, the estimates on dwellings should be complemented with the value of the land underlying the dwelling. Usually the value of land is estimated using administrative data or survey data. Alternatively, land can be estimated as a residual of HHW and households' dwelling stock. In the current estimates, we use available national data on HHW to calculate the average ratio of net HHW over the net dwelling stock.[11] This ratio is subsequently used to estimate HHW for non-reporting MUMS. Next, euro area HHW is estimated as an aggregate of the reported MUMS HHW and the estimated ones.

Annex A.6 shows households' wealth in the euro area, broken down by asset type. Non-financial assets are by far the largest component (60%) of gross wealth (sum of financial and non-financial assets) and they accounted for most of the marked pre-crisis growth (2000-07). Their importance has increased significantly since 2000, mainly due to increasing property prices.

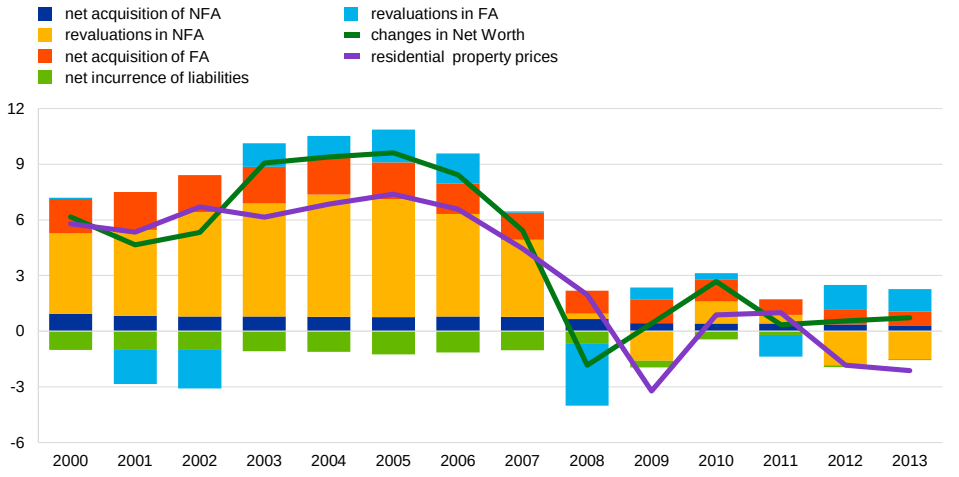
This also becomes clear from Figure 6, which decomposes growth of euro area households' net worth into household transactions and valuation changes. Valuation changes (or holding gains and losses) account for most of the changes in households' net worth, notably those of non-financial assets. However, holding losses, reflecting negative stock price developments, contributed significantly to the marked deceleration and fall of households' net worth in 2008, which was followed

[11] Official series up to 2012 (except for Spain: 2013) are published for Belgium, Germany, France, Italy and the Netherlands. In addition, figures for Greece, up to 2001, were taken from the November 2002 Monetary Policy Report of the Bank of Greece; provisional estimates for 2002-05 were provided by the Bank of Greece; data after 2005 were estimated by extrapolation using residential property prices and housing investment.

by the fall in prices of non-financial assets (e.g. houses) in 2009. Net acquisitions of assets and net incurrence of liabilities provide a fairly stable, though modest contribution. From 2007 onwards, growth in the net incurrence of liabilities decelerates, reflecting the deleveraging process of euro area households.

