Irving Fisher Committee on
Central Bank Statistics

BANK FOR INTERNATIONAL SETTLEMENTS

Ninth IFC Conference on "Are post-crisis statistical initiatives completed?"

Basel, 30-31 August 2018

Estimating a country's currency circulation within a monetary union[1]

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[1] This paper was prepared for the meeting. The views expressed are those of the authors and do not necessarily reflect the views of the BIS, the IFC or the central banks and other institutions represented at the meeting.

Estimating a country's currency circulation within a monetary union

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Abstract

We discuss the non-trivial problem of a country's currency circulation within a monetary union, focusing on an internationally relevant currency with significant intra monetary union cash flows: the euro. We compare the results currently published with a set of alternatives to estimate the Euros in circulation in some Euro area countries, based on different hypothesis, techniques and data. Although using a structural money demand model may be useful for some countries, our conclusions suggest that allocating a proportion of the Euros estimated to circulate in the Euro area to each country is more adoption ready and could offer relatively harmonized estimates.

Keywords: Currency union; Euro circulation; Structural money demand models

JEL classification: E41; E50

[1] The views expressed in this paper are those of the author and do not necessarily reflect the views of Banco de Portugal or the Eurosystem.

[2] The paper benefited from valuable contributions and insights by Mr. António Jorge Silva, Mr. Luís D'Aguiar and Ms. Filipa Lima, to whom I would like to express my sincere gratitude.

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"The true currency of life is time, not money, and we've all got a limited stock of that."
Robert Harris

Introduction

Unlike time, money is a dimension of our world that can be controlled and which serves an instrumental role in the way we live. Indeed, the central bank usually has the power to control the supply of cash to the economy, which is used to fulfil different needs of the agents in such economy. Although recent technological advances, affecting especially the financial industry and involving innovative payments solutions, have built the narrative for a growing demise of the use of cash, recent studies for different jurisdictions and currencies have somewhat dispelled this belief and have shown that cash still holds a critical role in the way we make payments and store value.

Esselink & Hernández (2017) concluded, through a survey conducted in 2016, that 79% of the number of payments (and 54% of the value of payments) done in the Euro area were made in cash, whereas only 19% of the number (and 39% of the value) of payments in the same area were settled through cards. On a similar note, using data collected by the Bank of International Settlements' (BIS) Committee on Payments and Market Infrastructures (CPMI), Bech *et al.* (2018) argue that, although card payments have recorded a consistent increase over the last decade, cash in circulation also increased in CPMI countries[3], therefore curtailing the theory of a progressive move towards a cashless society[4]. From a different perspective, Judson (2017) also reports that, despite the increasing pressure for the fading out of cash, demand for U.S. Dollars keeps growing.

Against this backdrop, it is reasonable to argue that cash still holds an important role in modern economies and that it warrants the attention and study of its different stakeholders, spearheaded by central banks. In this domain, several topics can be approached with relevant insights for policy making. However, many of them depart from the assumption that the volume of cash in circulation is perfectly known. Yet, this assumption does not always hold for all economies and deserves scrutiny.

In fact, one of the most interesting topics concerning cash is the actual determination of the stock of cash in circulation in a given economy, which ultimately is available to fulfil the resident's needs. While it may appear as a straightforward computation, the international role of the concerned currency and/or the impact of intra-currency union cash flows can significantly affect this stock and, hence, complicate its calculation process. This is particularly the case of the U.S. Dollar and the Euro: since these currencies are typically accepted for international settlements and are used as a means of storage of value in countries outside of the currency's jurisdictions, the circulation of U.S. Dollar and Euro in such countries is not negligible and significantly reduces the amount of cash in circulation in the issuing

[3] Australia, Belgium, Brazil, Canada, China, Euro area, France, Germany, Hong Kong SAR, India, Italy, Japan, Korea, Mexico, Netherlands, Russia, Saudi Arabia, Singapore, South Africa, Sweden, Switzerland, Turkey, United Kingdom and United States.

[4] According to the same authors, the only countries where evidence of the substitution of cash for cards was found was in Russia and Sweden.

country/area[5]. Moreover, in the case of currency unions, such as the European Economic and Monetary Union (EMU), the intra-currency union cash migrations, due to, *inter alia*, tourism and the shadow economy, also increase the complexity of the computation of the amount of cash in circulation in each currency union country, given that such movements are typically not recorded directly at the central bank's cash counter and, therefore, need to be estimated.[6]

To this end, we opted to address the issue of the compilation of the stock of cash in circulation. For this endeavour, we opted to focus specifically on the Euro area countries (fixed 2002 composition)[7], given that they encompass arguably the most complex framing of this problem: the Euro is an internationally relevant currency and there are non-negligible intra-Euro Area cash flows.

In this paper, we present three methods that allow the computation of an estimate for the volume of cash in circulation for the 12 countries: Method 1 consists in a naïve forecast according to legacy currency data; Method 2 departs from the ECB's indirect estimation of the cash in circulation in the Euro area and allocates a proportion of such volume to each country according to *ad hoc* criteria; Method 3 leverages on the derivation of a structural money demand function for each country, taking a non-Euro area European Union country as reference, to determine the cash in circulation in each country. The results are benchmarked against the volume of cash in circulation currently shown in the financial accounts[8].

The goal of this paper is therefore to provide a further contribution for the discussion on the possible methods to estimate cash in circulation when a country participates in a currency union and/or when its currency has a relevant international role. By the same token, the objective is also to raise awareness to the potential of each of the techniques used in supporting, together with national practices and expertise in this field, the development of a methodology for the explanation of cash holdings in each country.

The paper is organized as follows: section 1 briefly presents the methodological guidelines adopted; sections 2 to 4 introduce and discuss the outcome of the methods used and section 5 concludes.

5 In fact, recent estimates by the European Central Bank point that 30% of the Euros put in circulation until the end of 2016 were actually circulating outside the Euro area while Judson (2012) estimates that about 50% of U.S. Dollars were held outside the United States. For a deeper discussion of this issue, please consult ECB (2017a), ECB (2017b) or Judson (2012).

6 For an introduction on the issue of tourism in the compilation of the national currency in circulation, check, for example, box 1 in Politronacci *et al.* (2017).

7 In 2002, the Euro Area comprised 12 countries: Belgium, Germany, Ireland, Greece, Spain, France, Italy, Luxembourg, Netherlands, Austria, Portugal and Finland.

8 For this purpose, we considered the stock of instrument F.21 (currency) held in the financial balance sheet of each country, which is reported by each country to Eurostat in the framework of the Quarterly Financial Accounts (according to ESA 2010).

1. Methodological principles

Throughout this study, we opted to resort exclusively to data publicly available, in order to ensure a level playing field between countries and to maximize the replicability of our exercises. The data shown are mostly available through the Eurostat's, the European Central Bank's (ECB) and/or through the National Central Banks' (NCB) websites.

We refer to the concepts of currency union and monetary union as synonyms and in line with the concepts defined in Appendix 3 of the International Monetary Fund's 6th edition of the Balance of Payments and International Investment Position Manual (BPM6).[9]

We interpret cash in circulation as the value of the legal tender in circulation in each Euro Area country, in the form of banknotes. Hence, we exclude from the scope of the term 'cash in circulation' the role of coins, due to their relatively low relevance in the Euro Area – as of March 2018, coins represented only 2,35% of the Euros put in circulation.

The estimations that we compute for Euro Area countries concern the period from 2002 to the end of 2017 and, when possible, are shown on a monthly basis. In all other cases, the data presented has a quarterly frequency.

For simplicity, we cover only the countries that first introduced the Euro at its inception in 2002: Belgium, Germany, Ireland, Greece, Spain, France, Italy, Luxembourg, Netherlands, Austria, Portugal and Finland. Countries who joined the Euro Area later on (Slovenia, Cyprus, Malta, Slovakia, Estonia, Latvia and Lithuania) are excluded, to avoid the impact of different changeover periods.

2. Method 1 – Extrapolating legacy currencies

As referenced previously, the impact of intra Euro Area cash flows and the international role of the Euro prompted Euro Area countries to develop complex estimation methods to determine the volume of cash in circulation after the adoption of the Euro. By contrast, during the legacy era[10], when no intra currency union flows were to be estimated and not all currencies had a relevant international role, the compilation of the cash in circulation was relatively simpler: in broad terms, it corresponded to the currency put into circulation by the central bank subtracted by the cash in the vaults of resident monetary and financial institutions.[11] Within this framework, the series yielded were generally relatively free of estimation uncertainty,

[9] "*For statistical purposes, a currency union is defined as a union to which two or more economies belong and that has a regional central decision making body, commonly a currency union central bank (CUCB), endowed with the legal authority to conduct a single monetary policy and issue the single currency of the union.*" BPM6, Appendix 3.9

[10] We refer to the era of currencies that immediately preceded the Euro in each country – *e.g.* the Deutsche Mark in Germany or the French Franc in France.

[11] This premise implies that the concerned currency is not internationally relevant. In case it is internationally relevant, a correction for the international circulation (transaction and hoarding motive) is due.

given that the core information necessary was typically known by the central bank with a high degree of accuracy.

