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An Empirical Investigation for Euro Area Countries and Beyond

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Abstract

We analyze the net issues of the national euro area central banks in relation to the dynamics of the shadow economy within a panel cointegration framework. Besides the total net issues, we distinguish between large, medium and small euro banknotes and take due account of other determinants of cash demand. We find a significant and positive relationship between the net issues and the size of the shadow economy only for medium notes. And this result seems to be driven by the smaller euro area countries. The use of large and small denominations is obviously not driven by the shadow economy. For comparison purposes, we also present panel results for eight non-euro area countries (Australia, Canada, Japan, Norway, Sweden, Switzerland, UK, US). For these countries, we are not able to establish an economically meaningful and statistically significant cash demand equation including the shadow economy.

JEL-Codes: C230, E410, E580.

Keywords: banknotes, net issues, shadow economy, cash demand function, panel cointegration.

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An empirical investigation for euro area countries and beyond*

1 Introduction and literature review

In the last decade and especially since the financial and economic crises 2008/09, cash in circulation increased drastically nearly worldwide and faster than GDP due to several reasons (Jobst & Stix, 2017). One criticism repeatedly levelled at cash for quite some time and which still echoes today is that it is used for illegal activities in the shadow economy and encourages moonlighting, tax evasion and money laundering, in particular. Therefore, there are attempts and proposals in the last few years to abolish cash altogether or certain denominations (see Bussmann, 2015; Rogoff, 2016, Part 1) or to restrict the use of cash (eg Sands, 2016; Sands et al, 2017). Characteristic in this respect is the title of a paper by Peter Sands (2016): "Making it Harder for the Bad Guys: The Case for Eliminating High Denomination Notes".[1]

It is often (implicitly) assumed in this discussion that anonymous transactions are almost exclusively of the illegal kind and that these illegal activities are predominantly undertaken by cash (Buiter, 2009; Sands, 2016). However, empirical evidence to back this hypothesis is lacking. In the debate about withdrawing the €500 banknote from circulation, ECB Executive Board Member Yves Mersch said: "European Central Bank officials want to see evidence that high-denomination euro banknotes facilitate criminal activity rather than relying on unproven assertions" (Schneeweiss, 2016). The head of the ECB's Currency Management Division also stated that there is no statistically proven link between criminal activity and the use of cash, or, in fact, between the size of the shadow economy and cash (FAZ, 2016). With respect to anonymity, Drehmann et al (2002) wrote: "There are many reasons why people may prefer anonymity – many of which are connected with "bad" behaviour." But "bad" does not always mean "illegal". It can also include the small human weaknesses we are prone to. Economic agents do not necessarily want these documented in full in the form of proof of payment. Moreover, large-scale crime that involves huge sums of money often prefers cashless means of payment (Mai, 2016). By using complicated and convoluted cross-border chains of transactions, criminals are remarkably adept at concealing the origin of their funds.

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[1] Arguments why abolishing cash (or high denomination banknotes) might not be helpful in reducing shadow economic activities can be found in Krüger & Seitz (2017), ch 7.1 and Schneider (2017).

The present paper tries to shed light on the relationship between the size of the shadow economy and cash in circulation for euro area countries within a banknote demand framework; to our knowledge such an investigation is done for the first time. For that purpose, we use the net issues of banknotes of each individual euro area central bank and estimates of the size of the shadow economy relative to GDP, while controlling for the transactions motive and opportunity costs of holding cash as well as national peculiarities in cash demand. We do this in an adequate panel cointegration setup for different denominational subgroups of cash, ie small, medium and large banknotes. We also distinguish between the large (Germany, France, Italy, Spain) and the smaller euro area countries. Finally, we compare the results to those of a panel of non-euro area countries (Australia, Canada, Japan, Norway, Sweden, Switzerland, UK, US). We also augment this panel by the euro area as a whole to investigate whether the results are altered.