Figure 6

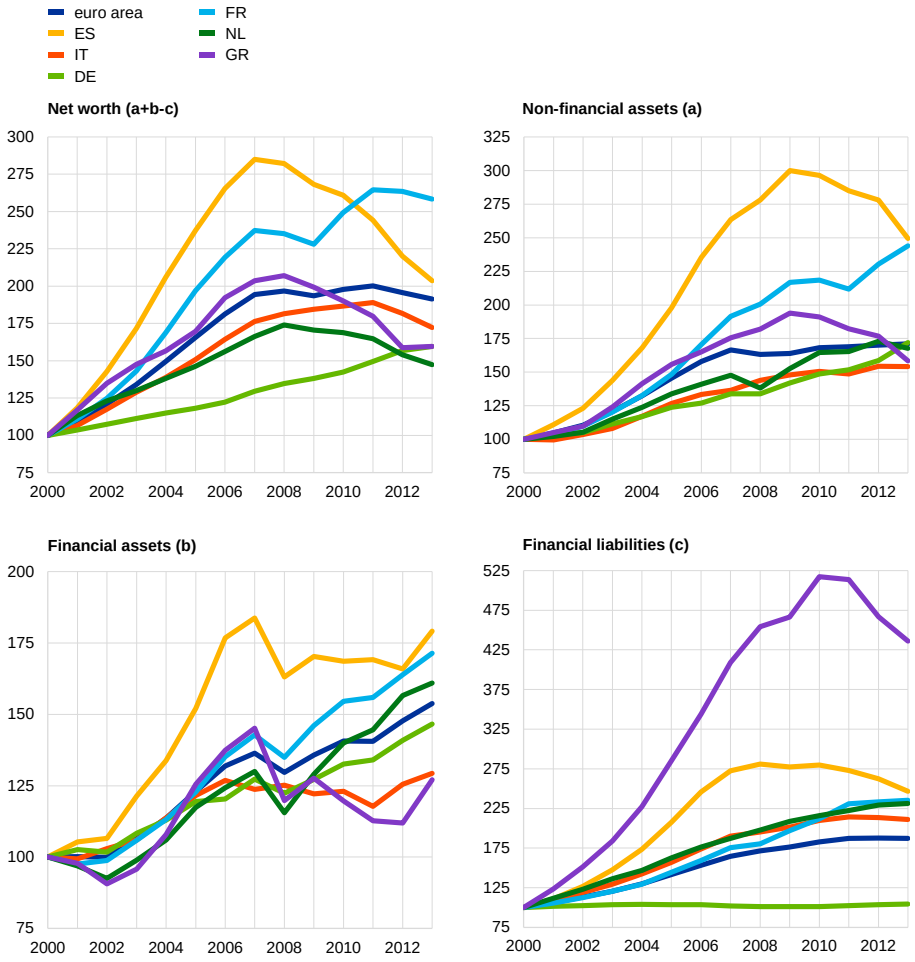
Growth in euro area households' net worth and contributions by asset type



Household wealth is unevenly distributed among MUMS and developments in such wealth are quite heterogeneous across countries (see Annex A.7 and Figure 7). This implies that a single monetary policy for the euro area may have differing impacts across euro area economies. Annex A.7 shows the main wealth characteristics for Germany, Greece, Spain, France, Italy and the Netherlands. Figure 7 shows the developments in net worth, financial and non-financial assets and financial liabilities in the euro area as a whole and in selected countries from 2000 onwards. The housing boom-bust cycle is clearly observed for Greece, Spain and the Netherlands, pushing down their non-financial wealth to pre-crisis levels. Developments in financial assets are less dispersed, as their prices (valuation changes) follow general market trends, which are mostly determined at the euro area and more likely even global level, rather than within a single country.

Figure 7

Developments of households' net worth and its components in the euro are and selected countries



6 Conclusion

Contrary to data on financial assets, official euro area-wide statistics on non-financial assets by asset type and sector are not yet available, but would be very useful for economic and financial stability analysis, since they complete sectoral balance sheets. This paper proposes a constrained optimisation model with the help of which a full cross-sector classification of the capital stock can be estimated. The model is applied for the estimation of the capital stock by institutional sector, including households' non-financial asset types and housing wealth, both for the euro area as a whole and for euro area countries currently not estimating and/or publishing such data.[12] The obtained capital stock estimates are very useful for policymakers and financial stability exerts as they are a building block of gross wealth. The new figures complement the sectoral assessment of the monetary policy transmission mechanism and the analysis of the different sectors' resilience to financial shocks.