Considering this, one method that can be constructed to provide an estimate of the cash in circulation in each Euro area country can be drawn from extrapolating legacy cash in circulation data. This is one of the approaches proposed in Politronacci *et al.* (2017)[12] and referred in Bartzsch *et al.* (2015) as part of the annual banknote production plan in Germany.

To this end, we have surveyed the information published by the NCBs of the countries under analysis and sought to extract historical time-series of cash in circulation, registered in the liabilities of the central bank. To maximize the utility of our analysis, we imposed that such series should be relatively long – over 5 years of legacy era data. We were able to retrieve information for Spain, Portugal, France, Italy and Greece, for the period spanning from 1980 to 2001 (monthly data – 264 observations). For all other countries, the series were either not published or not long enough.[13]

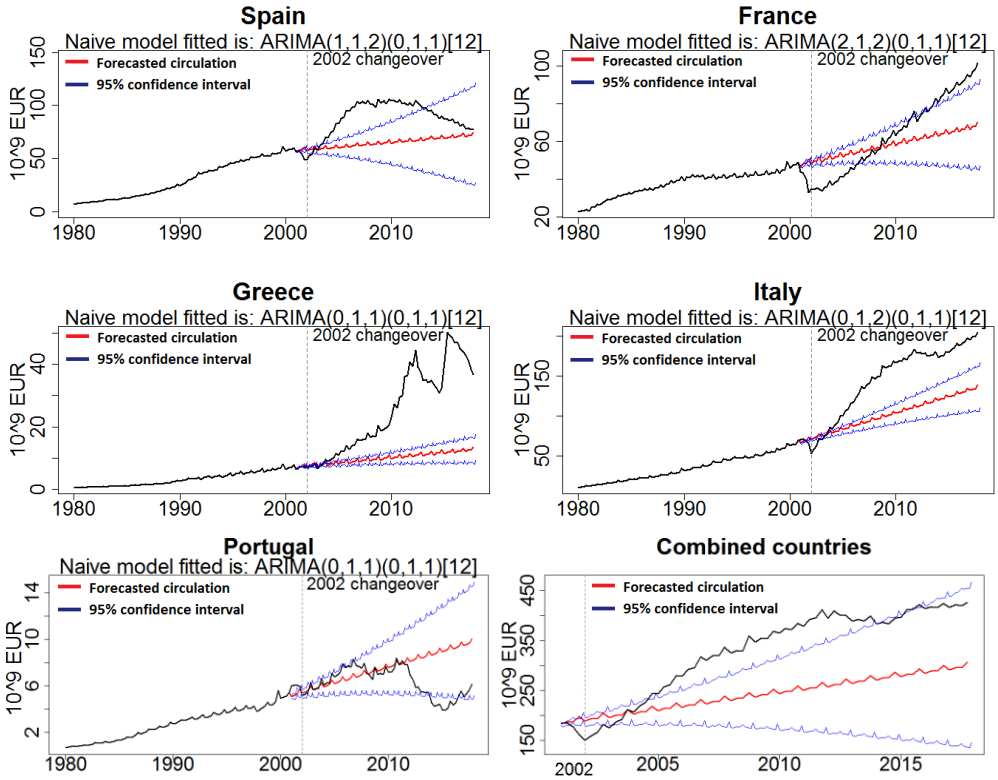
To produce the results of this method, we opted to automatically fit an ARIMA model to the historical cash in circulation series. In this exercise, we opted to estimate such model for the 1980-2000 period, to avoid the pre-cash changeover effect felt in 2001, which could somehow bias our parametric results. The candidate models were chosen according to the Bayesian information criteria presented in Schwarz (1978). [14] The forecasts for the cash in circulation during the Euro area were then obtained by using the parametric estimates yielded by the fitted model and are shown in figure 1 below, with a 95% confidence interval (blue lines).

[12] To estimate the Euros in circulation in France for 2002-2017, the authors extrapolate the circulation of French Francs from 1979 to 2000 to the Euro era.

[13] The ECB publishes the series "Currency in circulation" for all Euro area countries. However, this information only dates back to 1999, which does not fit our time-frame requirements.

[14] To prevent that the selected model was over fitted, we restricted the maximum number of p and q auto-regressive and moving-average terms, respectively, to 3, the number of P and Q seasonal auto-regressive and moving-average terms, respectively, to 1. For further explanations and details on automatic ARIMA modelling, please consult, for example, Hyndman & Khandakar (2008).

Figure 1 – Method 1 estimation results | Reported circulation (black)[15] *vs* forecasted circulation (red)



Source: NCBs and author's calculations

The results shown project the model observed for legacy currencies to the Euro era. When compared to the stocks currently reported by each country, the method is able to produce a 95% confidence interval which includes the values currently reported by Portugal and Spain (and France in several periods). The estimations for Greece and Italy are below the reported stocks. However, when we combine the estimates produced for these 5 countries and compare them with the sum of the reported stocks of cash in circulation, it seems that method 1 underestimates the aggregated cash in circulation in such countries.

The methodology supporting this forecast implies assuming that the time-series structure determining such model holds in both the Euro and the legacy era. However, the changeover to the Euro in 2002 can arguably be interpreted as a structural change, as well as the impact of the developments in payment systems since the introduction of the Euro. Moreover, as Miller (2017) highlights, forecasting on historical data can be useful in the short-term, but if the structural factors underlying such forecast change significantly, then the model will most probably underperform over the long-run. This is the reason why the confidence intervals significantly expand over time and why we have named this estimate as 'naïve'.

Against this background, the estimates rendered through this method, derived through the time-series structures verified for the cash in circulation during the legacy era – which have, most likely, developed and changed significantly over the years –,

15 The series used until December of 2000 for each country correspond to the amount inscribed as cash in circulation in the respective central bank's liabilities. After that period, the values considered are those reported as the stock of instrument F.21 (currency) held in the financial balance sheet of each country.

should be taken with caution. Concurrently, they can be understood as a smoothened forecast of the Euros in circulation in each country – had the time-series structure of cash in circulation remained constant since the 1980-2000 era – and can be used to support the validation of the methods currently employed by each country to estimate cash in circulation.

3. Method 2 – Estimating the Euros held within the Euro area and allocating a proportion to each country

The European Central Bank, as the supranational central bank of the European currency union, is interested in studying and modelling the circulation of Euros within and outside the Euro area. That is why it develops regularly a report on the international role of the Euro and why it has recently been studying the methodological issue of estimating the circulation of Euros outside the Euro area. In ECB (2017a), the ECB published an upgrade to the method it used to estimate the Euros circulating outside the Euro area, which now includes an upper bound, based on a fixed coins to banknotes ratio, and a lower bound for this stock, derived from data on the shipments to non Euro area countries of Euro currency by denominations. These lower and upper bounds are used to calculate the point estimate of the Euros circulating outside the Euro area, which consists in the arithmetic average between such bounds.

Although the end-purpose of the ECB (2017a)'s method is different from ours, it can still be adapted as a tool to estimate the amount of Euros in circulation in each country. Indeed, if the ECB (2017a) defined a method to estimate the Euros circulating outside the Euro area, then, by difference, one can obtain the Euros circulating within the Euro area. Using this stock as a reference, it is possible to allocate a proportion to each country according to specific and harmonized criteria, which will then be used to obtain the point estimate of the circulation that we are seeking. This is the reasoning behind method 2.

To compute the ECB (2017a)'s estimate for the Euros circulating outside the Euro area, we need its two elements: the upper and the lower bounds. The upper bound is obtained by applying the ratio of coins to banknotes used in ECB (2017a)[16] to the Euro coins in circulation in the Euro area in each period. The lower bound is more complex and demands more in-depth data. Indeed, the ECB (2017a)'s lower bound relies on data on official shipments of Euro banknotes to non Euro area countries by denomination since 2013, which is then combined with the data on the issuance of banknotes by the Eurosystem since 2002[17]. However, the data on official shipments by denomination is not currently published and cannot be accessed by the public. For this reason, to proxy the lower bound amount, we opted to use a fixed proportion of the total Euros in circulation in each period, based on the lower bound published for December of 2016 in ECB (2017a). The lower bound was then proxied as follows:

$$Lower\ bound\ proxy_t = Total\ euros\ in\ circulation_t * fixed\ proportion$$[18]