The literature on the relationship between cash and the shadow economy is scarce. Since the shadow economy is not directly observable, there are some authors who use indicator variables that are positively related to it, eg the share of self-employment to labor force, the share of direct and indirect taxes in GDP or the unemployment rate. Klovland (1984) pursues such an indicator-driven procedure for Sweden and Norway. He finds no effects in the case of Norway, but a positive relationship for Sweden. Using the same methodology, Herwartz et al (2016) investigate whether shadow economic activities have a measurable influence on the demand for currency in a cross section of 11 OECD countries (including Germany, Italy, Norway, Spain and Switzerland) from 1970 to 2012. They find within an error-correction model based on pooled data that some of these variables have a significant influence on cash demand. In line with the positive finding of Klovland (1984) for Sweden is Guibourg & Segendorf's (2007) analysis of the difference between households' incomes and the expenditures. In their view, this difference captures transactions in the shadow economy which they find to be positively correlated with the unexplained part of cash demand. In contrast, Flannigan & Parsons (2018) are unable to establish econometrically a meaningful relationship for large denomination bills in Australia, Canada and the UK. By using a survey from 2016 in Austria, Schneider (2016) establishes that only about 10 % of cash is used for shadow economy purposes. In looking at the situation since the beginning of the 2000s, Takala & Virén (2010) also find that changes in cash demand do not seem to correspond to changes in existing measures of shadow economy, nor do cross-country measures correspond very well with each other.[2] Schneider & Linsbauer

[2] In a white paper for "Cash Matters", Dalinghaus (2017) examines a range of institutional, legal, scholarly, policy and news media sources to understand the current state of debate about – and evidence for – the links between cash, crime, and terrorism. It emphasizes that singling out cash when criminal activities depend upon multiple

(2016) give a literature review on the finances of international crime organizations which shows that cash is used in many crime activities. Therefore, restrictions of cash might reduce crime activities as transaction costs rise, but as the profits of crime activities are very high, the reduction will be modest.

Our paper differs in several aspects from the existing literature. First, we are the first to use net issues of cash of all national euro area central banks to analyze the relationship between cash demand and the shadow economy within a currency union. Up to now, these net issues are only investigated for individual countries (see Bartzsch et al, 2013; Rua, 2017) or, instead, currency (banknotes) in circulation is used (see Herwartz et al, 2016; Klovland, 1984). Second, we distinguish between large and small countries as well as between large, medium and small denominations. Third, we use estimates of the shadow economy which do not rely on the currency demand approach (see, e.g., Medina & Schneider, 2018, ch 3).[3] This is necessary to circumvent the circularity problem of estimating the shadow economy with cash figures and in a second step to estimate cash demand functions including as regressor the size of the shadow economy estimated in the first step (see also Herwartz et al, 2016, 1634f).

The paper is structured as follows: It starts with some theoretical reflections and our basic hypothesis in section 2. Section 3 presents the data and explains the concept of net issues of banknotes and the selected estimation procedure for the shadow economy. Moreover, the econometric methodology is briefly described. The main results for euro area countries as well as a control panel of non-euro area countries are in section 4. Section 5 summarizes and concludes.

2 Some theoretical considerations

As we showed in the short literature review, there are only few studies (e.g. Herwartz et al., 2016; Schneider, 2017; Guibourg & Segendorf, 2007)) who use a proper econometric framework to demonstrate minor empirical evidence that the shadow economy positively influences cash or increases the demand for cash. Contrary to this result, Flannigan & Parson (2018) as well as Takala & Virén (2010) find no evidence. Empirically, this relationship seems open. Theoretically, we argue, that, when shadow economy activities have been undertaken, mostly cash is used, because cash does not leave a trace (for state authorities), minimizes

tools and methods is ultimately likely to fail in isolation of restrictions on other tools and methods used by criminals to move money and evade restrictions.

[3] Pickhardt & Sardà (2012) modify this approach by taking due account of hoarded cash and foreign demand for cash.

transaction costs and is completely anonymous. These arguments seem convincing and cash should be an attractive and efficient means when undertaking underground activities. However, which denominations are mostly used is theoretically open. High-denomination notes should be the most attractive ones. This is theoretically plausible, but depends on the one side on the size of the shadow economy payment, and on the other side on whether high-denomination banknotes are accepted in day-to-day life. From these considerations, we formulate the following hypothesis:

"A growing shadow economy increases the amount of cash in circulation, ceteris paribus. The concrete denomination which will be predominantly used, is ambiguous." In the next paragraphs, we will empirically test this hypothesis for the case of euro area countries and, as a robustness check, also for non-euro area countries.