[12] The euro area capital stock estimates are published in the ECB's Statistical Data Warehouse

Annex

A.1 Data availability table 20 ESA95 transmission programme

Cross-classification of fixed assets by industry and assets

Country	Fixed assets	Dwellings	Other buildings and structures	Machinery and equipment	Cultivated assets plus intangible fixed assets
Belgium	2000-2012	2000-2012	2000-2012	2000-2012	2000-2012
Germany	2000-2011	2000-2011	2000-2011	2000-2011	2000-2011
Estonia*	2000-2011	2000-2011	2000-2011	2000-2011	2000-2011
Ireland	2000-2011	2000-2011	2000-2011	2000-2011	2000-2011
Greece	x	x	x	x	x
Spain	x	x	x	x	x
France	1998-2012	1998-2012	1998-2012	1998-2012	1998-2012
Italy	1998-2012	1998-2012	1998-2012	1998-2012	1998-2012
Cyprus*	1998-2012	1998-2012	1998-2012	1998-2012	1998-2012
Latvia	2007-2010	2007-2010	2007-2010	2007-2010	2007-2010
Luxembourg	1998-2011	1998-2011	1998-2011	1998-2011	1998-2011
Malta	x	x	x	x	x
Netherlands	2000-2012	2000-2012	2000-2012	2000-2012	2000-2012
Austria	1998-2012	1998-2012	1998-2012	1998-2012	1998-2012
Portugal**	2005	2005	2005	2005	2005
Slovenia	2000-2011	2000-2011	2000-2011	2000-2011	2000-2011
Slovakia	2004-2012	2004-2012	2004-2012	2004-2012	2004-2012
Finland	1998-2012	1998-2012	1998-2012	1998-2012	1998-2012

*Some figures are missing for 2011.
**Total NACE only.

A.1.2 Data availability table 22 ESA95 transmission programme

Cross-classification of gross fixed capital formation by industry and assets

Country	Fixed assets	Dwellings	Other buildings and structures	Machinery and equipment	Cultivated assets plus intangible fixed assets
Belgium	1998-2013	1998-2012	1998-2013	1998-2013	1998-2013
Germany	1998-2013	1998-2013	1998-2013	1998-2013	1998-2013
Estonia	1998-2013	1998-2013	1998-2013	1998-2013	1998-2013
Ireland	1998-2012	1998-2012	1998-2012	1998-2012	1998-2012
Greece	2000-2013	2000-2013	2000-2013	2000-2013	2000-2013
Spain	1998-2013	1998-2013	1998-2013	1998-2013	1998-2013
France	1998-2013	1998-2013	1998-2013	1998-2013	1998-2013
Italy	1998-2013	1998-2013	1998-2013	1998-2013	1998-2013
Cyprus	1998-2013	1998-2013	1998-2013	1998-2013	1998-2013
Latvia	1998-2013	1998-2013	1998-2013	1998-2013	1998-2013
Luxembourg	1998-2013	1998-2013	1998-2013	1998-2013	1998-2013
Malta	1998-2013	1998-2013	1998-2013	1998-2013	1998-2013
Netherlands	1998-2013	1998-2013	1998-2013	1998-2013	1998-2013
Austria	1998-2013	1998-2013	1998-2013	1998-2013	1998-2013
Portugal	1998-2013	1998-2013	1998-2013	1998-2013	1998-2013
Slovenia	1998-2013	1998-2013	1998-2013	1998-2013	1998-2013
Slovakia	1998-2013	1998-2013	1998-2013	1998-2013	1998-2013
Finland	1998-2013	1998-2013	1998-2013	1998-2013	1998-2013

