The demand for cash in France: review of evidence[1]

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Abstract

Despite the well-known difficulties to measure national euro circulations within the euro area, several methods have been used to estimate the national demand for euro banknotes in France, such as key-based calculations (ECB capital), approaches using average return time of banknotes or extrapolated data from legacy currencies historical trends, methods relying on the replacement indicators of the first euro banknote series.

This paper proposes an update of these approaches and complements them with two additional methods. First, exportations of banknotes data enable to infer the French national circulation from the difference between banknotes issued by the Banque de France and the banknotes it shipped outside the euro area, directly or via the French wholesale bank. Second, a "bottom-up" approach can be built-up, where the cash holdings of the different institutional sectors (MFIs, households, non-financial corporations) are summed up in order to estimate the use of cash for transactional purpose.

Bearing in mind that those various approaches do not always separate the hoarding from the transactional purposes nor take into account banknotes migrations flows across countries, the analysis of the similarities and differences between those several methods sheds light on the French national demand for cash by giving hints on both the low and the top ends of the range.

Introduction

As at December 31, 2016, more than 20 billion banknotes issued by the 19 national central banks of the Eurosystem circulated worldwide for a total value of 1,126 billion euros. Since the introduction of euro banknotes and coins in 2002, the number of euro banknotes in circulation has grown by 7% each year on average.

However, while the total number of euro banknotes in circulation is known, the number of banknotes circulating in the euro area Member States is not. After being issued by the central bank, the behaviour of banknotes in circulation is unknown. Lightweight, transportable and accepted throughout the euro area and beyond, banknotes often migrate far from their point of emission.

In the absence of a better measure, the euro area Member States use the concept of "net issuance". Purely statistical, this concept represents the difference between the notes withdrawn and the notes lodged since 2002 at the national central banks' counters. At the end of 2016, the net issuance of France amounted to nearly 120 billion euros and accounted for 4.8 billion banknotes. However, these aggregate data mask inconsistencies: the net issuance of €5, €200 and €500 notes is negative, which means that for these denominations the number of banknotes lodged at the Banque de France's counters since 2002 is greater than the number of banknotes it has issued.

The actual number of banknotes in circulation in France is estimated through various methods. These estimates have a rather wide margin of uncertainty, especially since banknotes are used for various purposes. Being the only available medium physically representing the holding of central bank money, banknotes are used to carry out transactions, but also to constitute reserves of value.

First, this study finds that the existing estimates of the number of banknotes in circulation in France have usually been based on observed flows or net emissions, sometimes in relation to macroeconomic aggregates, and that they have significant methodological limitations (1).

Second, it proposes to introduce two complementary approaches, both based on estimating the cash holdings of the various institutional sectors within the meaning of the national financial accounts (2).

Third, the comparison of the results reveals very substantial differences, the amplitude of which is however reduced if the comparison focuses on the "active" circulation (banknotes held for transaction purposes). With a lower limit estimated at 12.2 billion euros in 2015, representing about 11% of French net issuance, this study leaves unexplained a significant "residue", even when taking into account the non-observed economy. The wide range of banknote circulation estimates, as well as the gap with the actual national net issuance, highlights the need for further research, in particular in order to better assess the volumes of hoarded notes in France and the non-resident detention (3).

Definitions and methodological clarifications

In the context of this study:

- "Cash" only refers to banknotes: coins are not included in the analysis;
- "Cash holdings" refers to stocks of banknotes;
- "Active circulation" refers to notes held for transaction purposes. It should be distinguished from the circulation of "transactional" denominations (€5 to €50 banknotes) because it does not include the fraction of €50 notes used for hoarding purposes (which accounts for more than half)[2];
- « Banknotes in circulation » includes banknotes held by euro area Monetary and Financial Institutions (MFIs), as well as banknotes circulating outside the euro area;
- Due to the late availability of certain data, the study covers the year 2015;
- Banknotes put into circulation by the overseas departments note-issuing bank (IEDOM) are included in the data.

Stylized facts about French net issuance of banknotes
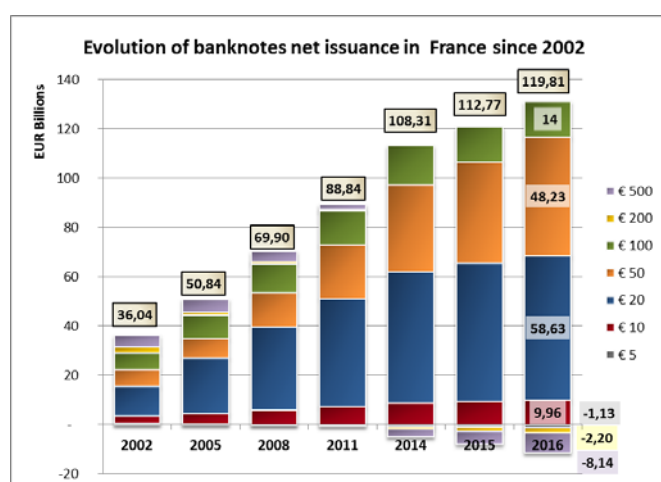
At December 31, 2016, French net issuance amounted to 4.8 billion banknotes, for a total of 119.8 billion euros, representing an increase of 6.7% in volume terms and 6.2% in value terms over 1 year.

The breakdown of the French net issuance by denomination highlights disparities in the use of the euro banknotes, with the €20 note representing 48.9% of the value of the French net issuance. On the other hand, the net issuance of €5, €200 and €500 denominations are negative, which means that since 2002, the Banque de France has registered more lodgements than withdrawals at its counters for these denominations.

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[2] Since the European return time (expressed in months between the issuance of a banknote and its lodgement at the central bank) of the €50 note is more than twice that of the €10 and €20 notes, it can be estimated that more than half of the European net issuance of €50 would be used for hoarding purposes.

I- The banknote circulation of one country is usually estimated from banknotes flows or net issuance

Since the euro introduction, measuring the number of banknotes in circulation has become more complex. Several methods for estimating national circulations have been used at the European level (method 1 based on the capital key), as well as by the Banque de France (method 2 based on the return time and method 3 which extrapolates on the French franc circulation).

More recently, new methods for estimating national banknote circulations have been proposed by the European Central Bank (ECB)[3] :
- A method based on a stabilisation of the net issuance after the euro introduction, taking into account the growth rate of consumption (method 4) ;
- Two approaches related to the introduction of a new series of euro banknotes (ES2) :
  - One method based on the stability of ES2 lodgements and withdrawals (method 5 a).
  - Another approach based on the stability of the ES1 share in sorting (method 5 b).

Finally, another method based on "adjusted active circulation" has been also recently developed by the Directorate banknotes of the ECB.

1/ Method 1: Capital key

The simplest method for estimating the French banknote circulation consists in applying the ECB capital key share of a given country to the average monthly circulation of euro banknotes.

Indeed, NCBs' shares in this capital are calculated using a key which reflects the respective country's share in the total population and gross domestic product of the European Union (EU). These two determinants have equal weighting. The ECB adjusts the shares every five years and whenever a new country joins the EU.

Using this key presumes that the circulation of each country is proportional to the size of its population and of its economy.

For France, the capital key is currently 14.18%. As part of the estimation of national banknote circulation, only the paid-up capital by the 19 central banks of the euro area countries is taken into account, i.e. currently 20.14%.

According to this method, French banknotes circulation would amount to EUR 209.6 billion on average in 2015[4].

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[3] ECB presentation, "Lessons learnt from the ES2 introduction on the determination of a national circulation and euro banknote needs", J. Vrana, July 2016

[4] This figure differs from the theoretical share of France in the total value of euro banknotes issued by the Eurosystem, for two reasons: the share allocated to the ECB (8% of the total outstanding amount in circulation) is not deducted here and the figure displays the average circulation value by denomination in the course of 2015 instead of the value at 31 December 2015

Average estimated French banknote circulation and average total circulation of euros banknotes

EUR billions		€5	€10	€20	€50	€100	€200	€500	Total
2015	France	1,71	4,43	12,94	78,99	41,77	8,30	61,45	209,60
	Eurosystem	8,50	22,01	64,23	392,14	207,37	41,19	305,09	1 040,53

Source: CIS

This method assumes a same usage of cash in the euro area. However, in practice, cash payment habits are different from one country to another. For instance, as noted above, France is a major issuer of €20 banknotes, whereas the share of high denomination notes (€100, €200 and €500) is rather limited.

