EUROPEAN CENTRAL BANK

EUROSYSTEM

Estimating quarterly non-financial assets and household housing wealth for the euro area: a methodological update

Executive summary

In response to increasing ECB user demand for data on the euro area's non-financial assets (capital stock) and household housing wealth, and given improved data availability, the European Central Bank's Directorate General Statistics has introduced a series of changes to the methodology it uses to estimate quarterly non-financial assets by institutional sector and household housing wealth.

All EU Member States – and therefore euro area countries – are required to report annual non-financial assets (capital stock) by industry and by asset type, as well as balance sheets for non-financial assets, according to the data transmission programme of the 2010 European System of Accounts (ESA). Recently, because of the expiration of the derogations granted to some countries in respect of the adoption of the ESA in 2013, data availability has improved significantly. Furthermore, the availability of national accounts data for land, which are required to estimate household housing wealth, has also improved, as some countries have started to report various land data breakdowns on a voluntary basis.

In line with the methodology, the Perpetual Inventory Method (PIM) is used by the ECB's Directorate General Statistics to fill in the data gaps for the very few countries that do not yet report annual capital stock. Similarly, the institutional sector breakdown, where missing, is estimated via an optimisation model that links the investment's asset-by-industry structure between countries. For example, if the investment's asset-by-industry structure is the same for two countries, the reporting country's institutional sector structure can be extrapolated to the non-reporting country. The estimated national data are then aggregated to compute the euro area figures, using a bottom-up approach. Finally, household housing wealth is estimated both for euro area countries and for all other EU Member States.

1. Background

The ECB published its estimates of quarterly non-financial assets by institutional sector for the euro area for the first time in 2011, applying a methodology that had been developed in 2008. Since then the methodology has been further developed (see Hofmeister and van der Helm, 2017). These

estimates are used in "Euro area accounts" and associated quarterly press releases, as well as for economic analysis at the ECB.[1]

The aim of this methodological note is to describe the updated model used to compile the euro area quarterly non-financial assets by institutional sector and to estimate household housing wealth.

Section 2 provides an overview of the currently available statistical data used to estimate quarterly non-financial assets; Section 3 outlines the main features of the methodology; and Section 4 presents some results and explains how the available data can be accessed.

2. Data availability

The ECB model used to estimate quarterly non-financial assets for the euro area relies on the national annual data reported to Eurostat (investment and balance sheets cross-classified by industry and asset type, and balance sheets by institutional sector). The availability of the underlying annual country data has improved significantly in recent years, which is the result of the efforts made by the national statistical institutes because of the expiration of derogations granted to EU Member States in the context of "ESA 2010 - Transmission programme of data" (Eurostat, 2014). This has made it possible to reduce the amount of data imputations initially applied by the ECB on the input data (net nominal annual data at the country level) while still obtaining the main results from the model (quarterly euro area, net and gross, nominal and chain-linked volumes). Although many of the data gaps have been closed, it is still necessary to make estimations for missing series.[2]

Currently, almost all EU Member States report complete balance sheets for non-financial assets (in current prices). Data coverage for the euro area is above 95% (in terms of annual capital stock for 2018). In addition, most EU Member States publish capital stock estimates, broken down by asset type and by economic activity, as net and gross stock, both in current prices and in the previous year's prices. At this point, however, quarterly time series for non-financial assets are not required by Eurostat.

With regard to gross fixed capital formation (GFCF), which economists often refer to as simply "investment", EU Member States report the annual data broken down by asset type and by economic activity (industry). GFCF is also available at a quarterly frequency, albeit on a more aggregated basis (total GFCF by main non-financial assets).

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1 ECB (2021), "The euro area capital stock since the beginning of the COVID-19 pandemic", *Economic Bulletin*, Issue 2, Box 2.

2 For capital stock tables, the deadline for reporting national data to Eurostat (Eurostat, 2014) is t + 24 months, meaning that countries are required to report 2018 data by the end of 2020. The ECB model estimates data up to the most recent quarter for which investment data are reported.