A.1.3 Data availability table 26 ESA95 transmission programme

Balance sheet for non-financial assets by sector

Country	Fixed assets	Dwellings	Other buildings and structures	Machinery and equipment	Cultivated assets plus intangible fixed assets
Germany	1998-2012	1998-2012	1998-2012	1998-2012	1998-2012
Estonia	x	2000-2011	x	x	x
France	1998-2012	1998-2012	1998-2012	1998-2012	1998-2012
Italy	x	1998-2013	x	x	x
Cyprus*	x	1998-2013	x	x	x
Latvia	2000-2010	2007-2010	2007-2010	2007-2010	2007-2010
Luxembourg	1998-2012	1998-2012	1998-2012	1998-2012	1998-2012
Netherlands	1998-2012	1998-2012	1998-2012	1998-2012	1998-2012
Austria	1998-2012	1998-2012	1998-2012	1998-2012	1998-2012
Slovenia	2000-2011	2000-2011	2000-2011	2000-2011	2000-2011
Slovakia	x	1998-2012	x	x	x
Finland	1998-2012	1998-2012	1998-2012	1998-2012	1998-2012

*Sector allocation only available for dwellings.

A.2 Non-financial asset classification

AN.1	Produced assets
AN.11	Fixed assets
AN.111	Tangible fixed assets
AN.1111	Dwellings
AN.1112	Other buildings and structures
AN.11121	Non-residential buildings
AN.11122	Other structures
AN.1113	Machinery and equipment
AN.11131	Transport equipment
AN.11132	Other machinery and equipment
AN.1114	Cultivated assets
AN.11141	Livestock for breeding, dairy, draught, etc.
AN.11142	Vineyards, orchards and other plantations of trees yielding repeat products
AN.112	Intangible fixed assets
AN.1121	Mineral exploration
AN.1122	Computer software
AN.1123	Entertainment, literary or artistic originals
AN.1129	Other intangible fixed assets
AN.111N	Cultivated assets plus intangible fixed assets (N1114 + N112)
AN.12	Inventories
AN.121	Materials and supplies
AN.122	Work in progress
AN.1221	Work in progress on cultivated assets
AN.1222	Other work in progress
AN.123	Finished goods
AN.124	Goods for resale
AN.13	Valuables
AN.131	Precious metals and stones
AN.132	Antiques and other art objects
AN.139	Other valuables

A.3 Sector classification

S1	Total economy
S11	Non-financial corporations
S12	Financial corporations
S13	General government
S1M	Households and NPISH

A.4 Economic activity classification

V	Total
VA	Agriculture, forestry and fishing
VB	Mining and quarrying
VC	Manufacturing
VD	Electricity, gas, steam and air conditioning supply
VE	Water supply, sewerage, waste management and remediation activities
VF	Construction
VG	Wholesale and retail trade; repair of motor vehicles and motorcycles
VI	Accommodation and service activities
VH	Transportation and storage
VJ	Information and communication
VK	Financial and insurance activities
VL	Real estate activities
VM	Professional, scientific and technical activities
VN	Administrative and support service activities
VO	Public administration and defence; compulsory social security
VP	Education
VQ	Human health and social work activities
VR	Arts, entertainment and recreation
VS	Other service activities
VT	Activities of households as employers; undifferentiated goods- and service-producing activities of households for own use
VU	Activities of extraterritorial organisations and bodies

A.5 Bray-Curtis measure

The Bray-Curtis distance measure is usually used to measure the similarity between countries' trade structures, but here it is used for comparing investment structures. We follow the same notation as in Section 3.2.2. The index measures the distance between two countries' investment composition for certain assets using their industry shares (the data source is Table 22). Let us denote with $(R_i)_V^{AN}$ the investment ratio of industry V in an asset AN for country i relative to the total investment in this asset. Thus the Bray-Curtis distance measure between countries i and j can be written as:

$$\beta_{ij}^{N} = \frac{\sum_V \left| (R_i)_V^{AN} - (R_j)_V^{AN} \right|}{\sum_V \left((R_i)_V^{AN} + (R_j)_V^{AN} \right)}$$

Lower values indicate a shorter distance and thus greater similarity.