3 Data used and econometric methodology

Although shadow economic activities have been studied for a long time, the discussion regarding the "appropriate" methodology to assess them has not come to an end yet. Generally, the size of the shadow economy can be measured in two ways: at the micro level using surveys or questionnaires; alternatively, indirect methods such as the currency demand or latent Multiple Indicators Multiple Causes (MIMIC) approaches making use of macroeconomic indicators can be used (see, eg, Medina & Schneider, 2018, ch 3). The virtue of the latter is that the shadow economy is formalized as the outcome of a multitude of measurable causes like tax rates, the degree of regulation, or the level of unemployment. While those methods allow approximating the development of the shadow economy over time, direct approaches better reveal the motivation of individuals to escape into the shadow economy. In recent years, indirect estimation of the shadow economy is mostly based on the MIMIC procedure and/or the currency demand method. Due to methodological reasons and our research question we rely on the MIMIC approach *without* cash. To be more concrete, we use light intensity as an indicator variable (Medina & Schneider, 2018, ch 3C).

Our measure of the shadow economy is defined as those economic activities and income earned that circumvent government regulation, taxation or observation. More narrowly, the shadow economy refers to monetary and non-monetary transactions of a legal nature, hence all productive economic activities that would generally be taxable were they reported to the tax authorities. Such activities are deliberately concealed from public authorities to avoid payment of income, value added or other taxes and social security contributions, or to avoid compliance

with certain legal labour market standards such as minimum wages, maximum working hours, or safety standards and administrative procedures. The shadow economy thus focuses on productive economic activities that should normally be included in national accounts, but which remain underground due to tax or regulatory burdens.

The cash series we use is the net banknote issues of euro area central banks. The total volume of banknotes in circulation (including banks' vault cash) corresponds to the cumulated net issuance, ie the cumulated difference between monthly withdrawals and lodgements at the respective national central banks. However, it is not identical to the circulation of banknotes in the respective country as the banknotes can freely flow from one euro area country to another and as all national issues are perfect substitutes for each other. Nevertheless, the net issues should be closely related to economic activities and developments in the country. Due to cross-border migration flows the net issues can even be negative for some countries (see Rua, 2017, for the case of Portugal with high tourism inflows). As the demand for euro banknotes from outside the euro area is mainly satisfied via Germany, the Deutsche Bundesbank records very high net issues of banknotes (see Bartzsch et al, 2013). Both, the traditional national determinants of cash demand (transactions and hoarding motive) as well as the national peculiarities have to be taken into account in the econometric specification (see below). As the influence of the shadow economy might differ depending on the denomination considered, we differentiate between small (*cash_sm*: €5, € 10, € 20), medium (*cash_mi*: € 50, € 100) and large (*cash_la*: € 200, € 500) banknotes.[4]

As shadow economic activities are not the only potential determinant of cash demand, we control for the transactions and opportunity cost (hoarding) motives of holding cash. The transactions variable is captured by private nominal consumption and nominal disposable income, respectively. The data are taken from the AMECO database of the European Commission. Our main focus is on the consumption variable as is usual in macro studies on cash demand (see, eg, Bartzsch & Seitz, 2016; Fischer at al, 2004; Rua, 2017). Opportunity costs are proxied by a short-term interest rate. More specifically, we use interest rates of household deposits with agreed maturity from the ECB Statistical Data Warehouse.

We consider all euro area countries since they have introduced the euro, except Cyprus and Malta (no data on the shadow economy available) and Lithuania (euro area accession in 2015).

[4] See Bartzsch & Seitz (2016) for the case of Germany.

Consequently, our annual sample runs form 2002-2017 or shorter with at most 16 countries, ie we have an unbalanced panel structure.

The trend behavior of the variables included necessitates an analysis of their stationarity properties to determine an appropriate specification of the empirical model. However, it is well-known that standard unit root and cointegration tests suffer a short sample bias, ie they have low power against stationary alternatives. Panel tests improve the situation in this respect as they augment the time series dimension by the cross section. Consequently, inference is based on a broader information set with resulting gains in power and more reliable statistical inference.