16 The ECB (2017a) considers the ratio of coins to banknotes verified in 2002: 4,16%.

17 For an explanation of how this combination is operated, please consult the ECB (2017a).

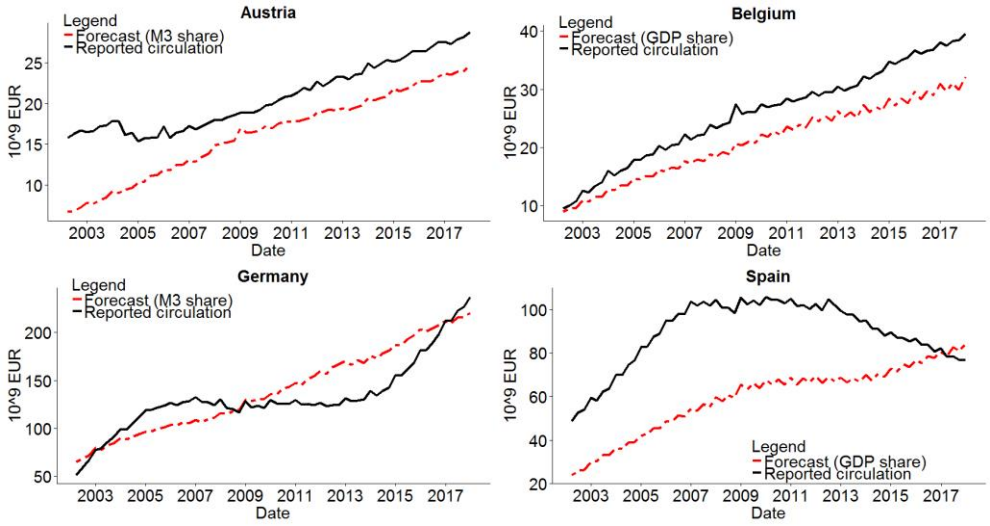
18 $Fixed\ proportion = \frac{Lower\ bound\ in\ ECB(2017a)_{Dec.2016}}{Total\ euros\ in\ circulation_{Dec.2016}} = 25\%$

Having calculated the monthly point estimate for the Euros circulating outside the Euro area, in line with the ECB (2017a) methodology, we computed the estimate for the Euros circulating within the Euro area by subtracting the referred point estimate to the stock of Euros in circulation in each period. To complete this estimation method for the amount of Euros circulating in each country, we allocated a proportion of the Euros circulating in the Euro area according to two alternatives: the proportion of each country's GDP in the Euro area (fixed 2002 composition) and the relative weight of the contribution of each country to the collective contribution of the countries under analysis to the Euro Area's M3[19].

Using each of these keys will naturally reflect the rationale behind each one, and their underlying premises, which will therefore confer to the resulting allocation a harmonized distribution across countries. The reasoning behind the usage of each country's GDP share in the Euro area's GDP is that it allows to allocate the Euros circulating in the Euro area according to an objective, harmonized, measure of wealth, which seeks to portray economic activity, and thereby "linking" our estimate to this phenomenon. Concurrently, the argument for the usage of the relative weight of the contribution of each country to the collective contribution of the countries under analysis to the Euro Area's M3 is that it allows to understand and reflect the relative importance of each country in this important monetary aggregate.

The results generated by each allocation key are summarized as follows:

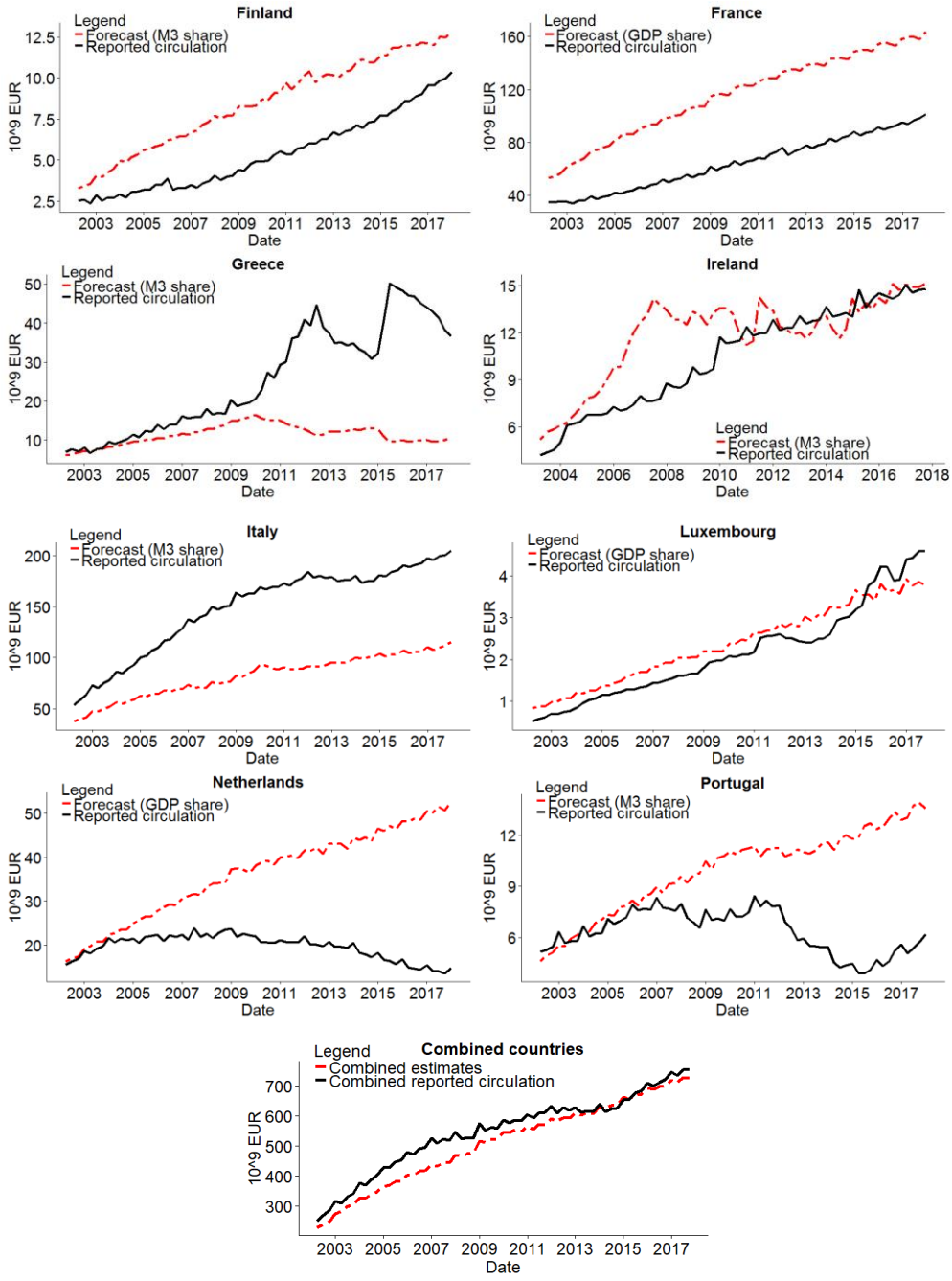
Figure 2 – Method 2 estimation results (2002-2017)



[19] This was obtained as follows:

$$M3\ share\ Country\ X = \frac{Contribution\ to\ M3_{Country\ X_t}}{\sum_x^N Contribution\ to\ M3_{Country\ X_t}}$$

Where X are the countries Euro area countries under analysis (fixed 2002 composition)



Source: ECB, NCBs and author's calculations

The results presented in figure 2 show somewhat mixed results: it appears that in some countries the forecast consistently overestimates (Finland, France, Portugal and Netherlands) or underestimates (Austria, Belgium, Spain, Greece and Italy) the reported circulation, while in others it seems to be following closely the reported stocks (Germany, Ireland and Luxembourg). However, if one compares the combined estimates with the sum of cash in circulation reported by each country, it hints at the idea that, overall, method 2 follows closely the combined reported circulation. Note that, for all countries, we opted to show only the most conservative estimate by retaining the smallest estimates resulting from the M3 and GDP share allocations, to avoid that the forecasts are inflated by the particularities associated with the compilation of country's GDP or M3 contribution.

In any case, regardless of the allocation measures chosen, there are two key virtues worth highlighting. Firstly, method 2 estimates the Euros circulating in each country based on an ECB approved method to estimate the Euros circulating outside the Euro area. In that sense, the estimate rendered for the Euros circulating within the Euro area is one that stems from a commonly accepted and published method, which reinforces the quality of the end results. Secondly, by using relatively fair and impartial allocation keys, we are also ensuring a clear and objective estimation criterium for all countries, which can further promote the consistency of the different estimation methods currently used by each country.

4. Method 3 – Estimating a structural money demand function

To explore additional methods for estimating the Euros in circulation in each country, we have investigated the existing literature, with particular emphasis on structural models of money demand, given that they can incorporate short and long run dynamics between that aggregate and its selected determinants. Two good examples of such models are the Bundesbank (2009)'s model[20] and Bartzsch *et al.* (2015) model for explaining and forecasting the demand for Euro banknotes in Germany[21].

From this investigation, a possible solution to the estimation of the cash in circulation in each Euro area country was found in the estimation of a banknote demand function, in line with one of the proposals in Bartzsch *et al.* (2011b, section 2.2.4). In this study, the authors estimate foreign demand for Euro banknotes issued in Germany departing from the setup of a demand function for German banknotes without foreign demand, which is then applied to a country whose banknote demand is comparable to Germany, except for foreign demand.[22] The authors used the domestic circulation estimated for Germany via this banknote demand function to obtain, by difference of the total cumulated net issuance of German banknotes, a point estimate of the German banknotes in circulation abroad.