Moreover, the relative place of cash among all means of payment is also variable within the euro area. In some countries, as in Germany or in Italy, the use of cash compared to the other means of payment is more important than in other countries where the use of payment card is more developed, as in France. According to studies based on payment diaries in France[5] and in Germany[6], cash payments accounted for 56% of payments in volume and for 18% of payments in value in France (in 2011), compared with 79% of payments in volume and 53% of payments in value in Germany (in 2014).

It should be noted that the large-scale survey conducted by the Eurosystem in 2015-2016 on the use of cash by households (SUCH survey, for "*Study on the Use of CasH*"), whose results are pending at the date of this writing, could lead to update the respective market share of the card and the cash in the point of sale (POS) payments of households in France.

2/ Method 2: Return time

Banque de France usually bases its own estimates of cash demand on the return time of euro banknotes. The return time of a denomination is defined as follows in a given geographic area:

Return time = average monthly net issuance / average monthly lodgements

Assuming a similar return time within the euro area, the national banknotes circulation by denomination can be deducted from the European return time and the lodgements at the given BCN's counters.

According to this method, the French banknote circulation is estimated to be EUR 125.5 billion in average in 2015.

		€5	€10	€20	€50	€100	€200	€500	Total
2015	European return time (in month)	5,5	3,1	3,6	8,6	21,0	34,9	43,4	
	Monthly average logdement France (millions of pieces)	25,5	188,3	228,6	106,2	9,1	1,4	1,3	
	Estimated circulation in France (millions of pieces)	141,2	579,7	830,9	918,9	190,2	47,5	55,8	2 764,1
	Estimated circulation in France (Eur billions)	0,7	5,8	16,6	45,9	19,0	9,5	27,9	125,5

Source: CIS

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[5] David Bounie, Abel François, «Towards an Electronic Payment Society? » », Revue d'économie financière 2013/1 (N° 109)

[6] Deutsche Bundesbank, "Payment behaviour in Germany in 2014", p. 27.

This approach presents two major biases:

On the one hand, the European return time calculation is based on the total euro banknote circulation, of which a significant part is held abroad[7]. Thus, the application of these return times at national levels overestimates the banknote circulation of the given country.

On the other hand, it is unlikely that the return times would be the same between euro area Member States, because of the national specificities regarding cash cycle and in particular the development at different speeds from one country to another of the recirculation by private operators.
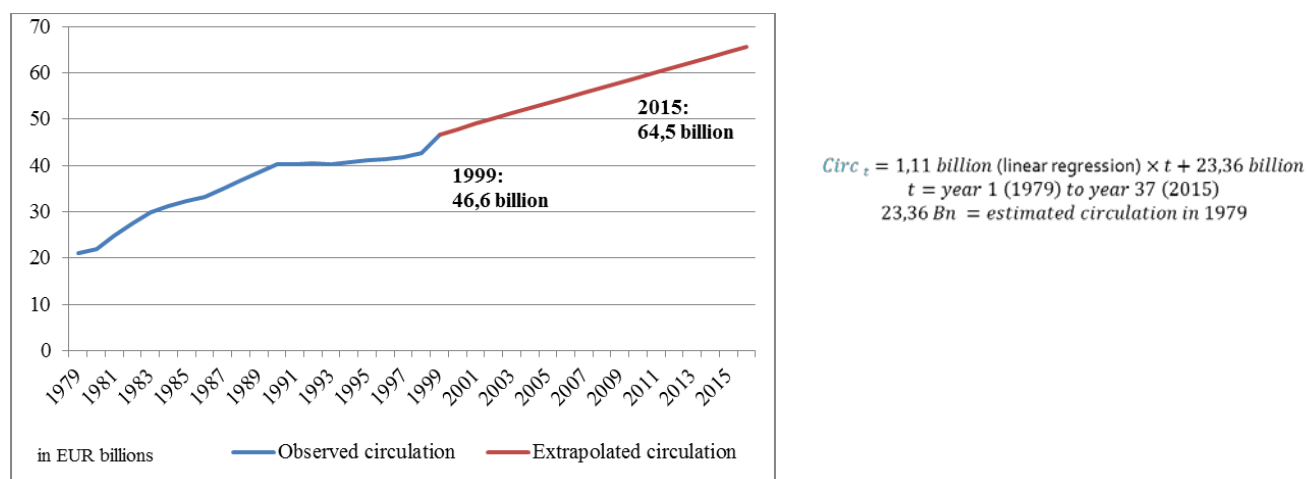
3/ Method 3: Extrapolation of the French franc circulation

This method extrapolates the French franc banknote circulation observed between 1979 and 2000. This reference period is justified both by data availability considerations and by the impact of the cash changeover in 2002, which led to a decline in the French franc banknote circulation as of the end of the year 2000.

During the period under review, several notes ceased to be legal tender[8]. These notes were still exchangeable for euro at the Banque de France's counters a long time after the introduction of the euro banknotes (until between 2005 and 2009). During this period, the Banque de France paid advances representing the French Treasury's claims on the Banque de France for the balance of notes issued but not presented for exchange. These advances were deducted from the franc banknote circulation, so they have been added here to avoid breaks in statistical series.

According to this method, the French euro banknote circulation would reach EUR 64.4 billion at the end of 2015.

Extrapolation of the French banknote circulation

$$Circ_t = 1,11 \; billion \; (\text{linear regression}) \times t + 23,36 \; billion$$
$$t = year \; 1 \; (1979) \; to \; year \; 37 \; (2015)$$
$$23,36 \; Bn = estimated \; circulation \; in \; 1979$$

Source: Banque de France

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[7] According to the ECB, around one-third of the total value of euro banknote circulation is held outside the euro area.

[8] Four notes from the antepenultimate range of banknotes: 10 francs Voltaire, 10 francs Berlioz, 50 francs Racine and 100 francs Corneille (15 September 1986), as well as the whole penultimate range of banknotes: 500 francs Pascal (1st March 1997), 200 francs Montesquieu (1st April 1998), 100 francs Delacroix (1st February 1999) and 50 francs Quentin de La Tour (1st December 1995).

To evaluate the breakdown by denomination, the so-called "gap-method", which models the replacement of the francs by euros, is used. In this method, each denomination in francs is substituted by the euro denominations immediately above and below. The allocation keys for this replacement result from the difference between the franc denomination and the two nearest euro denominations[9].

According to this rule, the demand in French franc would switch to euros banknotes and coins as follows:

	2 €	5 €	10 €	20 €	50 €	100 €	200 €	500 €
20FF	65,0%	35,0%						
50FF		47,6%	52,4%					
100FF			47,6%	52,4%				
200FF				65,0%	35,0%			
500FF					47,6%	52,4%		

By denomination, the French euro banknotes circulation would be broken down as follows:

EUR billions	€2	€5	€10	€20	€50	€100	€200	€500
2015	0,1	0,8	5,4	18,4	22,7		17,2	
For the record: French net issuance		-1,0	9,4	56,0	41,1	14,4	-1,7	-5,4

Source: Banque de France

The limits of this approach:

- This method assumes that the real national banknote circulation followed a growth rate in line with the trend observed over the previous 20 years (1979 – 1999), after the cash changeover. However, several events between 2000 and 2015 may have affected the dynamics of the banknote circulation, in particular with respect to the evolution of the cash cycle, the economic crises in 2001 and in 2008, the development of electronic means of payment, etc. Moreover, between 1979 and 2000, the French franc circulation did not grow at an even pace, with periods of rapid growth (1981-1984) and periods of stagnation (1992-1995).

- The range of French franc notes is difficult to compare with the much wider range of euro notes. Indeed, the French franc notes did not include a note higher than 500FF (i.e. €76) So, it is therefore difficult to define the extent to which the present circulation of higher value denominations, in particular €200 and €500, corresponds to a changeover of the circulation of 500 franc note or to a growth in circulation in absolute terms due to the introduction of high value notes. The absence of obvious correspondence between the two denomination structures limits their comparability.