Our main interest is to establish a meaningful panel cointegration relationship for the different specifications. Thus, the cash demand equations should be statistically significant and economically valid in having the theoretically expected signs, ie a positive sign for the transaction and shadow economy variable and a negative sign for the interest rate. As there might be national peculiarities besides transactions demand, hoarding and the shadow economy, we estimate the regressions with fixed country effects. Reasons for this decision are, for instance, foreign demand in the case of Germany (see Bartzsch et al, 2013) or tourism flows in the case of southern European countries (see Rua, 2017).

Panel unit root tests generalize the unit root tests for single series to cross section data sets. We apply a battery of these tests. These include the common root approach of Levin, Lin & Chu (2002) as well as the method of a common unit root of Breitung (2000). Both approaches share the assumption that there is a common unit root process, which is identical across the cross sections. The respective null hypothesis is the existence of a unit root. The individual unit root approaches of Im, Pesaran & Shin (2003) (IPS) and the two Fisher tests (ADF and PP) combine individual unit root tests to determine a panel test statistic (see, e g, Maddala & Wu, 1999). The IPS relies on the t-statistics of the ADF regression. The Fisher-ADF and the Fisher PP use p-values from individual unit root tests. All these approaches allow for individual intercepts to model individual fixed effects or individual intercepts and individual trends. The optimal lag lengths are in each case selected using the criterion of Hannan-Quinn (H-Q).

Due to the non-stationarity of the variables, the next natural step is to test for a cointegrating relationship. Pedroni (2004) suggests residual based tests for the null of no cointegration under the assumption of a heterogeneous panel. He suggests two classes of tests. The first is based on pooling the residuals of the Engle-Granger type regression along the within dimension of the

panel. Besides the individual approach, cross sectional dependency is taken into account by weighting which uses a generalized least squares method based on the estimation of the panel-wide asymptotic covariance matrix. The second uses the pooling of the residuals adopting the between-dimension of the panel. The test of Kao (1999) follows the same basic approach as the Pedroni tests, but requires homogeneous coefficients of the cointegrating relationship and allows for country-specific intercepts. We use the augmented version of the test. Finally, the combined test (Fisher-Johansen) evaluates the results (p-values) of individual Johansen trace cointegration tests (see Maddala & Wu, 1999). The multitude of tests applied (unit root, cointegration) should be regarded as a kind of robustness check of our results.

If there is evidence for cointegration, it is of interest whether the relationship might be interpreted as a cash demand equation including the shadow economy. Pedroni (2001) suggests a panel estimator for one cointegrating relationship as an extension of the fully modified OLS estimator of Phillips & Hansen (1990) called panel fully modified OLS (P-FMOLS). The OLS estimator is a super-consistent estimator of the coefficients of cointegrated variables. Often used variants are the Pedroni (2001) and Mark & Sul (2003) procedures which are based on a consistent estimator of the moments of the regressors. Moreover, the authors propose an extension of the Stock & Watson (1993) estimator for panels known as panel dynamic OLS (P-DOLS). This estimator uses lags and leads of the explanatory variables to reduce the asymptotic endogeneity and serial correlation. In our case with annual data, we restrict the leads and lags to one or select the lag-lead structure depending on the information criterion of Hannan- Quinn.[5] In a simulation study Wagner & Hlouskova (2012) show that the P-DOLS estimator performs best across a large set of experiments. They confirm evidence of Kao & Chiang (2001). Therefore, we prefer and present the results of the P-DOLS methodology.[6]

4 Results

4.1 Euro area countries

Table 1 comprises the results of the panel unit root tests. As some countries have negative net issues of banknotes in certain years, the cash variables are in absolute values, not in logarithms. The short-term interest (*in*) and the share of the shadow economy in GDP (*bm*) are also in absolute values (percentages). However, the two transactions variables private consumption

[5] An alternative estimation method would be a vector error correction model. However, this approach is not implementable for panels given the high number of parameters to estimate (see Christiansen et al, 2009).
[6] Results of the P-FMOLS case are available upon request.

(*cons*) and disposable income (*inc*) are in logs (*l*). The second column indicates the specification of the deterministic part in the test regressions. The coefficients of this part are country-specific. The null hypothesis of a common unit root of the LLC tests is rejected in nearly all the cases, whereas the more general null of the IPS, ADFF and PPF is usually not rejected for the level variable (as it is for the reported Breitung test). However, it is generally rejected for the change (*d*) of the variables. Therefore, we conclude that all variables are I(1).