Although we do not intend to use this framework for the same purposes, we can adapt it to estimate the cash in circulation in each Euro area country. To do this, we need to apply the same reasoning as in Bartzsch *et al.* (2011b) and, for each Euro area country, find another country whose structural drivers for cash in circulation are

[20] The Bundesbank (2009)'s model seeks to explain, through a vector error correction model, the demand for small, medium and large denominations via cash consumption, the opportunity cost to hold cash (proxied by the interest rate level), the demand from non-Euro area countries (proxied by the real exchange rate of the Euro *vis-à-vis* the Euro area's 22 most important trade partners), house prices (BIS housing price indicator), an estimate of the shadow economy, the unemployment rate and the preference for alternative payment methods (proxied by the number of settled payment cards). The model ends up by concluding that, in the long run, the demand for small denominations is mainly influenced by cash consumption, the demand from non-Euro area countries and the opportunity costs, whereas the demand for large denominations is mainly driven by house prices and the demand from non-Euro area countries.

[21] Bartzsch *et al.* (2015) also approach the issue via an error correction model where the demand for Euro banknotes is regressed against a set of variables depicting the motives to hold cash (transactions motive, store of wealth, availability of alternative means of payment, size of shadow economy and demand by non-residents).

[22] For this purpose, Bartzsch *et al.* (2011b) chose France.

relatively comparable. To avoid that the method becomes endogenous – Euro area countries predicting the cash in circulation in other Euro area countries –, we opted to consider as possible reference countries all European Union Member-States who currently do not belong to the Euro Area[23]. This guarantees that the time series of the circulation of national currency of such a benchmark country are relatively free of uncertainty (given that they have their own currency), and that all countries involved have strong economic connections and tend to share the economic cycle[24].

To allocate a reference country to each Euro area country, we decided to cluster European Union countries according to proxies for the level of transactions, wealth, degree of openness of the economy, dimension, importance of tourism, hoarding motive and role of cashless payment instruments. This implies assuming that the possible reference country/ies for each Euro area country will be the set of non-Euro area countries who are classified in the same cluster.

The variables that we used for this exercise are detailed in table 1 below:

Table 1 – Proxies used in clustering analysis

Variable	Proxy for	Source
Gross domestic product at market prices (Current prices, 10^6 €)	Transactions level	Eurostat
Final consumption expenditure of households (Current prices, 10^6 €)	Transactions level	Eurostat
Population	Dimension	Eurostat
GDP *per capita*	Wealth	Author's calculations
Consumption *per capita*	Wealth	Author's calculations
Percentage of exports and imports of goods and services in GDP	Openness of economy	Eurostat and author's calculations
Nights spent at tourist accommodation establishments	Importance of tourism	Eurostat
Nights spent at tourist accommodation establishments *per capita*	Importance of tourism	Eurostat
Balance of travel account in balance of payments	Importance of tourism	Eurostat
Long term government bond yields – Maastricht definition (average)	Hoarding motive	Eurostat
Unemployment rate	Hoarding motive	Eurostat
Value of ATM cash withdrawals with cards issued by resident PSPs – at terminals provided by resident PSPs – *per capita*	Importance of cashless payments	ECB, Eurostat, and author's calculations
Human Development Index (HDI)	Wealth	World Bank

To determine the cluster where each country fits, we applied Ward's (1963) agglomerative hierarchical method and MacQueen's (1967) non-hierarchical *k-means*

[23] Bulgaria, Czech Republic, Denmark, Croatia, Hungary, Poland, Romania, Sweden and the United Kingdom.

[24] The European Commission's publication "European Business Cycle Indicators" is a good source for an overview of the EU business cycle and for a primary assessment of the business cycle in each EU country.

approach. In both cases, we set the number of clusters to three, to maximize the possibility that at least one non-Euro area country fits each cluster. The methods were applied to data from 2015, given that HDI data was not available for later years. Denmark and Estonia were circumstantially excluded from the analysis due to data shortages in different variables.[25] The results that we obtained through this partitioning are as follows:

Figure 3 – Ward's method results – 3 clusters

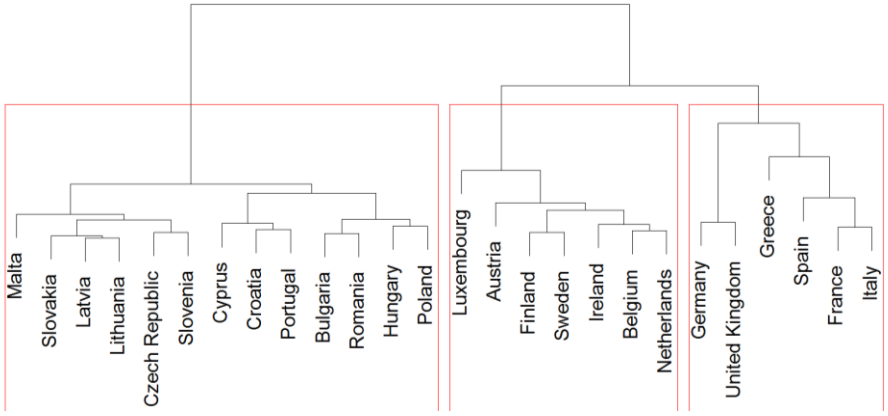
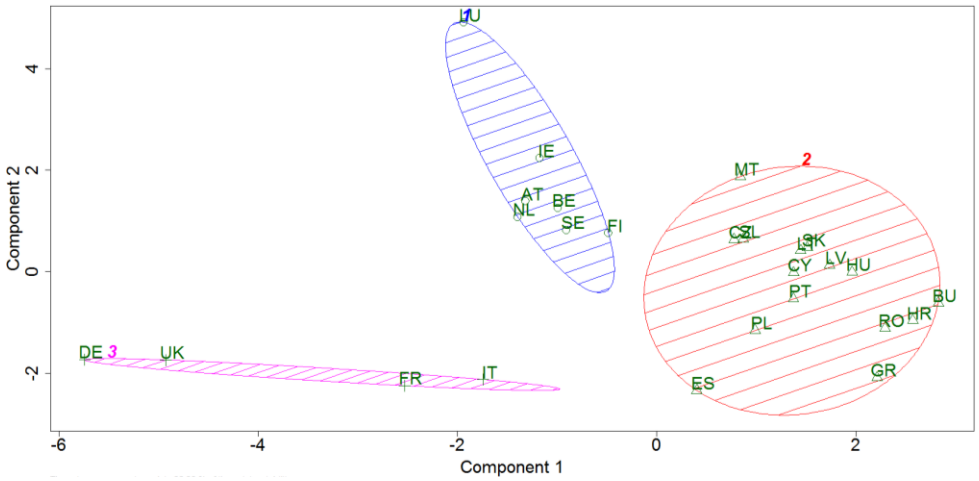


Figure 4 – K-means results[26] – 3 clusters



[25] The data sources through which we extracted data for all countries did not include, for 2015, the proxy for the importance of cashless payments for Denmark and the long term government bond yields - Maastricht definition (average) – for Estonia.

[26] We show the cluster representation against the score of each country in the two first principal components of the data used, which represent 66,33% of the variability of the data.

Table 2 – Ward's cluster descriptions

	Cluster 1	Cluster 2	Cluster 3
Population	-0.46	-0.44	1.12
GDP	-0.25	-0.53	0.84
Consumption	-0.31	-0.51	0.87
GDP_capita	1.20	-0.70	-0.12
cons_capita	1.04	-0.83	0.18
Openess	0.53	0.11	-0.89
Travel_exports	-0.18	0.08	1.29
10y_bond	-0.63	0.16	0.79
Unemployment	-0.43	-0.07	1.49
Card payment_capita	0.50	-0.50	0.05
HDI	0.92	-0.78	0.31

Table 3 – Summary of cluster results

	Ward's method	K-means	Non euro-area reference country
Austria	Cluster 1	Cluster 1	Sweden
Belgium	Cluster 1	Cluster 1	Sweden
Finland	Cluster 1	Cluster 1	Sweden
Ireland	Cluster 1	Cluster 1	Sweden
Luxembourg	Cluster 1	Cluster 1	Sweden
Netherlands	Cluster 1	Cluster 1	Sweden
Sweden	Cluster 1	Cluster 1	N/A
Bulgaria	Cluster 2	Cluster 2	N/A
Croatia	Cluster 2	Cluster 2	N/A
Cyprus	Cluster 2	Cluster 2	N/A
Czech Republic	Cluster 2	Cluster 2	N/A
Hungary	Cluster 2	Cluster 2	N/A
Latvia	Cluster 2	Cluster 2	N/A
Lithuania	Cluster 2	Cluster 2	N/A
Malta	Cluster 2	Cluster 2	N/A
Poland	Cluster 2	Cluster 2	N/A
Portugal	Cluster 2	Cluster 2	Bulgaria, Croatia, Czech Republic, Hungary, Poland, Romenia
Romania	Cluster 2	Cluster 2	N/A
Slovakia	Cluster 2	Cluster 2	N/A
Slovenia	Cluster 2	Cluster 2	N/A
France	Cluster 3	Cluster 3	United Kingdom
Germany	Cluster 3	Cluster 3	United Kingdom
Greece	Cluster 3	Cluster 2	United Kingdom, Bulgaria, Croatia, Czech Republic, Hungary, Poland, Romenia
Italy	Cluster 3	Cluster 3	United Kingdom
Spain	Cluster 3	Cluster 2	United Kingdom, Bulgaria, Croatia, Czech Republic, Hungary, Poland, Romenia
United Kingdom	Cluster 3	Cluster 3	N/A

As table 2 and 3 show, both Ward's method and the *k-means* procedure yielded approximately the same group configuration. Greece and Spain are the only countries that are classified in different clusters. Table 2 shows cluster means for each of the clusters computed through Ward's method. In a nutshell, one can describe cluster 1 as countries where wealth proxies stand out, and cluster 3 as countries where

population, transactions and wealth proxies are most prominent.[27] Table 3 shows that cluster 2 is the one with the highest number of candidate reference countries and that Spain and Greece are the countries with the highest number of possible candidate countries, given that they are classified in clusters 2 and 3 in *k-means* and Ward's (1963) methods, respectively.