- The available data about the French franc circulation includes all the banknotes issued by France, including franc notes which were held outside the country. However, these banknotes should not be taken into account in estimating national banknote circulation. Moreover, given the international role of the euro, the foreign demand for banknotes from France is probably significantly stronger than at the time of the francs.

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[9] For example, the "gap" between the 50 franc note (i.e. €7.62) and the €5 note is €2.62 and the gap with the €10 note is €2.38. Therefore, 1-(2.62 / 5) of the 50 franc note was transferred to the €5 note (representing 47.6%), and 1- (2.38 / 5) of the 50 franc note was transferred to the €10 note (representing 52.4%)

4/ Method 4: re-optimised circulation after the euro adoption

This method consists in determining the month from which national net issuance adopts a stable and predictable seasonal pattern after 1 January 2002. The net issuance of this month is identified as the actual circulation in the country. This estimated circulation is then extrapolated for the following years by applying the growth rate of final consumption expenditure of households and associations (NPISHs, Non-profit Institutions Serving Households).

There are two assumptions underlying this method:

- There is a point in time where the national net issuance and the actual national circulation matched: when, for each denomination, the holdings of the various stakeholders did stabilise.
- From that date, the evolution of net issuance would be mainly due to banknote migrations, while national circulation would increase at the rate of final consumption by households and associations.

This approach is limited to low and medium denominations, for which there is little or no hoarding. Indeed, the application of this method to the high denominations would imply to take into account an additional time required to rebuild hoarded cash. In addition, the extrapolation of the circulation from the growth rate of final consumption do not suit denominations of high value, as they are not usually used for transaction purposes in France. For the €50, this method is not fully relevant since a large part of its circulation is presumably hoarded. Nevertheless, for the sake of comparability with other methods, we hereafter provide an estimate of the €50 circulation based on method 4.

Estimated circulation of €5 to €50 denominations at the end of 2015

	€5	€10	€20	€50
Stabilisation date	Jul-02	Apr-02	Feb-02	Jun-02
Estimated circulation (EUR billions)	0,6	3,8	12,4	9,0
For the record: French net issuance	-1,0	9,4	56,0	41,1

Source: ECB

In total, €25.8 billion would be the value of the circulation of low and medium denominations (€5 to €50) at the end of 2015.

This method presents several limits, all the more pronounced as we move away from the date of the euro introduction.

Firstly, it assumes that, after 2002, real circulation increased at the rate of the final consumption. However, this is not necessarily the case, in particular because of the substitution of other means of payment and changes in the cash cycle which may have impacted the demand for cash. Actually, the sum of the estimated national banknote circulation does not correspond to the net issuance of the

whole Eurosystem, because the latter increased much faster than the rate of final consumption, as can be seen in the table below (ECB estimates)[10]:

**Difference between the sum of estimated national banknote circulations
and the actual euro banknote circulation by the end of 2015**

EUR billions	€5	€10	€20	€50
Sum of estimated national circulation	7,5	21,2	52,0	128,5
Eurosystem circulation	8,8	23,3	68,8	419,9

Source: ECB

Secondly, applied to each denomination, this method assumes that the composition of the banknote circulation has not changed since 2002. For France, evidence suggest an increasing use of the €50 banknote, gradually bringing the structure of French net issuance closer to the trends observed at the European level:

**Share of each denomination in the total value of the withdrawals in France
(Banque de France and IEDOM)**

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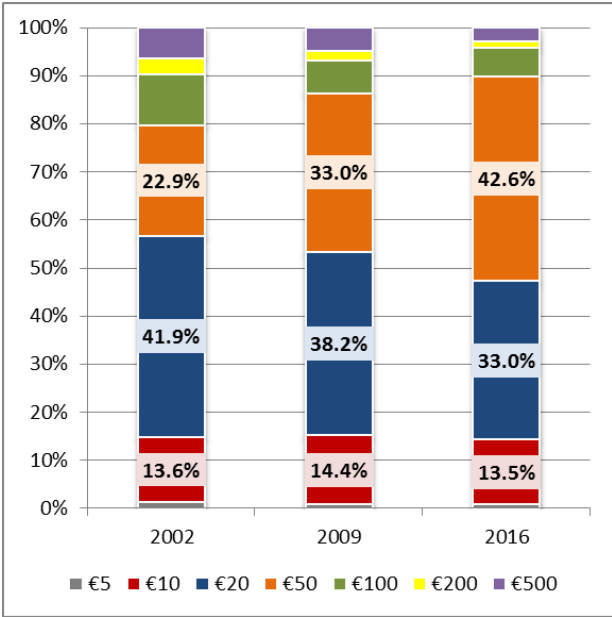
[10] ECB presentation, "Lessons learnt from the ES2 introduction on the determination of a national circulation and euro banknote needs",
J. Vrana, July 2016

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5/ Method 5: approaches based on the ES2 introduction

In the context of the on-going replacement of the first series of euro banknotes (ES1) by the new "Europa" series, the ECB proposed two new approaches to determine national circulations:

    a. An approach based on stable volumes of ES2 net issuance;

    b. An approach based on stable volumes of the ES2 sorting data within NCBs.

These two methods are based on a stabilisation of ES2 net issuance when most of the ES1 national circulation has been replaced by the ES2 series (a share of the ES1 banknotes will never come back to the NCBs' counters). At that time, the net issuance is deemed to represent the actual euro banknote circulation.

    a. The first method (5-a) is based on the identification of the stabilisation period of ES2 lodgements and withdrawals at central bank's counters, as well as ES1 lodgements.

    b. The second method (5-b) determines the month from which the share of the ES2 in the banknotes sorted by the NCB (ES2 saturation rate in sorting) is stable, that is to say when change in the share of ES2 notes in sorting data is less than 1% for three consecutive months.

Then, the estimated circulation by denomination is adjusted in order to take into account the impact of banknote cross-border migrations.

For a given country, the average of the annual increase of the net issuance for the last 5 years (2011 - 2015) is proportionally subtracted from the estimated circulation:

Estimated circulation = $NI_a - (ANI_a \times T)$

With NI_a = ES2 net issuance stabilised at a given date
ANI_a = average of the annual increase of the net issuance for the last 5 years (2011 - 2015)
T = time between the date of the ES2 introduction and the stabilisation date of the net issuance, in years

The two methods lead to similar results with an estimated circulation of EUR 0.6 billion for the €5 note and around EUR 3.0 billion for the €10 note.

		€5	€10
Method 5 a	Stabilisation date	May-15	Sept-15
	Estimated circulation (EUR billions)	0,6	3,1
Method 5 b	Stabilisation date	Jul-15	Jan-16
	Estimated circulation (EUR billions)	0,6	3,0

Source: ECB

These two approaches have also some limits:

- At this stage, they can only be used for the ES2 notes that have been put into circulation for a sufficient period of time to observe a stabilisation of the net issuance. For the moment, this approach cannot be applied to the ES2 €20 note, issued in November 2015. For France, where the share of this note is important, the results will be particularly interesting to analyse.

- The adjustment used to neutralise the migration impact assumes that the full variation of the net issuance is attributed to cross-border migrations. However, at national levels, changes in net issuance may be linked to other factors (changes in payment or hoarding behaviours, macroeconomic developments: GDP, savings rate, inflation, etc.).

- For the method 5-a: in France, the banknotes lodged by the customers are mixed without distinction between series. As a result, the ES1 and ES2 distribution can only be estimated based on the share of each series after sorting.

- For the method 5-b : the existence of a stock of unprocessed banknotes entails a gap between the moment when the ES2 notes become dominant in the circulation and the moment when this saturation is apparent in the sorting data.

6/ Method 6: Active circulation allocated according to the capital key and adjusted with the unfits ratio

This method, recently developed by the ECB, is based on the estimation of an European active circulation. The European return time of €10 note (ie 3.1 months in 2015) is applied to the average monthly logdements of low and medium value banknotes.