Estimates for household housing wealth can be derived from reported national accounts data and involve making further estimations. Household housing wealth is defined as the sum of residential buildings plus the land on which those buildings are built. Data on the stock of residential buildings held by the household sector are available for all countries except Ireland. A key element required for estimating household housing wealth is the data on the land underlying dwellings – as these data are not readily available. Although a few countries publish an estimate of household housing wealth or the land underlying dwellings, most countries only report total land by institutional sector.

3. Methodology

The methodology used to estimate euro area quarterly non-financial assets by institutional sector is based on the available data reported by the euro area countries. A bottom-up approach is followed, i.e. the first estimation is performed at the country level for each of the 19 euro area countries and the euro area aggregate is subsequently derived by summing the country estimates. The result is capital stock data by asset type and by institutional sector for the euro area and for each individual country.

The ECB's estimation procedure follows a number of steps. First, the complete series of annual capital stock by asset type is obtained for the total economy using the perpetual inventory method (PIM) explained in paragraph 3.1. Next, the breakdown by asset and by institutional sector is obtained (see paragraph 3.2) and household housing wealth is computed (see paragraph 3.3). Finally, annual data are converted to quarterly frequency data and the euro area results are computed, as described in paragraph 3.4.

3.1. Perpetual inventory method and capital stock by asset type

In the first step, annual capital stock estimates are derived for the total economy, broken down by main asset type, for all euro area countries. The method used is based on equation (1), known as the accumulation equation, which can be used to approximate the PIM. The capital stock in period *t* can be written as a function of the capital stock of the previous period, which has been corrected for the effects of capital depreciation, retirement and revaluation (captured by δ_t) and investment in period *t*:

$$K_t = (1 - \delta_t) \times K_{t-1} + I_t \qquad (1)$$

In the ECB's estimation model a combined rate (i.e. one that captures depreciation, retirement and revaluation) for each country-year pair is derived as follows:

- For countries that have data on both investment and capital stock, i.e. which are defined as "reporting countries", equation (1) is rearranged to compute $\delta_t = (1 - \frac{K_t - I_t}{K_{t-1}})$.

- For the remaining countries, i.e. those for which some variables of equation (1) are missing, and which are referred to, for the sake of brevity, as "missing countries", the weighted average of the combined rate of reporting countries is taken instead.

The ECB's estimation is, therefore, built on two assumptions. The first approximates the initial capital stock[3] for euro area missing countries in order to obtain a starting point for equation (1). The second estimates a set of combined rates (i.e. those capturing depreciation, retirement and revaluation) for those countries for which there are no data on non-financial assets, as described above.

In order to estimate the initial capital stock of a missing country, it is assumed that the ratio of the accumulated consumption of fixed capital (P51C) to the accumulated stock of capital (K) for a missing country is considered to be the same as it is for the aggregation of the reporting countries.

If *N* represents the number of reporting countries and *m* a missing country, then:

$$\frac{P51C^{m}_{2004}}{K^{m}_{2004}} = \frac{\sum_{n=1}^{N} P51C^{i}_{2004}}{\sum_{n=1}^{N} K^{i}_{2004}} \longrightarrow K^{m}_{2004} = \frac{\sum_{n=1}^{N} K^{i}_{2004}}{\sum_{n=1}^{N} P51C^{i}_{2004}} \times P51C^{m}_{2004} \qquad (2)$$

3.2. Breakdown by institutional sector

The aim of the estimation model is to obtain, in addition to data for the total economy, the breakdown of euro area non-financial assets by main institutional sector.

A sector breakdown of capital stock by asset type, at an annual frequency and in net terms, is available for most euro area countries. The aim of this step is to estimate a sector breakdown for the remaining countries that do not report it, and thereby obtain a decomposition of assets by institutional sector as shown in Table 1. This is done by following an approach which maps missing countries to reporting countries, identifying similarities between non-reporting and reporting countries.