To apply the reasoning established in Bartzsch *et al.* (2011b) to each Euro area country, we have drawn a banknote demand function according to the following equation, where X is the respective reference country:

$$c_t^X = \beta_0 + \beta_1 P_t^X + \beta_2 Y_t^X + \beta_3 i_t^X + \varepsilon_t \quad (1)$$

Equation 1 seeks to decompose the determinants of banknote demand and encompasses a set of key factors included in similar models.[28] In our model, the cash in circulation in the reference country (c_t^X) is regressed by the price level (P_t^X) and a transactions variable (Y_t^X) in the reference country, as well as the opportunity cost of holding money in (i_t^X). If we assume, as the core hypothesis for this estimation method, that the parameters yielded from the reference countries hold in all countries of the same cluster, then the volume of banknotes circulating in each Euro area country (represented by Z below) can be obtained by applying the parameters estimated in equation 1:

$$\hat{c}_t^Z = \hat{\beta}_0 + \hat{\beta}_1 P_t^Z + \hat{\beta}_2 Y_t^Z + \hat{\beta}_3 i_t^Z \quad (2)$$

To proxy each of these regressors, we used as independent variables of our model the all-items harmonized index of consumer prices (to portray the fluctuation of prices in each economy), the final consumption expenditure of households (to mimic the overall behaviour of transactions in each economy) and the long term government bond yields – Maastricht definition (average) – to incorporate the effect of the opportunity cost of holding cash. All of this data is published by Eurostat. For this study, we considered a quarterly sample from 2002 to 2017 (64 observations), where all of the dependent and independent variables were not differenced, not seasonally adjusted and were considered in their logarithmic form, with the exception of bond yields.[29] Therefore, all parameters can be interpreted as a pure elasticities, except for the parameter associated with bond yields.

Using this set of variables, we applied the standard unit root, stationarity (Phillips & Perron (1988), Augmented Dickey-Fuller (1979, 1981) and Kwiatkowski *et al.* (1992)) and cointegration tests, which have shown that the vast majority of variables are I(1) and cointegrated.[30]

[27] In cluster 2, the most comprehensive one, there is no clear-cut proxy deserving highlight in comparison with other clusters.

[28] See, for example, the variables used by the Deutsche Bundesbank (2009), Rua (2017) and Bartzsch *et al.* (2015) in similar models for banknote demand.

[29] This was due to the fact that in the latter end of our sample, bond yields drop to negative values for many countries, which jeopardizes the utilization of natural logarithms.

[30] Results are available upon request to the author.

After concluding that their variables were also I(1) and cointegrated, Bartzsch *et al.* (2011b) consider 5 different estimation models[31] to compute their parametric estimates and conclude that, given their small sample size, the fully modified least squares (FM–OLS)[32] method with non-seasonally adjusted data would be the most robust method. Given that the characteristics of our data match those of Bartzsch *et al.* (2011b) and that our sample size (64 observations) is also not very large, we have also opted to use this estimation algorithm.

Applying this estimation method to our dataset, we have computed a set of regressions which considered the circulation in each possible reference country in national currency and in Euros and we have also tested the inclusion of seasonal dummies. After taking into account individual and global significance, the adjusted coefficient of determination in each regression and the Bayesian information criteria, we concluded that the best regressions for each cluster are the following:

Table 4 – Summary of estimation results

Cluster	Regression	Currency of y var.	Adj. R^2	σ Reg.
1	$\hat{c}_t^{SE} = 2{,}70P_t^{SE} - 0{,}14Y_t^{SE} + 0{,}24i_t^{SE***}$	SEK	0.574	0.134
2	$\hat{c}_t^{CZ} = 1{,}88P_t^{CZ***} + 0{,}44Y_t^{CZ***} - 0{,}03i_t^{CZ***}$	CZK	0.96	0.054
3	$\hat{c}_t^{UK} = 1{,}47P_t^{UK***} + 0{,}35Y_t^{UK***} - 0{,}04i_t^{UK*}$	GBP	0.978	0.036
	*** 0,001 significance level (99,9% confidence)			
	** 0,01 significance level (99% confidence)			
	* 0,05 significance level (95% confidence)			
	. 0,1 significance level (90% confidence)			

Note that in all but cluster 1, the regressions estimated are showing the expected signs, that is, an increase in prices and in transactions leads to an increase in the amount of cash in circulation, while an increase in the opportunity cost of holding money leads to a decrease of cash circulation. However, the regression estimated for Sweden has counterintuitive parameters (hoarding with positive sign, transactions with negative sign). This is mainly due to the fact that Sweden is one of the few countries were cash in circulation has been consistently decreasing, as was reported by Bech *et al.* (2018)[33]. For this reason, we opted to use the reference country of the nearest cluster (cluster 3 – United Kingdom) as a reference for countries belonging to cluster 1.

Hence, the estimates for the Euros in circulation in each Euro area country according to this method are calculated through equation 3 below, where the parameters are those drawn from the regressions in table 4 featuring the respective reference country and Z is the Euro area country.

[31] The estimation methods considered were a static regression Engle and Granger (1987), dynamic ordinary least squares, fully modified ordinary least squares, canonical cointegration and Johansen (1995) system estimator.

[32] In a nutshell, as Phillips (1995) describes, FM–OLS is an estimator developed by Phillips & Hansen (1990) that provides optimal estimates of cointegrating regressions, by modifying the traditional least squares estimation to take into account serial correlation effects and possible endogeneity in the independent variables stemming from the existing cointegration relationships.

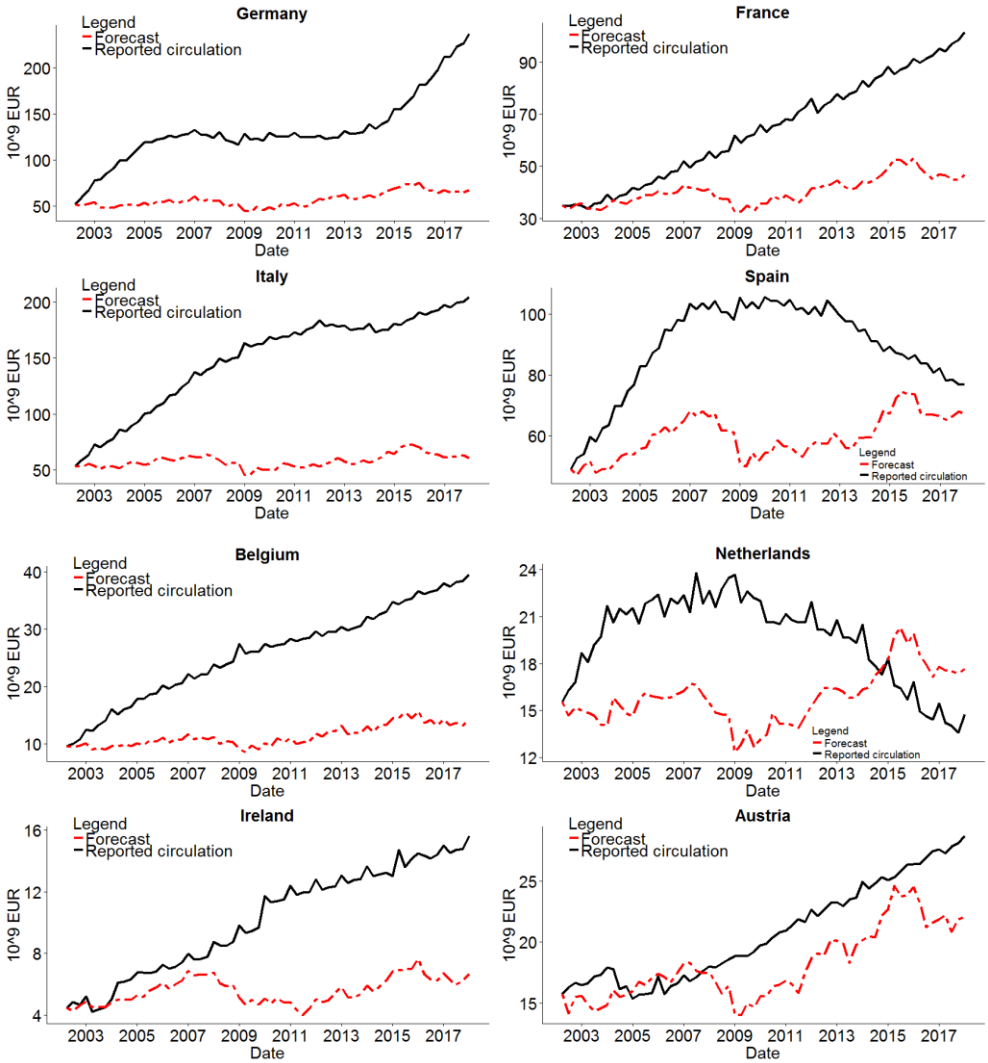
[33] The Central Bank of Sweden (Sveriges Riksbank) reports that in January 2006 the amount of cash in circulation was 105.864 SEK, whereas in January of 2018 the same stock was 55.125 SEK.