Then, the estimated European active circulation is allocated among the euro area countries in proportion to their capital key and then corrected by applying the ratio between the share of the denomination in national unfits and the share of that denomination in European unfits.

Finally, a last adjustment is applied to make equal the sum of estimated national circulations and the European active circulation.

There are two assumptions underlying this approach:
- The €10 note is only used for transaction purposes, whereas the changes in the other denominations return time result from hoarding patterns.
- The difference between the share of a denomination in the unfits of a given country and the share of that denomination in the European unfits is representative of the over- or under-representation of this denomination in the national circulation compared to the European circulation.

Estimated active circulation in France

EUR billions	€5	€10	€20	€50
2015	0,9	5,2	11,5	22,4

<div align="right">Source: ECB</div>

Two limits can be underlined:

- The use of the €10 note return time is relevant for the denominations of €20 and €50 because they share with the €10 note a similar cycle, at least in France (these three denominations are dispensed by ATMs). However, this method cannot be used for high value denominations and its application to the €5 note is questionable: indeed, this denomination has a specific return time, higher than that of the €10 note, because it is widely used for change purposes in stores.
- It is likely that the sorting criteria are not completely homogeneous in the various European countries depending on the denomination. As in consequence, a denomination can be overrepresented in a given country unfits compared to its share in the European unfits, not because of a proportionally higher circulation, but due to various national sorting priorities.

To sum up, each method has some limits and they are not immediately comparable:

2015	€5	€10	€20	€50	€100	€200	€500	Total
Method 1: Capital key	1,7	4,4	12,9	79,0	41,8	8,3	61,5	209,6
Method 2 : Return time	0,7	5,8	16,6	45,9	19,0	9,5	27,9	125,5
Method 3 : circulation of francs banknotes	0,8	5,4	18,4	22,7	17,2			64,4
Method 4 : re-optimised circulation after the euro adoption	0,6	3,8	12,4	9,0	detail not available			
Méthode 5 a: stable Europa series net issuance	0,6	3,1	detail not available					
Méthode 5 b: stable level of the Europa series banknotes sorted by NCBs	0,6	3,0	detail not available					
Method 6: ajusted active circulation	0,9	5,2	11,5	22,4	detail not available			

Three of them provide an estimated total value of the banknote in circulation in one country (methods 1, 2 and 3) and their results vary up to threefold: from EUR 64.4 billion to EUR 209.6 billion in 2015.

The three other approaches (methods 4, 5 and 6) focus on the low and medium denominations and provide insight into the "active" circulation (or transactional circulation). It may be noted that, all methods considered, the largest differences in the estimates are related to the €50 banknote.

This present study propose to complete the comparison by including additional approaches based on an evaluation of the cash holdings detained in the various institutional sectors of the national economy and abroad.

II- <u>Estimation of the euro banknote circulation based on banknote holdings</u>

This study attempts to evaluate the national circulation of banknotes in France by estimating the cash holdings of the various institutional sectors in the national financial accounts meaning. Two methods are detailed below:

- A subtractive approach based on an assessment of the stock of cash issued in France held by non-residents outside the euro area,

- A "bottom-up" approach based on the addition of the cash holdings stored at the various points of cash cycle: among banks and fund carriers, in commercial and service firms and by households.

1/ Method 7: Approach based on the assessment of the non-resident circulation

The actual share of euro banknotes held outside the euro area can only be estimated because of the anonymity of banknote flows across borders[11]. However, the use of official statistics on cross-border banknote shipments gives an indication of the bottom of the range of banknotes circulating outside the euro area.

At the Eurosystem level, cash held "officially" abroad is calculated on the basis of net shipments of banknotes outside the euro area by banknote wholesale banks active in the currency market[12]. At end-2015, the cumulated value of these net shipments since 2002 amounted to nearly €180 billion, i.e. 16.4% of the total euro banknote in circulation in terms of value[13]. As an estimation of banknotes circulating outside the euro-area, this figure is a lower limit since it doesn't take into account other outflow channels such as tourism, remittances from migrant workers or the "unobserved" economy. From this figure, the ECB estimates that the value of euro banknotes circulating outside the euro area represents around one-third of the total value of euro banknotes in circulation[14].

For France, according to the balance of payments and international investment position statistics, the cumulative imports and exports of euro banknotes outside France from 2002 to end-2015 amounts to 32,9 billions of euros. This figure is based on data collected from banknote wholesalers involved in the euro import / export market.
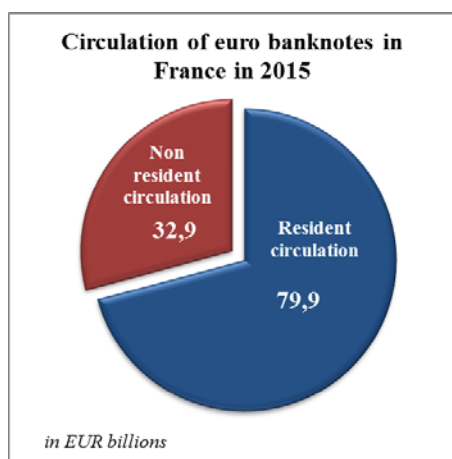
The Bank of Central African States and the Central Bank of West African States as well as Algeria were the main recipients of banknotes exports in 2015, while Switzerland, Cuba and Tunisia were the main countries of origin of imports.

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[11] Subject to the obligation for physical persons to declare all sums of cash in excess of EUR 10 000 when entering or exiting the European Union external borders; in France, as in some other European countries, this requirement also applies when moving across the national borders, within the EU

[12] European Central Bank (2016), the international role of the euro, Interim report, June 2016

[13] The recent methodological revision by ECB of its method for estimating the euro circulation outside the euro area (6 April 2017) is not taken into account in the present paper

[14] European Central Bank (2017), Annual report 2016, April 2017

Circulation of euro banknotes in France in 2015

Non resident circulation 32,9

Resident circulation 79,9

in EUR billions

This foreign demand for banknotes, either by foreign central banks or intended to cover the needs of non-euro area business clients (banks, exchange offices, etc.), makes it possible to approximate the non-resident holding of cash. Indeed, by subtraction, we can deduce the share of French net issuance that might be held in France by residents.

Thus, using the French net issuance (€ 112.8 billion at the end-2015), the resident circulation in France can be estimated at **€79.9 billion in 2015**.

There are two limits to this approach:

- Due to the lack of data on cross-border migrations inside the euro area, the share of French net issuance circulating in other countries of the euro area as well as the share of net issuance of partner countries circulating in France cannot be taken into account. These migrations, however, are likely to be significant, as illustrated by the fact that at end-2015, all euro area countries but two had negative net issuance for at least one denomination.
  In France, the €5 note has negative net issuance, which can be linked at least partly to the Deutsche Bundesbank's net issuance volumes of this denomination. By contrast, at the end of 2015, the €20 note represents 62.5% of the volume of the French net issuance, compared with only 4.4% of the net issuance of the Eurosystem outside France. It is therefore likely that France is a net exporter of €20 banknotes in the euro area, even if this denomination is more commonly used in France than elsewhere in the euro area.

- Banknotes issued in France leave the euro area by unofficial channels that are not monitored, such as tourism spending (see Box 1) and remittances, and thus are not taken into account. The figure of €32.9 billion of non-resident circulation is therefore likely to be a lower limit.

Box 1 : tourism spending in cash

One way to improve this estimate would be to assess expenditure in cash by tourists in 2015 using the data sources used for the compilation of the travel item of the balance of payments (source: Banque de France). Nevertheless, according to this data, it appears that tourism spending would have a very low, or even, no impact.

Expenditure by foreign tourists in France in 2015 :

- Tourists from euro area Member States: they spent a total of €20.9 billion in 2015; we subtract from this figure the amount of transactions paid by card and cash withdrawn directly in France at ATMs (11.4 billion + 1.8 billion, giving a total of 13.2 billion euros): thus, euro area tourists would have brought 7.6 billion in cash to France in 2015.

- Tourists from non-euro area Member States: they spent a total of €20.5 billion in France in 2015. By subtracting the amount of transactions paid by card and cash withdrawn from

ATMs (13.3 billion + 3.9 billion, giving a total of 17.2 billion), these tourists would have brought 3.3 billion in cash to France in 2015.