A.6 Households' net worth in the euro area (2000-13)

Wealth component	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	*2000-07 average*	*2007-13 average*
	Amounts (€ bln, current prices)															
Financial assets (a)	13445	13466	13438	14312	15275	16533	17733	18330	17429	18249	18935	18879	19751	20538		
Non-financial assets (b)	15483	16860	18557	20475	22713	25080	27382	29328	29726	29254	29907	30280	29659	29152		
of which: housing wealth	14336	15681	17348	19232	21423	23750	25994	27868	28203	27727	28370	28696	28055	27435		
Gross wealth (a+b)	28928	30326	31995	34787	37987	41613	45115	47658	47155	47503	48842	49159	49410	49690		
Liabilities (c)	3683	3907	4168	4438	4784	5216	5647	6050	6311	6492	6729	6901	6921	6895		
Net worth (a+b-c)	25245	26419	27826	30349	33203	36397	39468	41608	40844	41011	42113	42257	42489	42795		
Net worth as a % of disposable income	589%	592%	593%	625%	662%	700%	734%	743%	699%	679%	700%	695%	684%	686%		
Net worth per capita (1000 euro)	80.5	83.9	88.0	95.5	103.8	113.1	121.9	127.8	124.7	124.6	127.5	127.6	127.9	128.5		
	Wealth composition (as a percent of total gross wealth)															
Financial assets (a)	46.5	44.4	42.0	41.1	40.2	39.7	39.3	38.5	37.0	38.4	38.8	38.4	40.0	41.3		
Non-financial assets (b)	53.5	55.6	58.0	58.9	59.8	60.3	60.7	61.5	63.0	61.6	61.2	61.6	60.0	58.7		
of which: housing wealth	49.6	51.7	54.2	55.3	56.4	57.1	57.6	58.5	59.8	58.4	58.1	58.4	56.8	55.2		
Gross wealth (a+b)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0		
Liabilities to gross wealth	12.7	12.9	13.0	12.8	12.6	12.5	12.5	12.7	13.4	13.7	13.8	14.0	14.0	13.9		
	Annual growth (year on year percentage change)															
Financial assets	3.5	0.2	-0.2	6.5	6.7	8.2	7.3	3.4	-4.9	4.7	3.8	-0.3	4.6	4.0	4.5	2.3
Non-financial assets	8.8	8.9	10.1	10.3	10.9	10.4	9.2	7.1	1.4	-1.6	2.2	1.2	-2.1	-1.7	9.6	-0.1
of which: housing wealth	9.3	9.4	10.6	10.9	11.4	10.9	9.4	7.2	1.2	-1.7	2.3	1.1	-2.2	-2.2	10.0	-0.3
Gross wealth	6.3	4.8	5.5	8.7	9.2	9.5	8.4	5.6	-1.1	0.7	2.8	0.6	0.5	0.6	7.4	0.8
Liabilities	6.9	6.1	6.7	6.5	7.8	9.0	8.3	7.1	4.3	2.9	3.6	2.6	0.3	-0.4	7.3	2.7
Net worth	6.2	4.6	5.3	9.1	9.4	9.6	8.4	5.4	-1.8	0.4	2.7	0.3	0.5	0.7	7.4	0.6

A.7 Households' key indicators by country (2000-13)