$$\hat{c}_t^Z = \hat{\beta}_0 + \hat{\beta}_1 P_t^Z + \hat{\beta}_2 Y_t^Z + \hat{\beta}_3 i_t^Z \quad (3)$$

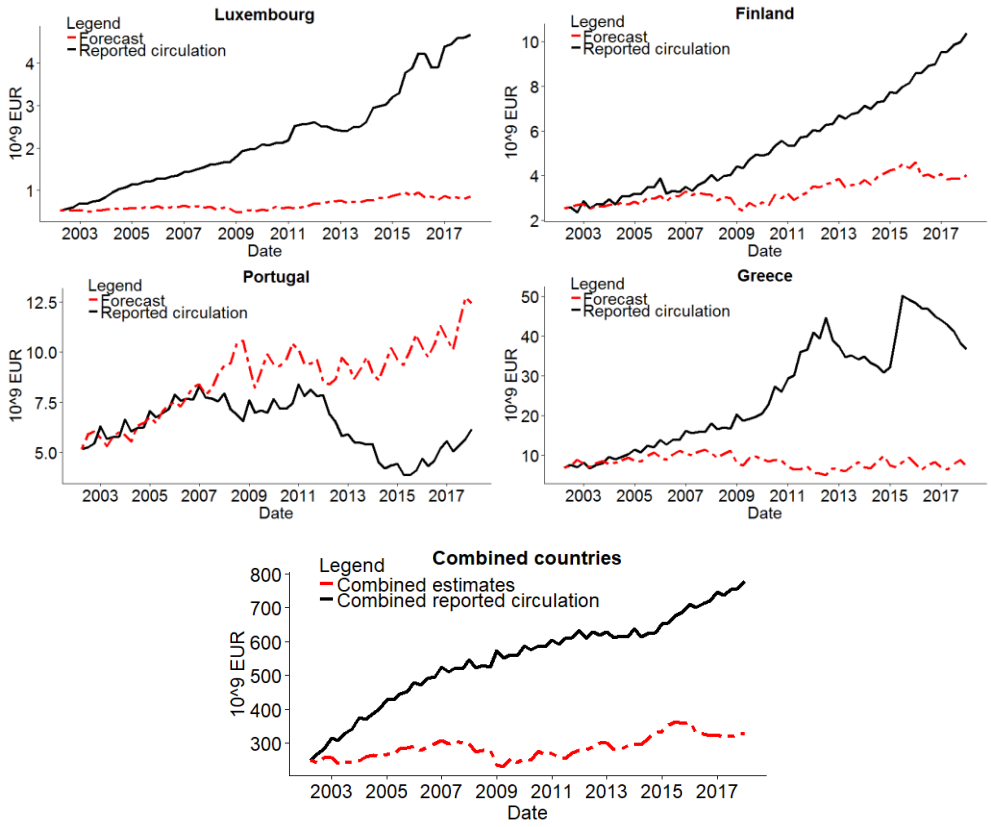
For Spain and Greece, the only countries that were classified in two different clusters, we used the parameters from the reference country whose regression showed the highest adjusted R^2 and lowest Bayesian information criteria: the United Kingdom.

Note that the resulting estimates ($\hat{c}_t^{XZ}$) are converted to Euros at the exchange rate prevailing in each period. Moreover, to ensure that both the forecasted and the reported series start from the same level[34], we have applied the annual rates of change derived from equation 3 to the level verified in the first quarter of 2002 to obtain the final forecast curve.

Figure 5 – Method 3 estimation results



[34] This is critical since, in many cases, there are important level differences between the reference country and the country being estimated (*e.g.* Luxembourg and United Kingdom).



Source: Eurostat, NCBs and author's calculations

The results of method 3, shown in figure 5, are somewhat mixed, but it appears that, in the majority of cases, it underestimates the stock of cash in circulation, especially when the stocks reported by each country show a strong upward trend (*e.g.* Germany, France, Italy, Belgium, Ireland, Luxembourg, Finland and Greece). A similar conclusion is also reached if one compares the combined estimates with the sum of the cash in circulation reported by each country. The method only overestimates the cash in circulation for Portugal and the Netherlands.

This can be due to the fact that the assumption of homogeneity of the structural impact of the variables chosen between countries might not hold in all pairs of reference and Euro area countries and that further investigation is needed. In fact, this is the risk one takes in applying a 'one-size fits all' technique such as method 3 and that calls for caution in the interpretation of the results.

Notwithstanding, unlike some of the estimation methods that we have formulated before, this design seems to be able to partially encompass the effect of the economic cycle, via the regressors it includes. Moreover, it also reflects the role of seasonality on the demand for Euro cash – due to the seasonality pattern embedded in the independent variables it includes –, which can be an interesting feature to explore for policy making.

All in all, the main merit of this model is that it departs from an hypothesis that can be reasonable in some specific pairs of reference and Euro area countries – similar structural impact of money demand factors and negligible foreign demand for the currency of the reference country – and incorporates such factors to obtain an estimate for money demand in each Euro area country. However, given that such assumptions might not always hold, these results must be taken carefully and as a further element to support the enhancement of the techniques currently used by each country.

5. Conclusions

The news about the demise of the use of cash seem somewhat exaggerated. Despite some punctual evidences of a shy decrease in its usage, cash still widely serves as a means of payment or of storage of value, regardless of the jurisdiction or of the currency concerned. Given its criticality, this paper focused on the issue of estimating the amount of cash in circulation in a given economy, under the special conditions introduced by the participation in a monetary union. For this purpose, all Euro area countries (fixed 2002 composition) were scrutinized.

Our goal was not one of persuading for the superiority of a specific technique, but rather to foster the discussion of this issue, particularly among central bank statisticians, with a view to propose practical solutions that may contribute to enhance current methods. Given the specificities of the estimation of cash in circulation in each economy/monetary union and since we are, in essence, trying to estimate a non-observable cross-border phenomenon, it should be underlined that there is no single method that can guarantee uncertainty-free results. Hence, any result of any estimation method must be duly validated from the theoretical point of view (e.g. the quality of the source data and the feasibility of the assumptions must be accurately factored in) and from the practical point of view (e.g. the results must be compared against the reality and idiosyncrasies of the countries under scrutiny).

In this spirit, this paper presents 3 possible estimation methods for the amount of Euros in circulation in each Euro area country, grounded on different data sources and statistical techniques.

Method 1 consists in the extrapolation, for the post 2002 period, of the time series structure of legacy currencies in the 1980-2000 period. The results of this method, which implies assuming no structural breaks in the cash in circulation series for the post 2002 era, appear to build confidence intervals that encompass the values currently reported by 3 of the 5 countries for which a forecast was possible.

Method 2 takes as starting point the method published by the ECB to estimate the Euros circulating outside the Euro area (published in ECB (2017a)) and takes as reference the estimate for the Euros circulating in the Euro area. A proportion of this stock was then allocated to each Euro area country according to harmonized criteria: (i) the share of each country's GDP in the Euro area's GDP; and (ii) the relative importance of the contribution of each country to the collective contribution of the countries under analysis to the Euro Area's M3. The overall results of this method appear to be more in line with the stocks currently reported, although there are some cases of noticeable under/overestimation. Notwithstanding, this method has the virtue of being based on a publicly available (ESCB approved) estimation method and of producing estimates according to well-defined, harmonized criteria.

Finally, method 3 adapts one of the methods used by Bartzsch et al. (2011b) to estimate the "German euros" in circulation outside the Euro area and consists in estimating a structural money demand model for a country similar to the country for which we seek to estimate the cash in circulation. To determine the reference country for each Euro area country, hierarchical and non-hierarchical clustering was applied to a dataset containing proxies for the level of transactions, wealth, degree of openness of the economy, dimension, importance of tourism, hoarding motive and role of cashless payment instruments in each EU country. Through this technique, the United Kingdom, Czech Republic and Sweden were selected as reference countries for the estimation of a structural money demand model. The structural factors

included in this regression were proxies for the evolution of prices, transactions and the opportunity cost of holding money. The results, which translate with greater emphasis the seasonality associated to each proxy, appear to underestimate the stock of cash in circulation in each Euro area country, especially when the stocks reported by each country show a strong upward trend. Hence, it must be highlighted that using this 'one-size fits-all' estimation approach carries the assumption that all pairs of reference and Euro area countries have similar structural money demand factors, which might not hold in all cases. Therefore, the results must be taken prudently and as a further element to support the development of the methods currently used by each country.