Table 1: Panel unit root tests

Variable	Test specification	LLC	Breitung	IPS	ADFF	PPF	Desi-cion
cash	intercept + tr	-4.13***	0.50	-0.43	37.51	77.43***	I(1)
d(cash)	intercept	-6.95***	-	-4.67***	73.48***	68.43***	
cash_la	intercept + tr	-5.10***	1.80	0.12	37.17	41.21*	I(1)
d(cash_la)	intercept	-2.90***	-	-0.94	37.16	60.71***	
cash_mi	intercept + tr	0.49	3.89	2.59	21.02	24.26	I(1)
d(cash_mi)	intercept	-1.61*	-	-0.39	51.38***	39.64	
cash_sm	intercept + tr	-1.07	1.66	2.12	25.21	23.42	I(1)
d(cash_sm)	intercept	-4.62***	-	-1.76**	59.77***	48.76***	
in	intercept	-2.40***	-	0.30	25.08	22.51	I(1)
d(in)	intercept	-10.94***	-	-7.24***	113.35***	125.22***	
lcons	intercept + tr	-4.22***	-0.70	-0.31	31.82	14.41	I(1)
d(lcons)	intercept	-6.22***	-	-4.01***	65.73***	58.55***	
linc	intercept +tr	-4.07***	-3.30***	-1.37*	39.16	23.98	I(1)
d(linc)	intercept	-7.17***	-	-5.50***	86.18***	87.28***	
bm	intercept	-1.72**	-	-0.93	40.11	43.57*	I(1)
d(bm)	intercept	-11.90***	-	-8.20***	121.65***	126.68***	

Notes: Cash: total banknotes; cash_la (cash_mi, cash_sm): large (medium, small) denominations; in: interest rate; lcons (linc): log of private consumption (disposable income); bm: shadow economy; d: difference operator. Bandwidth selection using Hannan-Quinn criterion; LLC: Levin, Lin & Chu t-statistic, Breitung: Breitung t-statistic (only available for specifications with intercept and trend), IPS: Im, Pesaran & Shin W-statistic, ADFF: ADF-Fisher Chi²-statistic, PPF: PP-Fisher Chi²-statistic; Newey-West automatic bandwidth selection and Bartlett kernel; *** (**, *): 1 (5, 10) percent significance level.

Due to the non-stationarity of our variables, we conduct panel cointegration tests in a second step. These are presented in table 2. It includes the systems containing the variables *cash* (including subgroups), *bm*, *in* and *lcons*. As mentioned, we concentrate on the transaction variable *lcons*. Using this transaction variable, the tests do not reveal unambiguous results. There is evidence of a cointegrating relationship for all cash specifications.[7] However, most of the tests reject the null of no cointegration. If at all, the weakest evidence of cointegration is found for the small denominations.

[7] The evidence is weaker for systems including *linc*. These results are available upon request.

Table 2: Panel cointegration tests

Test statistic	Variables: *cash, bm, in, lcons*		Variables: *cash_la, bm, in, lcon*s		Variables: *cash_mi, bm, in, lcons*		Variables: *cash_sm, bm, in, lcons*	
	Individual	Weighted	Individual	Weighted	Individual	Weighted	Individual	Weighted
Pedroni: Panel ν	2.46***	3.32***	17.58***	2.14**	4.09***	3.46***	25.1***	4.43***
Panel ρ	3.87	2.88	2.02	3.27	4.08	3.79	3.50	3.04
Panel PP	2.78	-1.46*	-2.13**	0.14	4.32	1.61	2.98	1.09
Panel ADF	-1.71**	-5.67***	-4.80***	-4.73***	-2.92***	-3.39***	-2.60***	-0.80
Group ρ	4.42		4.35		5.09		5.17	
Group PP	-1.66**		-2.73***		-0.23		2.57	
Group ADF	-6.22***		-5.75***		-5.00***		-1.37*	
Kao ADF	1.14		0.41		1.86**		1.86**	
Fisher Johansen trace r=0	380.0***		326.0***		360.8***		326.7***	
Fisher Johansen trace r ≤ 1	119***		129.9***		154.6***		161.2***	

Notes: Pedroni tests: lag length automatically selected by H-Q criterion, individual intercept and individual trend; Fisher Johansen test: lag length of the dynamic part 1, with intercept in cointegrating equation and VAR. *** (**, *): 1 (5, 10) percent significance level.