[3] The figure for initial capital stock is for 2004, as this was the first year for which there was extensive data availability for all countries. The ECB tried changing the initial year, but the results were very similar.

Table 1: Sector of economy broken down by asset type

		Institutional sector			
		Non-financial corporations (S.11)	Financial corporations (S.12)	General government (S.13)	Households and NPISH (S.1M = S.14 + S.15)
Produced non-financial assets	Dwellings (N.111)				
	Other buildings and structures (N.112)				
	Machinery and equipment (N.11M)				
	Cultivated biological resources (N.115)				
	Intellectual property products (N.117)				

In Finger and Kreinin (1979) the similarity between country *a* and country *b* is defined as $S_{a,b} = \sum_{i=1}^{n} \min\{\frac{x_{a,i}}{X_a}, \frac{x_{b,i}}{X_b}\}$, where $\frac{x_{c,i}}{X_c}$ is the share of good *i* of total exports in countries *a* and *b* respectively. Two countries will have a similarity index of **1** if they have identical exporting patterns and **0** if they have completely different exporting patterns. According to Finger and Kreinin (1979) this measure should not be affected by the relative size or scale of total exports as it is intended to capture patterns. In the ECB model, mapping between countries is defined in accordance with Hofmeister and van der Helm (2017).

In particular, the model defines the correspondence between reporting and non-reporting countries by looking at the level of similarity between countries' investment structures. The core assumption is that if two countries show similar patterns in the structure of investment by industry, they will also show similar patterns in the structure of capital stock by institutional sector.

Let **J** ∈ {1, 2, …, j} denote all euro area countries that report capital stock by asset type and by institutional sector; and define **J** as the subset of available countries. In addition, let **I** ∈ {1, 2, …, i} denote industry type.[4] On the assumption that two countries with the same investment structure will be similar, the optimisation problem may be defined as:

[4] All euro area countries are required to report investment by industry and by asset type.

$$\min_{x_1,\ldots x_j} \quad \frac{1}{2}\sum_{i=1}^{\mathbb{I}}\left(\sum_{j=1}^{\mathbb{J}}\frac{GFCF_{j,i}}{GFCF_{j,T}}\times x_j - \frac{GFCF_i^m}{GFCF_T^m}\right)^2$$

subject to:

$$\sum_{j=1}^{\mathbb{J}} x_j = 1 \qquad (3)$$

$$\forall j \; x_j \in \{0,1\}$$

where *GFCF* is gross fixed capital formation, *T* represents the total, and *m* represents a missing country.

As capital stock and GFCF, although tightly related, do not match exactly, an adjustment factor[5] y_j is introduced. Thus, the new weights may be defined as: $x_j' = \frac{x_j \times y_j}{\sum_{j=1}^{J} x_j \times y_j}$.

For each asset, the institutional sector breakdown for each missing country *m* may now be defined as:

$$\left.\frac{\text{S.Y}}{\text{S.1}}\right|_m = \sum_{j=1}^{\mathbb{J}}\left(x_j' \times \left.\frac{\text{S.Y}}{\text{S.1}}\right|_j\right) \qquad (4)$$

where *Y* represents each of the institutional sectors S.11, S.12, S.13, and S.1M into which the total economy can be split.

The weighting matrix is constructed in a way that makes optimal use of all the information the countries provide on capital stock and investment.

Finally, it is necessary to apply a balancing procedure.[6] This ensures that additivity constraints are respected, i.e. the sum of the stock in each sector equals the total stock available in the economy, and the sum of all assets equals the figure for total assets.

Once the country breakdown has been obtained, the euro area stock by asset type and by institutional sector is calculated as the sum of all countries. Note that the sector additivity constraints for the euro area are automatically respected due to the structure of the country weights implied by the constraints in the optimisation problem (3). At this stage a full matrix for all countries is available in

[5] See Annex for detailed information on the adjustment factor.