All in all, when the virtues and frailties of all three methods are considered, it is arguable that method 2 is seemingly more "adoption ready", given that it starts is grounded on an already approved and published methodology to estimate the Euros circulating outside the Euro area and employs relatively fair allocation criteria. Notwithstanding, the confidence interval yielded through method 1 can also be a useful reference to frame any future estimation experiments, and the structural model laid in method 3 can provide a basis for future country-specific adaptions that can prove important in supporting the methods currently used by each Euro area country. However, for future studies in this topic, new functional forms, techniques (e.g. country specific coins to banknotes ratio) and panels of variables can be tested to achieve a greater degree of accuracy in all countries. That said, any methodological changes arising from future refinements of the methods currently used must be duly contextualized and tested against the idiosyncrasies of each country.

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BANK FOR INTERNATIONAL SETTLEMENTS

Ninth IFC Conference on "Are post-crisis statistical initiatives completed?"

Basel, 30-31 August 2018

Estimating a country's currency circulation within a monetary union[1]

André Dias,
Bank of Portugal

[1] This presentation was prepared for the meeting. The views expressed are those of the authors and do not necessarily reflect the views of the BIS, the IFC or the central banks and other institutions represented at the meeting.

Estimating a country's currency circulation within a monetary union

9th biennial IFC Conference

André Cardoso Dias

BIS, Basel, 30-31 August 2018

Motivation

How many of us… carry cash when traveling abroad?

Over the last decade, cash in circulation **increased** in **CPMI countries***
(Bech *et al.*, 2018)

Despite **pressure** for the fading out of cash, demand for USD is **growing**
(Judson, 2017)

79% of the number of payments in the euro area **are settled in cash**
(Esselink & Hernández, 2017)

Cash is (still) king!

Stock of cash in circulation is an important input for central banks!

* The 24 CPMI jurisdictions are: AU, BE, BR, CA, CN, EA, FR, DE, HK, IN, IT, JP, KR, MX, NL, RU, SA, SG, ZA, SE, CH, TR, GB and US.

Objective

Address the issue of the compilation of the stock of cash in circulation

- Raise awareness to the complexity introduced by the participation in a monetary union and by the international relevance of the currency
- Discuss possible methods to consider such complexity in the techniques used to estimate currency in circulation
- Promote the debate within the central banking community on this issue

Methodology

Case-study: Cash in circulation in euro area countries (fixed 2002 composition)

- All information used is publicly accessible
- Cash in circulation is considered net of coins, due to their low quantitative relevance
- Estimation period: 2002 to 2017
- 3 different methods tested:

Extrapolation of legacy currencies

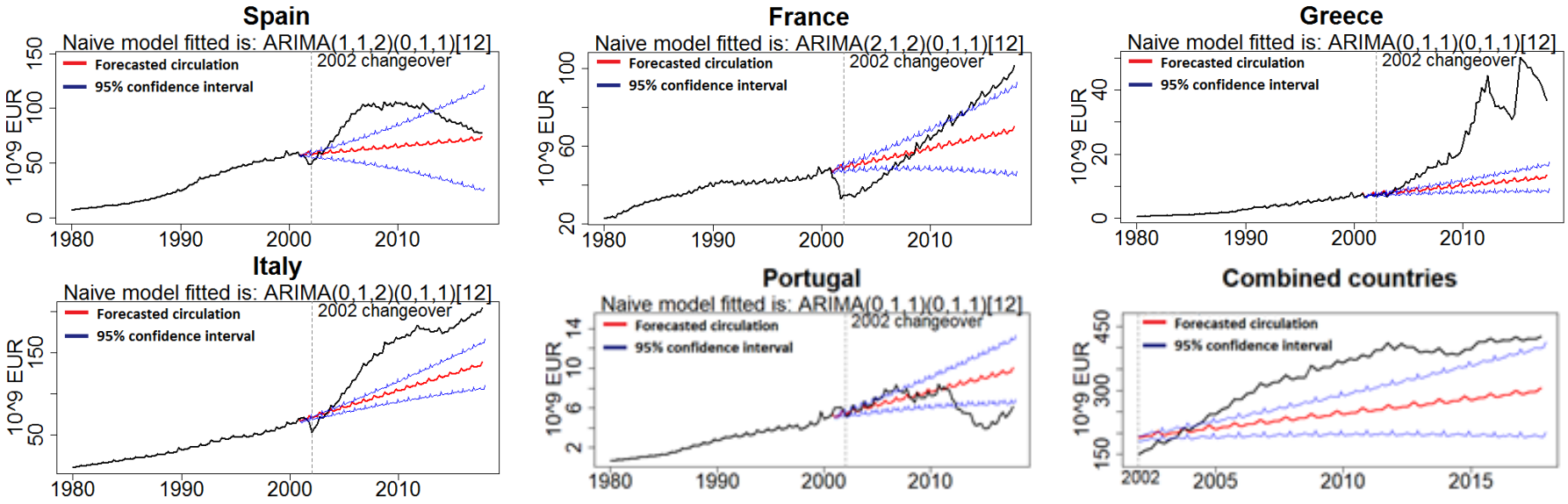
Allocating a proportion of the circulation estimated for the euro area

Exploring a structural money demand model

Method 1 - Extrapolation of legacy currencies

Application of auto.ARIMA to legacy cash in circulation and forecast for euro era

- Imposed relatively long time-series (> 5 years, monthly) and overfit restrictions
- Data available only for 5 countries: France, Italy, Spain, Greece and Portugal

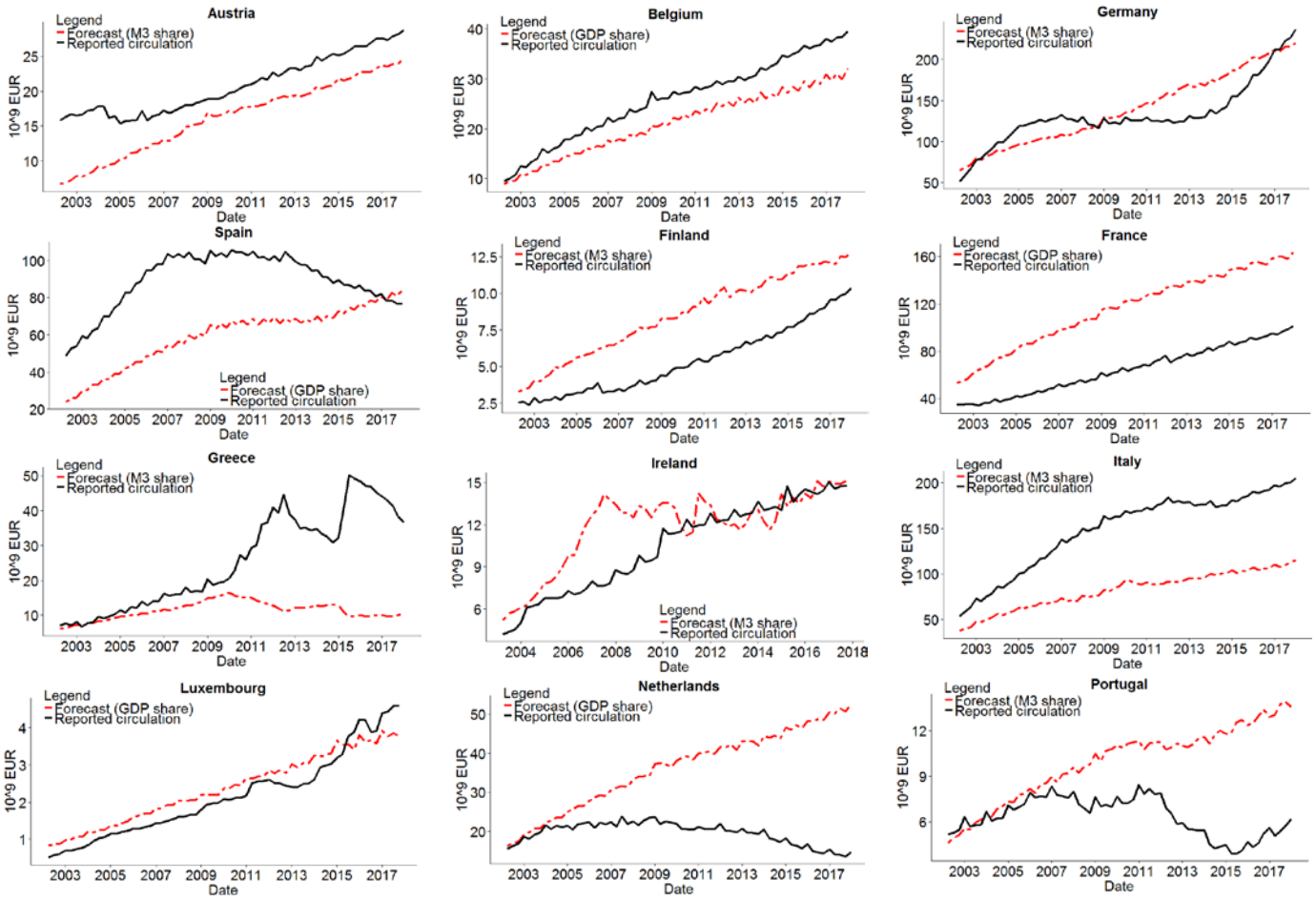


Method 2 - Allocating a proportion of the circulation estimated for the euro area