Expenditure in foreign countries by French tourists in 2015:

- In the euro area: French tourists spent 17.9 billion euros in 2015 in the euro area, of which about 10.1 billion were paid by card and 2.8 billion withdrawn on the spot. Therefore, French tourists would have spent in the euro area about 5.1 billion euros in cash withdrawn in France.

- Outside the euro area: French tourists spent 16.7 billion euros in 2015 outside the euro area, of which about 7.5 billion were paid by card and 3.7 billion were withdrawn on the spot. Thus, they would have spent outside the euro area about 5.4 billion euros in cash withdrawn in France[15].

Overall, it can be estimated that **11.0 billion euros** in cash entered in France and **10.5 billion euros** in cash exited France in 2015, i.e. a close-to-zero balance. According to this result, inflows and outflows of banknotes related to tourists' expenses would have a very limited impact on the value of cash in circulation in France. It should be noted that, regardless of the payment methods used (i.e. including card payments), expenses by foreign tourists in France exceeded French tourists expenses abroad by 7 billion euros.

Furthermore, these estimates must be taken cautiously as they suffer several biases:

- They are obtained using data from different sources: surveys of foreign visitors, surveys of French households, collection of data on card payments from French credit institutions.
- Different methods are used to estimate inflows and outflows of banknotes. Expenses paid by cards come from a survey carried out among foreign visitors. This figure must be taken cautiously as the response rates to the survey are not always significant (e.g. in the survey, card spending is supposed to be nil in case of a non-response). Regarding outflows of banknotes (French visitors in foreign countries), the figure for payments by card comes from the collection of data on card payments from credit institutions.
- All transactions not settled by card are assumed to be settled by cash. Alternative payment methods, such as electronic currency, are not taken into account.
- Estimates of cash in wallet held by tourists from outside the euro area seem low: EUR 3 billion (especially since this figure includes foreign currency exchanged in France upon arrival).

Despite these limitations, the impact of expenses by tourists is an idea to explore. Indeed, if the balance were not close to zero, its extrapolation over the last fifteen years would make it possible to estimate a cumulative stock of cash from tourism expenses, which could be potentially important.

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[15] The totals are rounded from each exact value and will not therefore necessarily represent the sum of the rounded figures

2/ Method 8: Estimation of banknote holdings for transaction purposes

This method is based on an analysis of the cash cycle in France as well as on an identification of cash holdings outside the central bank (Banque de France and IEDOM).

As a first step, we focus on the domestic transaction cycle in order to estimate the average daily cash held for transaction purposes in 2015 by three main institutional sectors: banks, including Cash-In-Transit (CIT) companies (CH_{fc}), retailers (CH_{nfc}) and households (CH_{hh}).

$$CC = CH_{fc} + CH_{nfc} + CH_{hh.}$$
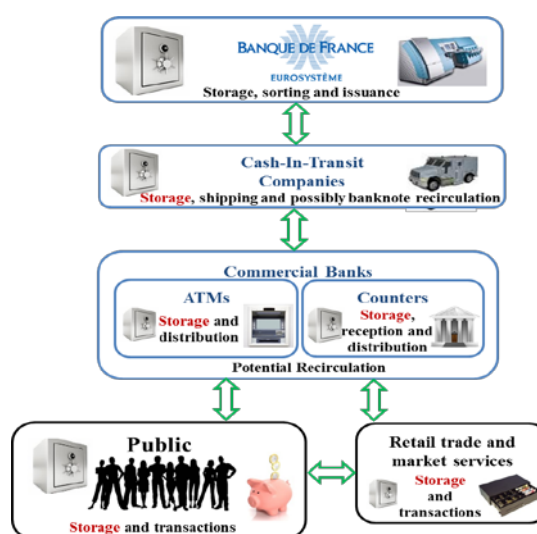
As a second step, the informal economy is included in order to refine this estimate (*for a more detailed description of the underlying methodology, see the methodological annex*).

It should be noted that this approach does not distinguish notes from coins, since the relative share of coins in the total cash circulation is very low[16].

To estimate the cash holdings held by the various stakeholders, two sources of information have been combined:
- The modeling of statistical data;
- The results of a qualitative survey (see Box 2).

Box 2: Methodology of the qualitative survey

For the purpose of this study, interviews have been conducted with various stakeholders of the French cash cycle:

- Credit institutions: seven banking networks participated, representing more than 60% of the withdrawals and lodgements of banknotes at Banque de France counters.
- Merchant sector: two trade federations and four large-scale retailers (supermarkets and independent franchisees);
- One Cash-In-Transit company and one tax refund service provider.

The interviews took place between January and March 2017.

The main topics covered were:

- The average and minimum cash holdings at the end of a typical month in 2015 and their distribution (automats, bank branches, etc.);
- The impact of the development of recirculation of banknotes on the level of cash holdings;

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[16] At the end of December 2015, coins accounted for 2.3% of the total value of the euro cash circulation

- The standards and the frequency of cash collecting in stores;
- Seasonal variations;
- The share of high value banknotes in cash holdings;
- The respective share of transactions settled by cash, card and cheques;
- The average amount of transactions settled by cash.

A/ Banknote holdings for transaction purpose in banks (including CIT Companies)

Transactional cash held by the banks was estimated on the basis of the monetary statistics collected by the Banque de France[17]. The estimated figure was then checked against the results of the qualitative survey.

- According to the monetary statistics, banknotes and coins held by monetary and financial institutions amounted to 9.8 billion of euros at the end of 2015. As we want to estimate the transactional cash of banks, it is necessary to deduct the share of high value banknotes to retain only the value of €5 - €50 banknotes. Since the €100, €200 and €500 represented 10.2% of the total value of banknotes withdrawn at Banque de France's counters in 2015, we estimate that the transactional cash holdings of banks amount to **8.8 billion euros**. This figure corresponds to the average value of €5 to €50 banknotes held by banks to meet the transaction needs of their clients.

- In addition to this approach, the interviews carried out during the qualitative survey shed light on the organisation of this cash holding.

  For security reasons, banks try to keep their stock of banknotes and coins at the minimum required to meet customer demand. This cash is stored in automated teller machines (ATMs), branches vaults, and possibly central cash offices, including cash held by banks at CIT companies.

  In the context of our survey, the participating banks reported an average of €2.8 billion held in cash (excluding cash at CITs). The cash holdings of resident banks that did *not* participate in the survey can be assessed by calculating their average share in the total value of withdrawals and lodgements of banknotes at the Banque de France and the IEDOM counters in 2015, i.e. 43%.
  On this basis, we estimate the total cash holdings of resident banks at 4.9 billion euros.

  Furthermore, to estimate the average daily value of cash held by banks at CITs, we assume, on the basis of the qualitative survey, that CITs hold two days of inflows (cash collected from clients) and two days of outflows (cash ordered by clients). On the basis of the following calculation, **the average cash holding of CITs is estimated at 2.3 billion euros**:

  Daily average flows:

$$\frac{\textit{Annual withdrawals and lodgements at Banque de France's counters}}{(\textit{excluding } €100, € 200 \textit{ and } €500 \textit{ notes})} \times 2 \textit{ days}$$
$$\textit{Number of working days in } 2015$$

  Withdrawals:

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[17] Amounts declared in France to the Banque de France by by resident MFIs under the item "Treasury operations – notes and coins"

$$\frac{151.9 \; billion \; euros}{252 \; working \; days} \; x \; 2 \; days = 1.205 \; billion \; euros$$

Lodgements:

$$\frac{142.7 \; billion \; euros}{252 \; working \; days} \; x \; 2 \; days = 1.133 \; billion \; euros$$

⇨ **Estimated average value of banknote holdings of CITs on a given day: 2.3 billion euros**

It is therefore possible to assess the total cash holding of credit institutions, including cash held by banks at CITs: 4.9 + 2.3 billion, giving **a total of 7.2 billion euros, 2.3 billion euros of which are held at CITs**.