[6] See Annex for more details on the mathematics underpinning the balancing procedure.

both current prices and the previous year's prices, which are used to derive annual data in chain-linked volumes.

3.3. Household housing wealth

Household housing wealth is defined as the sum of household housing stock and land underlying dwellings. Land is non-produced non-financial asset, i.e. it is not capitalised; thus, the national accounts do not record the acquisition of land as GFCF. Instead, the stock of land is usually estimated by national statistical compilers using administrative or survey data.[7]

As explained in Section 2, only a few countries report land underlying dwellings as a separate item. The ECB estimation is therefore based on a stepwise approach which determines an estimate for each country, aiming to use the most reliable available data. If a country reports an aggregate measure of household housing wealth as defined above, these data are used. As a second-best option, however, if a country reports land and household housing stock data the sum of these is used (if a country does not report land underlying dwellings, but instead uses another measure of land, a weighting is applied as shown in equation (5)).[8] Finally, if a country does not report any data for land, the estimate of household housing wealth is based on the assumption that the ratio of household housing wealth (including land) to household housing stock (not including land) is the same as that of the sum of the data for countries for which either household housing wealth is reported or a measure of land is reported, as shown in equation (6).

The ratio of land underlying dwellings to total land is computed as follows:

$$Ratio = \frac{\sum_{t=1}^{T} \text{land underlying dwellings}_t}{\sum_{t=1}^{T} \text{total land}_t} \quad (5)$$

For countries which do not report land and therefore fall into the third category, the ECB estimate is produced using the weighted average of net household housing wealth divided by household housing stock computed for the available euro area countries:

[7] A detailed manual on the compilation of land is available from Eurostat-OECD (2015).

[8] In fact, some countries report land underlying dwellings, while others do not distinguish between what underlies dwellings and what underlies other constructions.

$$Share = \frac{\sum_{j=1}^{J} \text{Household housing wealth}_j}{\sum_{j=1}^{J} \text{Household housing stock}_j} \quad (6)$$

The share in equation (6) is also used to estimate household housing wealth for non-reporting EU countries.[9]

3.4. From annual to quarterly estimates

The method of temporal disaggregation is used by the ECB to obtain the quarterly estimates for capital stock. Temporal disaggregation is the process of deriving high-frequency data (in this case quarterly data) from low-frequency data (in this case annual data). It may be used to produce out-of-sample forecasts[10] as well as the high-frequency values between two low-frequency data points.

The annual change of capital stock for two consecutive periods is temporally disaggregated using GFCF at a quarterly frequency. This is based on the assumption that investment flows are the main source of intra-annual capital stock variations, and that other sources of stock changes (like retirement and depreciation), although highly relevant, take place at a fairly steady rate over the year.

In the case of household housing wealth, in order to estimate quarterly series from annual data, quarterly-frequency residential property prices are used in the temporal disaggregation model. This assumes that housing stock variations during the year are mainly determined by changes in the price of housing. This indicator is available for all EU Member States as well as for the euro area aggregate.

4. Results and data accessibility

With its focus on delivering timely estimates at a quarterly frequency, the methodology presented here is an improvement on previous methods as it makes extensive use of already-available country data.

[9] The euro area share is also applied to other EU Member States.