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
	% Contribution to euro area net worth													
Germany	25%	25%	24%	23%	23%	22%	21%	20%	20%	20%	21%	21%	22%	23%
France	19%	19%	19%	20%	20%	21%	22%	22%	22%	22%	22%	23%	24%	24%
The Netherlands	7%	7%	7%	7%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%
Italy	22%	22%	21%	21%	21%	20%	20%	20%	19%	20%	20%	19%	19%	19%
Spain	11%	11%	12%	13%	14%	15%	16%	16%	17%	16%	16%	15%	14%	13%
Greece	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	2%	2%
	Net worth as a % of HGDI													
Germany	446	445	446	461	473	486	488	514	503	523	528	527	542	547
France	518	513	527	575	627	691	732	745	698	693	733	738	743	741
The Netherlands	809	748	724	760	793	838	859	864	802	848	871	858	873	873
Italy	663	643	657	674	697	726	745	736	738	754	752	727	744	730
Spain	663	710	764	844	927	983	1030	1024	918	886	884	841	795	789
Greece	698	729	755	749	752	775	797	759	717	702	706	712	719	823
	Net worth per capita (1000 euro)													
Germany	75.4	77.8	78.8	83.1	86.7	91.1	93.6	100.5	101.3	105.3	109.7	113.6	119.5	122.9
France	80.3	83.1	88.6	98.4	111.3	125.4	137.9	146.6	141.2	140.4	150.7	155.2	156.9	157.2
The Netherlands	112.8	114.0	112.5	117.6	124.6	134.0	141.2	148.1	138.2	143.9	149.1	148.6	150.4	151.1
Italy	96.3	98.5	104.6	109.9	116.6	124.3	131.4	133.2	135.0	133.5	133.6	131.3	131.6	129.0
Spain	69.4	78.4	88.4	102.9	118.6	133.3	147.3	153.2	144.4	139.1	134.9	128.1	117.5	116.5
Greece	64.8	71.2	77.0	82.8	88.0	95.5	106.2	111.0	106.0	104.0	97.2	91.6	83.6	85.9
	Share of housing wealth in gross wealth													
Germany	48%	49%	50%	49%	49%	49%	49%	49%	51%	51%	51%	51%	51%	51%
France	50%	53%	56%	58%	60%	62%	62%	63%	64%	61%	62%	63%	62%	60%
The Netherlands	32%	37%	42%	43%	42%	41%	41%	42%	46%	46%	44%	43%	41%	38%
Italy	45%	47%	48%	50%	50%	50%	51%	54%	54%	55%	55%	56%	54%	52%
Spain	64%	67%	71%	72%	73%	74%	73%	74%	75%	74%	73%	72%	70%	66%
Greece	66%	70%	74%	75%	74%	73%	73%	73%	77%	75%	75%	75%	73%	71%
	Share of debt (liabilities) in gross wealth													
Germany	20%	19%	19%	19%	18%	17%	17%	16%	16%	15%	15%	14%	14%	14%
France	11%	11%	11%	11%	10%	10%	10%	10%	11%	12%	12%	13%	12%	12%
The Netherlands	17%	18%	20%	21%	21%	21%	22%	22%	24%	24%	24%	25%	25%	25%
Italy	7%	8%	8%	8%	8%	9%	9%	9%	10%	10%	10%	10%	10%	10%
Spain	11%	11%	11%	10%	11%	11%	12%	12%	13%	13%	13%	14%	14%	14%
Greece	4%	4%	5%	6%	6%	7%	8%	9%	10%	11%	12%	13%	13%	12%
	Households' savings ratio													
Germany	15%	15%	16%	16%	16%	16%	16%	17%	17%	17%	17%	16%	16%	16%
France	14%	15%	16%	15%	15%	14%	15%	15%	15%	16%	16%	16%	15%	15%
The Netherlands	12%	15%	14%	13%	13%	12%	12%	13%	12%	12%	10%	12%	11%	11%
Italy	14%	16%	17%	16%	17%	16%	16%	15%	15%	14%	12%	12%	12%	13%
Spain	11%	11%	11%	12%	11%	11%	10%	10%	14%	18%	14%	13%	10%	10%
Greece	3%	2%	0%	1%	1%	5%	5%	8%	2%	3%	-2%	-4%	-5%	0%

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