This figure derived from a *bottom-up* approach is consistent with the global figure available in the monetary statistics. For the purpose of this study, we therefore retain the figure available in the monetary statistics, **i.e. 8.8 billion euros**.
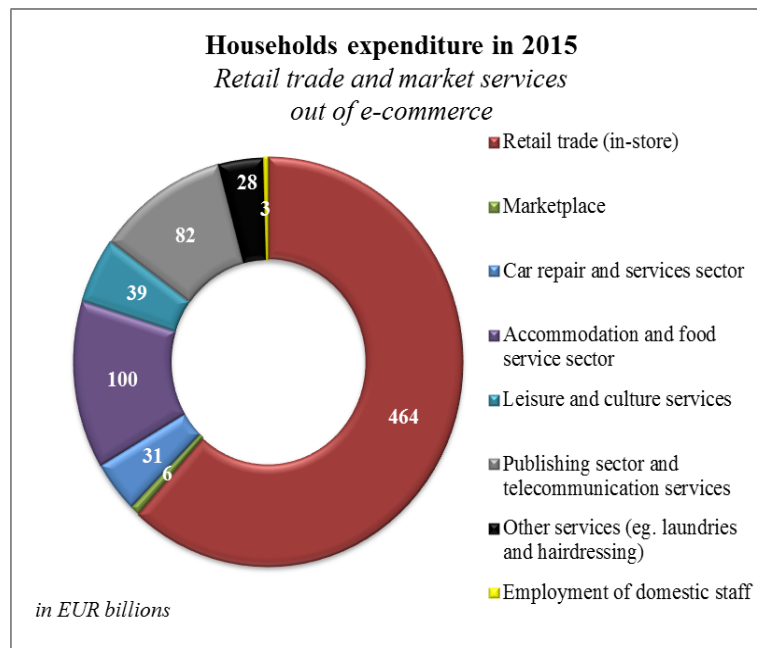
B/ Transactional banknotes held by retailers

In order to evaluate the average value of transactional cash held by non-financial companies in France, we use the turnover of retail and market-related services to households in 2015 (source: the French National Institute for Statistics and Economic Research - INSEE).

In accordance with the 2011 ECB study on the use of euro banknotes by households and firms[18], we consider that other businesses do not hold significant amounts of cash. In addition, wholesale trade, real estate services and services to firms and governments were excluded from this study in order to focus on households spending. E-commerce was also removed from the calculation owing to the very marginal use of cash in this type of spending.

On the basis of a restatement of the total turnover of retail and market-related services to households in 2015, we estimate that households' expenditure amounted to **753 billion euros** in 2015.

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[18] BCE, "The use of euro banknote – results of two surveys among households and firms" – ECB Monthly Bulletin April 2011

Households expenditure in 2015
Retail trade and market services
out of e-commerce

- Retail trade (in-store)
- Marketplace
- Car repair and services sector
- Accommodation and food service sector
- Leisure and culture services
- Publishing sector and telecommunication services
- Other services (eg. laundries and hairdressing)
- Employment of domestic staff

in EUR billions

Under the assumption that cash represents 18% of the value of payments at the point of sale (POS)[19], annual expenditure paid by cash would amount to **136 billion euros**. Hence, daily spending in cash in 2015 would be equal to 0.43 billion euros on the basis of 6 days of spending per week, over 52 weeks.

Besides, assuming that cash is collected by CITs at the POS or brought to the banks by retailers every 3 days, implying an average of two off-loadings per week[20], cash spent by consumers stays at the POS 1.5 day on average. On this basis, we assess that 0.43 * 1.5 = **0.7 billion euros** is held in the retail sector on any given day in 2015.

Moreover, the amount of cash held by retailers for change purposes should be added to this estimate. On the basis of the information gathered during the qualitative survey, we consider that cash held for change at the beginning of the day can be estimated by multiplying the value of a standard cash float (€60) by the number of cash registers. The number of electronic payment terminals (around 1.5 billion in France) is used as a proxy of the number of cash registers. Given the trend towards the individualisation of cash floats by cashier, we apply a ratio to take into account the rotation of several cash floats for one cash register during a standard day. On this basis, the total value of cash floats at the beginning of a day can be estimated at 1.5 million * €60 * 1.1 ratio = 100 million euros.

Overall, **the value of transactional cash held in the trade sector is estimated at 0.8 billion euros**.
It is important to underline that this result is sensitive to the assumed share of cash payments at the points of sale (18%). However, even if this assumption were revised upwards, the result would be relatively close: 1.2 billion with a 30% share for instance.

Note: the annual expenses paid by cash are estimated at 136 billion euros in this study, which is close to the value of cash withdrawn at ATMs and over the banks' counters in 2015 (190.5 billion euros). The difference may be explained by withdrawals by merchants for cash floats, withdrawals by private individuals for hoarding purposes (in particular, withdrawals of high value banknotes), or payments between individuals (person-to-person payments).

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[19] D. Bounie, A. François, « Towards an Electronic Payment Society? », Revue d'économie financière 2013
[20] This working assumption is commonly retained within the French financial community

C/ Transactional banknotes held by households

Pending the results of the SUCH study, we use an approach based on the value of withdrawals of €5 to €50 banknotes at ATMs and over-the-counter (OTC) in 2015:

Average value of cash withdrawals for transactional purposes:
$$= \frac{\text{Total value of ATMs and OTC withdrawals of €5 to €50 banknotes over one year}}{\text{Total number of withdrawals of banknotes at ATMs and OTC over one year}}$$

We estimate the total value of ATMs and OTC withdrawals for transaction purposes as follows:

Withdrawals at BDF counters (€5 to €50 notes)– net shipments by BDF + recirculated banknotes

Besides, the number of ATM and OTC withdrawals in France in 2015 accounts for 1.8 billion[21].

This results in:

Average amount withdrawn for transaction purposes:
$$= \frac{151.9 \text{ billion } - 0.1 \text{ billion } + 25.7 \text{ billion}}{1\,809 \text{ million of ATM and OTC withdrawals}} = 98.4 \text{ euros}$$

Assuming a linear decrease of the cash in wallet between two withdrawals, and that the totality of the cash withdrawn is spent before each new withdrawal, **we evaluate the average amount of cash in wallet by inhabitant (aged 16+) at 98.4 / 2 = €49.2.**

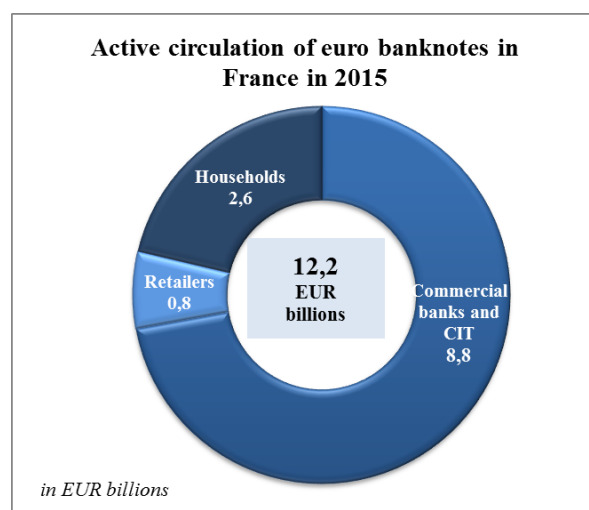The total amount of transactional cash held by households can therefore be estimated at:

€49.2 x 53 millions of inhabitants (aged 16+) = **2.6 billion of euros**.

This estimate seems robust, even if it is probably a lower limit since payments between private individuals are not taken into account. It is possible to compare it to the result of a survey carried out in 2015 for Brink's that estimated the average value of cash in wallet held by private individuals at €45 (using that figure would result in an estimated value of transactional cash held by households of 2.4 billion).

Overall, the total stock of transactional cash held by households, retailers, banks (including CIT companies) is estimated at 12.2 billion euros in France in 2015[22].

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[21] Source: ECB Statistical Data Warehouse, Banque de France calculations

[22] Holdings detained by Central government are not presented here because of their negligible amount (EUR 45 million at end 2015)

Active circulation of euro banknotes in France in 2015

Households 2,6

Retailers 0,8

12,2 EUR billions

Commercial banks and CIT 8,8

in EUR billions

Thus, only a limited portion of the French net issuance at the end of 2015 would be used for transaction purposes: around 11%.