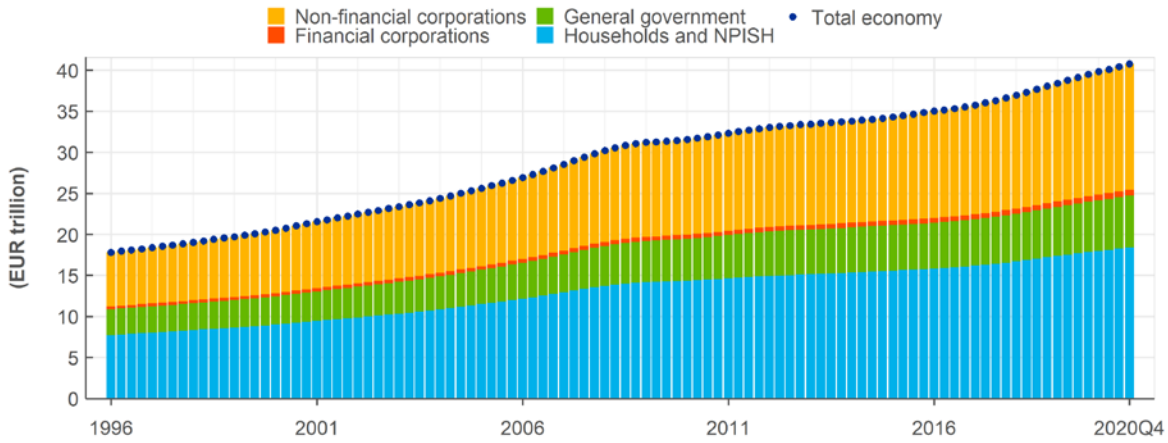
[10] There are many different methods that may be used in the temporal disaggregation of a time series; the choice will depend on the information available and user preference. In this case, for the quarterisation of capital stock data, highly correlated time series are available and can be used to apply a regression-based temporal disaggregation method. Specifically, the model used is that developed by Fernandez (1981), which is a variant of the model developed by Chow and Lin (1971). By assuming a random walk, Fernandez imposes a stronger restriction than Chow and Lin; the Fernandez model was chosen because its results were shown to be more stable for this dataset.

The methodology adopts a bottom-up approach and estimates a full cross-classification of stock by asset type and by institutional sector at the country level, thereby providing a more detailed analysis of developments in the euro area aggregate.

4.1. Results

Figure 1 below shows the estimated sector breakdown of euro area total capital stock (in nominal terms) derived following the described methodology.

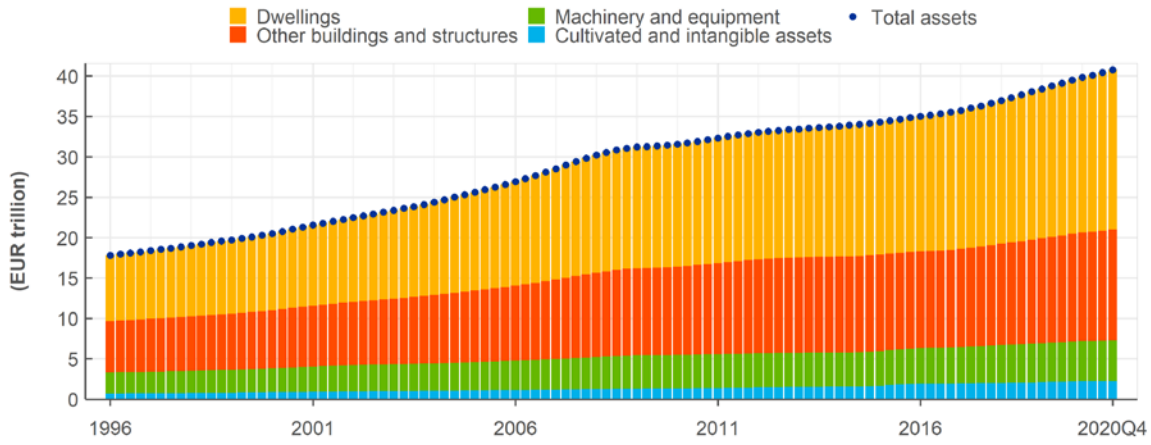
Figure 1: Euro area total capital stock by institutional sector (quarterly data)



The household and NPISH sector holds, on average for the period 1996-2020, 45% of non-financial assets – the figure fluctuates between 43.4% and 45.5%. This might be explained by the large proportion of dwellings (see Figure 2) owned mostly by this sector. Non-financial corporations and general government are next, while financial corporations hold a very small share of non-financial assets in the euro area. On average, dwellings and other buildings and structures account for 82% of total capital stock, while the machinery and equipment sector accounts for about 13%. Over the last 25 years, the shares by sectors and asset items remained broadly stable.[11]

[11] The share of dwellings plus other buildings and structures has fluctuated between 81.2% and 82.9%. On the other hand, the share of machinery and equipment has fluctuated between 12.4% and 14.7%.