Based on ECB (2017a)'s estimate for cash in circulation outside the euro area

- Estimate of cash in circulation in euro area is obtained by difference
- 2 allocation keys considered: GDP share & contribution to M3 share

Method 2 - Allocating a proportion of the circulation estimated for the euro area



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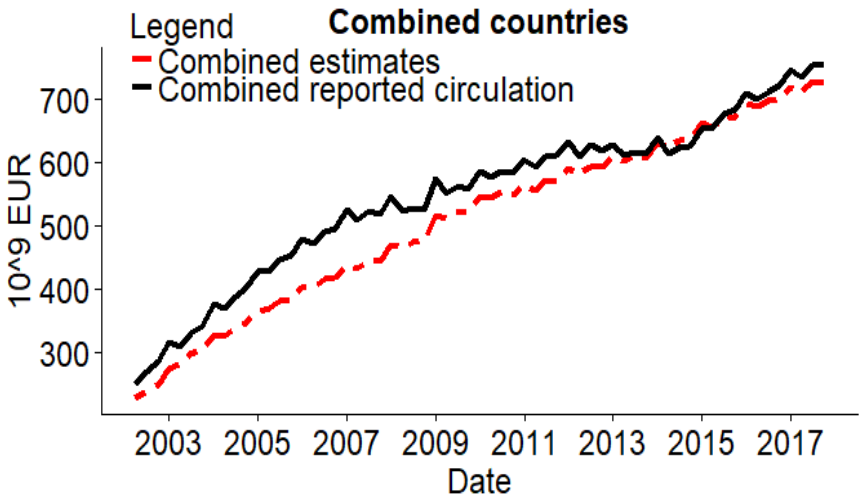
Method 2 - Allocating a proportion of the circulation estimated for the euro area



Method 3 - Exploring a structural money demand model

Estimate structural money demand for EU countries outside the euro area and apply structural parameters for euro area countries

- Technique similar to proposal in Bartzsch *et al.* (2011b, section 2.2.4)
- Assume negligible foreign demand for non-euro EU currencies
- Include proxies for price level, transactions level and opportunity cost of holding cash

Reference countries X

$$\hat{c}_t^X = \hat{\beta}_0 + \hat{\beta}_1 P_t^X + \hat{\beta}_2 Y_t^X + \hat{\beta}_3 i_t^X \quad (1)$$

Euro area country Z

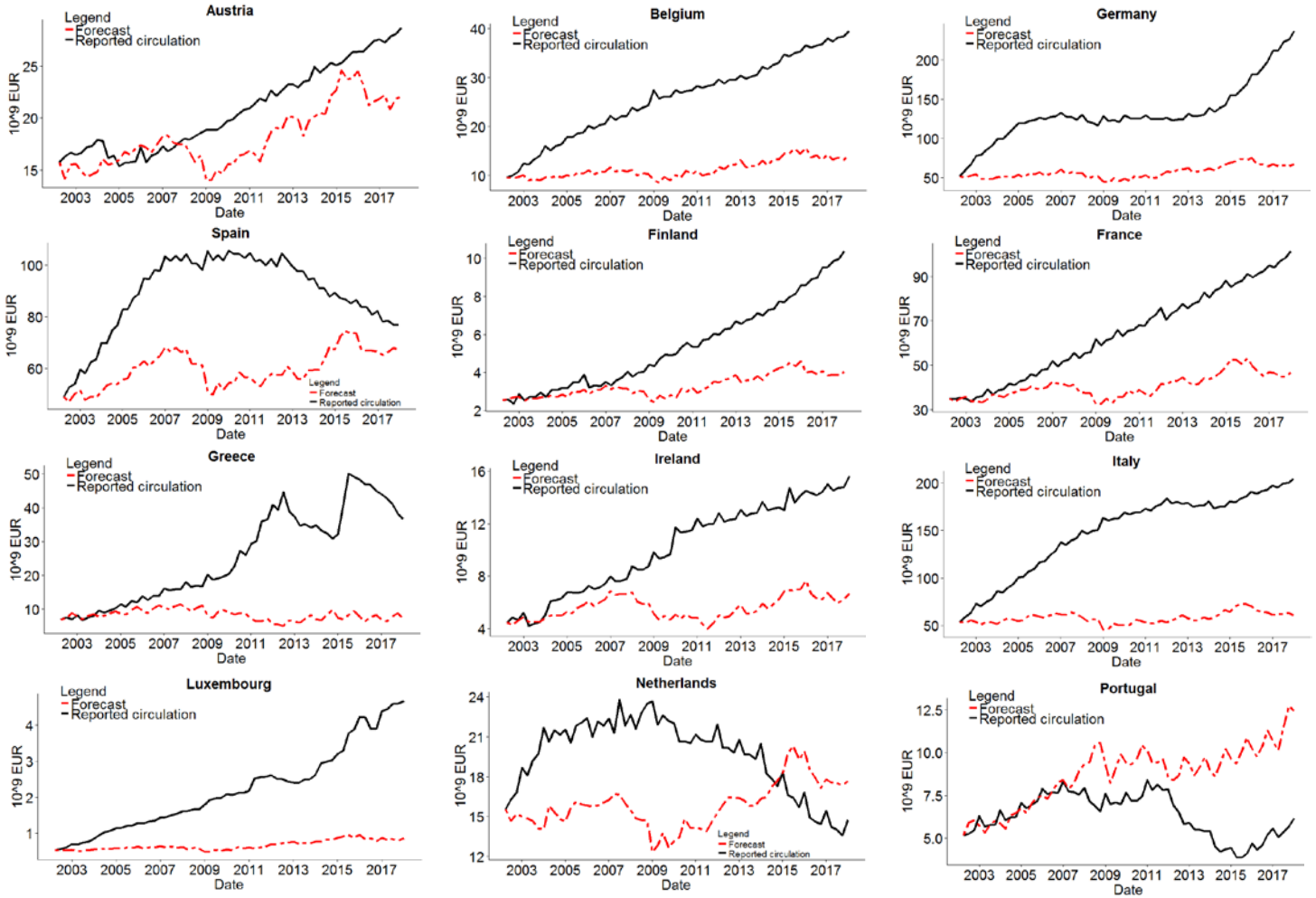
$$\hat{c}_t^Z = \hat{\beta}_0 + \hat{\beta}_1 P_t^Z + \hat{\beta}_2 Y_t^Z + \hat{\beta}_3 i_t^Z \quad (2)$$

Method 3 - Exploring a structural money demand model

Pairs of non-euro & euro countries were determined according to Ward's (1963) and MacQueen's (1967) clustering methods

- Clustering based on dataset with proxies for transaction level, wealth, dimension, importance of tourism, hoarding motive, importance of cashless payments
- Non-euro countries in each cluster with best econometric performance were selected as reference

Method 3 - Exploring a structural money demand model



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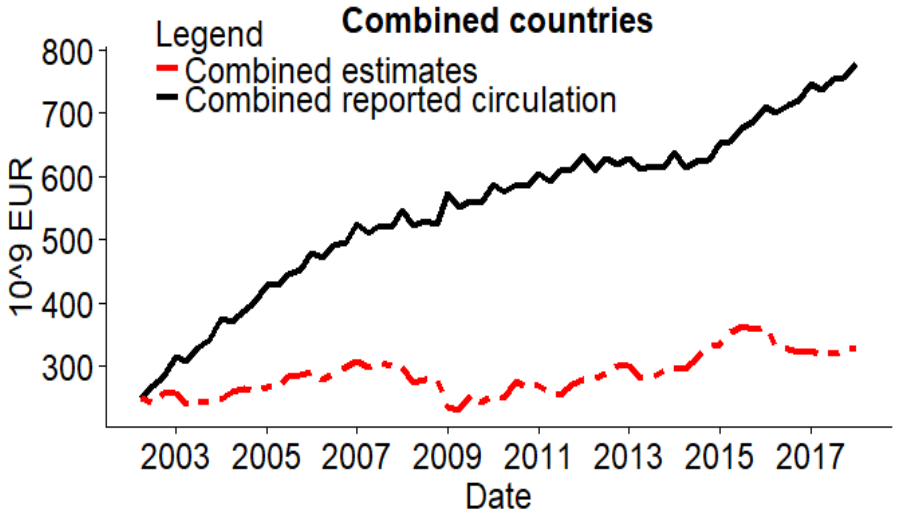
Method 3 - Exploring a structural money demand model



Conclusions

	Method	Merits	Limitations
1	Extrapolation of legacy currencies	Technically easy to implement	Assumes legacy time series structure holds in monetary union era
2	Allocating a proportion of the circulation estimated for the euro area	Enables the harmonization of the compilation of cash in circulation in the monetary union's countries	Assumes no differences between countries in the preference for cash
3	Exploring a structural money demand model	Proxies nearly all motives to hold cash and tracks their short & long run effects	Depends on structural resemblance between paired countries

- Cash still holds an instrumental role in the way we pay and 'save'
- Strong international role of currency & participation in a monetary union complexify the compilation of cash in circulation

There are no optimal answers to this issue...
further research & discussion are very much welcome!

Thank you!

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