This result is similar to the findings of other studies carried out elsewhere in the euro area, such as the one conducted in Germany in 2009 (10% share) or by the ECB in 2011 (30% share)[23].

D/ Transactional banknotes in the non-observed economy

It is possible to refine the result by including an estimation of the cash used in the transactions in the non-observed economy. In accordance with the typology established by the OECD, this concept refers to three types of activities:

- The underground economy (activities that are legal but deliberately concealed from public authorities or under-estimated);
- The informal economy (clandestine activities by unregistered entities; employment of clandestine workers by households);
- The illegal economy (illegal activities, forbidden by law or carried out by unauthorised persons: trade in illegal drugs or stolen goods for instance).
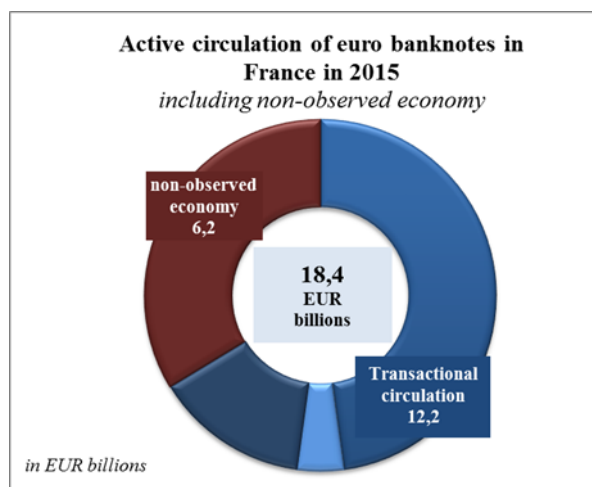
In 2015, the INSEE estimated at 68.1 billion of euros the value of the underground economy and the informal economy in France.

By comparing the estimated circulation used to settle transactions in the observed economy (12.2 billion) to the estimated annual expenditure in cash in 2015 (136 billion euros, or 18% of 753 billion euros), it can be deduced that with 1 euro in circulation in the economy, consumers pay about 11 euros of purchases. If this ratio of 1/11 is relevant for the non-observed economy, **the estimated value of the non-observed economy (68.1 billion of euros) would mobilise 6.2 billion of euros in cash**.

Due to the lack of data, the assessment of the cash in used in the *illegal* economy is difficult. We therefore suggest that it be excluded at this stage. Moreover, the above-mentioned figure probably partly overlaps with the figure regarding the observed economy (for instance, a part of the cash withdrawals is probably used indiscriminately in observed and non-observed transactions).

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[23] BCE, "The use of euro banknote – results of two surveys among households and firms" – ECB Monthly Bulletin April 2011

The aggregation of the estimated transactional cash holdings in the observed economy (12.2 billion) with the estimated cash in circulation in the underground and the informal economy (6.2 billion) gives **an average active resident circulation of 18.4 billion euros in France in 2015**.

Active circulation of euro banknotes in France in 2015
including non-observed economy

non-observed economy
6,2

18,4
EUR
billions

Transactional
circulation
12,2

in EUR billions

To fully estimate the total resident banknote circulation, hoarding by households should also be taken into account.

According to studies carried out by the Banque de France at the time of the cash euro changeover in 2002, 45% of the franc circulation was hoarded in 2000 (domestic hoarding accounting for the largest part of the total). However, due to the lack of reliable data on the actual volume of cash in circulation in France, the share of hoarded cash cannot be estimated.

Moreover, there are other avenues for further research works, in order to complete the analysis on:
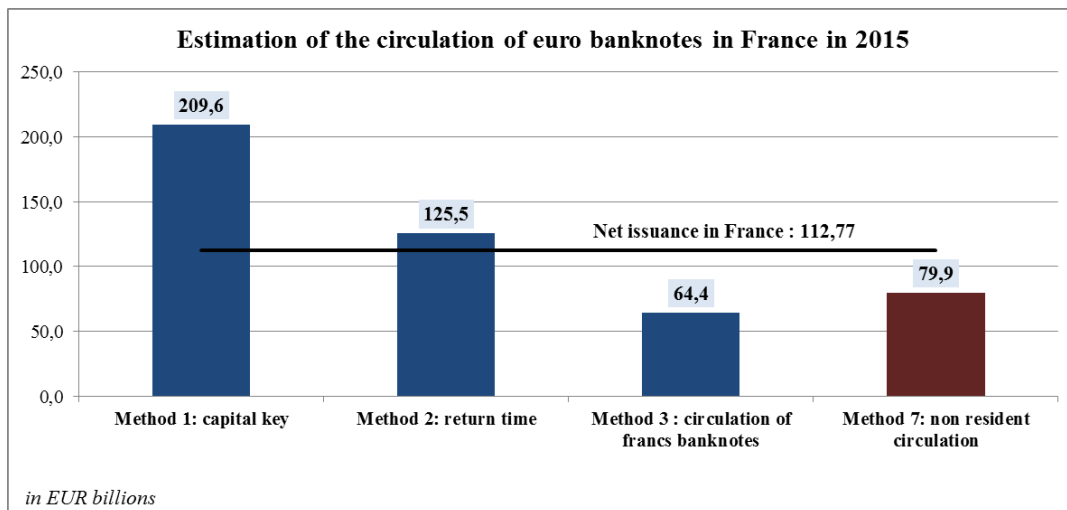
- Non-observed economy : illicit activities (eg : drug trafficking) is not estimated;
- Households: the exploitation of the results of the SUCH study on the use of cash should give an estimation of the cash carried in wallet in the various euro area countries; it should then be possible to allocate the euro banknote circulation according to cash carried in wallet, which should contribute to remove the bias stemming from the heterogeneous use of cash within the euro area.

III- Comparison of the various methods

Despite their methodological limits, the comparison of the results of the various approaches is highly instructive.

1/ Comparison of the results regarding the total French banknote circulation

Based on the different methods described in the study, the French banknote circulation would stand between EUR 64.4 billion and EUR 209.6 billion.

Estimation of the circulation of euro banknotes in France in 2015

Net issuance in France : 112,77

Method	Value
Method 1: capital key	209,6
Method 2: return time	125,5
Method 3 : circulation of francs banknotes	64,4
Method 7: non resident circulation	79,9

in EUR billions

The relatively wide range of results gives rise to several comments:

-   The methods 1 and 2, which split the European net issuance between countries, seems to lead to an overestimation of the French banknote circulation. Indeed, a large part of euro banknotes in circulation is held abroad and should not be included in the allocation.
    Their results are both at the top of the range. This reinforces the view that large volumes of euro banknotes are in circulation outside the euro area.

-   Between the methods 1 and 2, the results of the method 2 are logically the lowest. Indeed, the value of banknotes returned at the Banque de France's counters is lower than the expected value using the capital key (15.20 % versus 20%). This confirms both a relatively lower use of cash in France than in the rest of the euro area, and a greater use of low denomination notes.

-   The extrapolation of the French franc banknote circulation, whose legal tender ended 15 years ago, have to be regarded cautiously (method 3). Indeed, many factors could have changed the dynamics of the banknotes demand in France since 2002. In this respect, it is somewhat paradoxical that method 3 gives the lowest result. Unlike the other ones, this method does not take into account the development of non-cash means of payment and in particular the significant increase of payments by card. Thus, a higher result compared to the other methods would have seemed logical. This result may be an indicator of the importance of the cash hoarded in France, or "moved" outside France across borders.

-   The method 7 is based on a robust evaluation of non-resident banknote holdings. Its result is logically lower than in methods 1 and 2 as the banknotes held outside the euro area are excluded. However, this method does not take into account the banknotes migration between the euro area Member States whereas these flows are probably significant in France.

2/ Comparison focused on the active banknote circulation

Given the importance of the use of low and medium denominations in France (the average value of lodged banknotes amounts to €24.2 in France in 2015), an analysis focusing on the active circulation would help to refine the comparison by reducing the gap between the different approaches.