Figure 2: Euro area total capital stock by asset type (quarterly data)



4.2. Data accessibility

The ECB's euro area data on quarterly non-financial assets[12] by institutional sectors are published by the ECB's Statistical Data Warehouse, where separate views by assets and by sectors are defined for ease of access:

i. The following asset breakdowns, both net and gross, are made available: dwellings (N.111N/G), other buildings and structures (N.112N/G), cultivated and intangible assets (N.11LN/G), and machinery and equipment (N.11MN/G).

ii. The institutional sectors bring together economic agents with broadly similar behaviour patterns: non-financial corporations (S.11), financial corporations (S.12), general government (S.13), and households and non-profit institutions serving households (S.14 + S.15).

The data are available in euros (EUR) and in domestic currency (XDC). Data in domestic currency (including conversion to current currency made using a fixed parity) is different from the euros measure for the periods before the euro was adopted.

Household housing wealth (NUN) is the sum of dwellings and the land underlying these dwellings.

Underlying annual country data are regularly published by Eurostat in their official portal.

[12] Non-produced non-financial assets are out of the scope of the presented methodology.

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Annex

Adjustment factor

In addition to the baseline model, an adjustment factor is introduced. The idea is that capital stock and gross fixed capital formation, although tightly related, do not match exactly. Therefore, for each available country *j* a coefficient to link both instruments is computed as follows:

$$\min_{y_j} \quad \frac{1}{2}\sum_{i=1}^{\mathbb{I}}\left(\frac{GFCF_i}{GFCF_T}\times y_j - \frac{CS_i}{CS_T}\right)^2$$

where, *GFCF* is gross fixed capital formation, *T* represents the total, and *CS* is capital stock.

In this way, the weights of each available country are corrected by the adjustment coefficient y_j. This is done by multiplying both coefficients and adjusting them so that they add up to one. The new weights can thus be defined as: $x_j' = \frac{x_j \times y_j}{\sum_{j=1}^{J} x_j \times y_j}$.

Balancing

The balancing procedure aims to achieve internal consistency while minimising the changes needed to the initial matrix to accomplish this goal.

Let **N** = (n_1, n_2, …, n_Z) represent the value of capital stock for each asset-sector combination; let **X** = (x_1, x_2, …, x_Z) represent the final estimated value of capital stock for each asset-sector combination; and let **G** represent the set of linear constraints needed to ensure additivity across assets and sectors.

In addition, let **P** = (p_1, p_2, …, p_Z) represent a vector of positive numbers. **P** is a vector of (inverse) penalties, which is defined as a function of the total stock: $p_i = \left(\frac{n_i}{Total\ stock} + 0.0001\right) \times 10{,}000$. This means that if the value of stock n_i is high, a larger adjustment can be allocated to it, so that relatively small assets or sectors are excluded from having to take on a large share of the change. Moreover, an additional constraint aimed at keeping reported values unchanged is introduced, as data reported by countries are already balanced. The following problem may then be defined:

$$\min_{x_1,\ldots x_Z} \quad \frac{1}{2}\sum_{i=1}^{\mathbb{Z}}\left(\frac{x_i - n_i}{p_i}\right)^2$$

subject to:

$$\mathbb{G}\mathbb{X} = 0$$

$$x_i \geq 0 \quad \forall i$$

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This note was revised in April 2021. It may be subsequently amended if new or updated information becomes available.