For most of the methods of the total national circulation, it is possible to extract the portion of the banknotes used for transaction purposes assuming that only denominations of €5 to €50 are concerned:
- Method 1 : Capital key
- Method 2 : Return time
- Method 3: Extrapolation of the French franc circulation
- Method 4: Re-optimised circulation after the euro adoption
- Method 6: Active circulation allocated according to the capital key and adjusted with the unfits ratio

However, at this stage, methods 5 and 7 do not allow for an estimation of the transactional circulation.
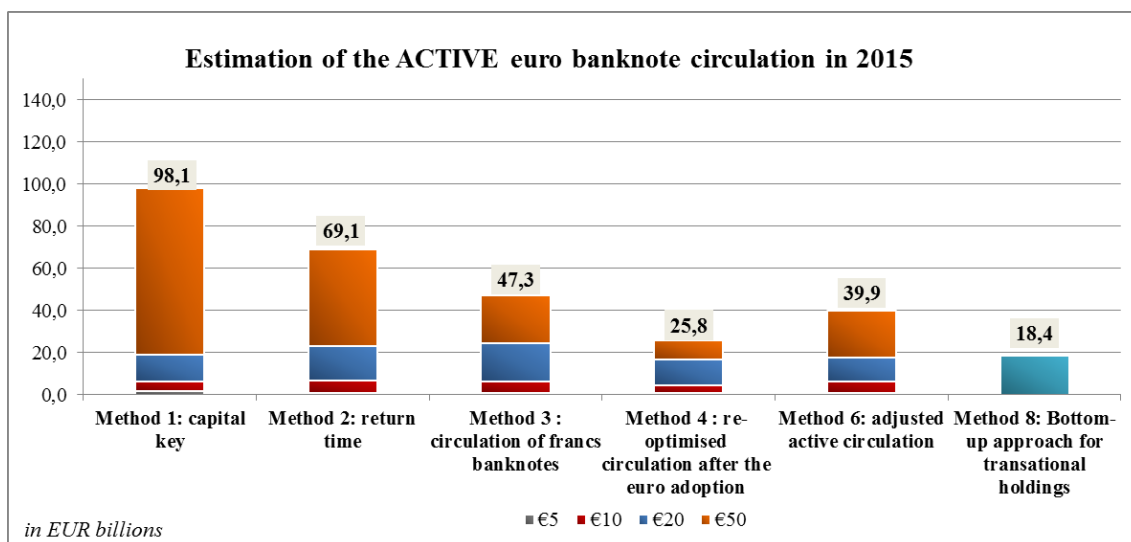
The active banknote circulation in France would stand between EUR 18.4 and 98.1 billion. There are several possible explanations for this wide range:

- The hoarded share of €50 banknote is taken into account differently among the methods. Methods 1, 2 and 3 include hoarded €50 notes, while methods 4 and 6 exclude them (since 2002 for method 4). Method 8 includes a very small share of them (the fraction of €50 notes hoarded for one single year). From this point of view, the comparison between the 6 methods should be done with caution.

- The use of the capital key in method 1 and the return time in method 2 lead to an overestimation of the national active banknote circulation because of the integration of the non-resident circulation in the estimation.

- The active banknote circulation stemming from method 1 is also overestimated given the breakdown by denomination based on the assumption of an identical use of cash in euro area countries. Indeed, according to this method, the €50 note would represent 80.5% of the circulation of transaction banknotes (€5 to €50). Despite a strong growth in the use of this denomination in France, this result is inconsistent with the breakdown by denomination of the flows recorded at the Banque de France's counters.

- In method 3, the breakdown per denomination of the banknote circulation relies on a hypothetical calculation as the banknote denomination structures in French franc and in

euro are very different. By extension, the estimation of active banknote circulation is also hypothetical.

- The three latter methods provide more homogeneous results, which fluctuate between 18.4 and 40 EUR billion. Their convergence tends to support the robustness of the result of our qualitative survey, which will nevertheless have to be extended over time.

Conclusion

This study aims to stimulate reflexion and improve the statistical processing and modeling of banknote demand in France.

It proposes a new evaluation of the active cash circulation in France in 2015 (on average and on a daily basis): EUR 12.2 billion (without the unobserved economy), or 11% of French net issuance. This result is consistent with the findings of comparable studies conducted in other countries or for the euro area. Adding an assessment of the cash use in underground and informal activities leads to a total active banknote circulation of around EUR 20 billion in France.

The comparison of the results of the different methods analysed in this paper already highlights interesting characteristics of the cash demand in France. Regular updating of these results will be necessary to get comparable benchmarks. Moreover, as soon as there is a sufficient lapse of time, the inclusion of the €20 banknote in the method based on the lessons learnt from the ES2 will be very interesting given the share of this denomination in France.

This study has methodological limitations and some weaknesses due to partial information, for example regarding households' hoardings in France. Further avenues thus need to be further explored, such as:

- Estimation of hoarded cash;
- Analysis of tourists' expenditure in cash;
- Estimation of the share of cash in the remittances of workers;
- Impact of the development of cashless payments and of current regulatory and technological developments in the payments industry;
- Use of the data collected by the new sorting machines (BPS M7), which are equipped with an optical sensor for tracking banknote serial numbers.

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Method based on banknote holdings

In this study, we use a bottom-up approach to estimate the cash in circulation (CC), by considering it as the sum of the cash holdings (CH) of the institutional sectors: households (hh), non-financial corporations (nfc), financial corporations (fc), the government sector (gs) and non-profit institutions serving households (npish).

$$CC = CH_{hh} + CH_{nfc} + CH_{fc} + CH_{gs} + CH_{npish}$$

Since the government sector and the NPISHs use relatively limited amounts of cash compared to the other institutional sectors, we focus on the cash held by households, financial and non-financial corporations.

We assume that the institutional sectors, particularly the households, hold cash for two main reasons: transaction (t) and hoarding (h). Due to the absence of data on hoarding, we limit the field of our study to the so-called "active" circulation, used to settle transactions, as opposed to hoarded cash.

By distinguishing between cash held for trading and hoarded cash, the cash held by households can be expressed as follows:

$$CH_{hh} = CH_{hh}^t + CH_{hh}^h$$

Financial institutions hold cash as a result of their customers' operations, i.e. withdrawals and deposits, mainly undertaken by households and non-financial companies. Their cash holdings are therefore a logistical stock, held either in the ATMs, in the vaults of bank branches, or in the centres of Cash-In-Transit (CIT) companies. A portion of the cash held by financial corporations is intended to be hoarded by households, or corresponds to holdings de-hoarded by households, and therefore should not be included in the active circulation.

$$CH_{fc} = CH_{fc}^t + CH_{fc}^h$$

Finally, the cash held by non-financial corporations (businesses) corresponds to their turnover in cash awaiting pick-up by CIT companies, as well as cash funds. It can therefore be entirely assimilated to the "active" circulation.

The « active circulation » (AC) can be expressed as follows:

$$AC = CH_{hh}^t + CH_{nfc} + CH_{fc}^t$$

The use of cash for transactions in the non-observed economy by households and non-financial corporations represents an additional difficulty when estimating the active circulation. Cash held by these two sectors can be expressed as the sum of cash held for transactions in the observed economy (ot) and cash held for transactions in the non-observed economy (nt).

$$CH_{hh}^t = CH_{hh}^{ot} + CH_{hh}^{nt}$$

$$CH_{nfc} = CH_{nfc}^{ot} + CH_{nfc}^{nt}$$

The use of cash in the non-observed economy is only partly captured by the data used to estimate the cash holdings of households and non-financial corporations.

Assuming that the ratio between the amount of transactions paid by cash and the currency in circulation is the same in the observed economy and in the non-observed economy, it is possible to estimate the cash in circulation used for transactions in the non-observed economy on the basis of the estimated amount of transactions in the observed (AOT) and non-observed (ANT) economy:

$$CH_{hh}^{nt} + CH_{nfc}^{nt} = \frac{AOT}{CH_{hh}^{ot} + CH_{nfc}^{ot} + CH_{fc}} \times ANT$$