As there is evidence of cointegration between the four variables, a natural last step is to investigate whether the relation might be interpreted as a sensible and economic meaningful cash demand equation. In our view and to be more specific, this means finding a relation that exhibits a positive and statistically significant influence from the shadow economy given the repercussions from the transactions variable and opportunity costs. Moreover, country-specific peculiarities in the form of fixed country effects should be taken into account in the unbalanced panel.

The results of the estimated long-run coefficients are given in the Table 3. The first column shows the normalized variable which is the different banknote series. These are measured in € billion. The second column presents the P-DOLS specification. We estimate in each case with fixed effects, either with equal weighting of all observations or with cross-section weights.[8] The latter estimates a GLS specification assuming the presence of cross-section heteroskedasticity. The next columns contain the estimates of the regression coefficients of the explanatory variables given in the heading row of the table. Therefore, the read of, for instance, the first row is as following:

$$cash_{t,i} = c_i + 0.6bm_{t,i} - 14.2in_{t,i} + 77.7lcons_{t,i}$$

[8] The results of the P-FMOLS and the Engle-Granger procedure are available upon request. They also indicate mixed evidence.

The high numbers are due to the non-logarithmizing of cash. Some interesting findings emerge from table 3. First, a statistical significant relation with the expected signs seems to exist for total cash issues and the medium denominations (€50 and € 100). Especially, the shadow economy variable has the expected positive sign. Obviously, the influence of the shadow economy stems from the medium denominations. Against the background of the definition of our shadow economy variable (see section 2), this seems intuitively plausible. Second, in the case of the large denominations, each of the three explanatory variables is individually statistically significant, but the shadow economy has the wrong sign. Third, there is no evidence of a cash demand equation for the small denominations: neither are the individual coefficients statistically significant nor is there a positive coefficient of the shadow economy. This is in line with the implications from table 2 where we found the weakest evidence for cointegration in the case of the small denominations. Fourth, the results do not depend on weighting or not weighting the observations.

Table 3: Cointegrating relationship estimates

Variable	Specification	Explanatory variables			
		bm	in	lcons	R^2
cash	c, no weights	0.6	-14.2***	77.7	0.89
cash	c, weights	7.1***	-5.0***	95.0***	0.92
cash_la	c, no weights	-5.8***	-6.9***	6.9	0.89
cash_la	c, weights	-5.0***	-32.2***	-5.0***	0.87
cash_mi	c, no weights	7.2***	-6.0**	65.4**	0.87
cash_mi	c, weights	4.8***	-4.7***	54.7***	0.88
cash_sm	c, no weights	-0.7	-1.4	5.4	0.85
cash_sm	c, weights	-0.2	0.2	2.7	0.83

Notes: Unbalanced panel; pooled DOLS Panel dynamic Least Squares with fixed 1 lead and 1 lag; equations deterministics c as fixed effects using no or cross-section weights; *** (**, *): 1 (5, 10) percent significance level.

What about magnitudes? These are of special interest as the proponents of cash abolition argue that the shadow economy is the main driver of the increase in cash demand. Let us concentrate on all banknotes and the specification with weighting. If the share of the shadow economy in GDP decreases by one percentage point, the demand for banknotes would fall by about 7 billion euros. In the euro area, the estimates of the shadow economy are in the range of about 18 % of GDP in 2017 (see Medina & Schneider, 2018). Consequently, reducing the shadow economy by 50 % diminishes the demand for banknotes by about 130 billion euros. This is approximately 10 % of total banknotes in circulation at the end of 2017. Let us assume that all shadow economic activities are settled in cash and that the velocity of circulation of cash in the shadow economy is around 10 (see Krüger & Seitz, 2017, fn 60). Then, abolishing euro cash altogether

would, ceteris paribus, reduce banknote demand by about € 200 billion. This is a relatively low number (16 %) given that total euro banknotes issued were about € 1.2 trillion at the end of 2017. An important driver for the cash holding is usually transactions. This is also the case in the euro area. An increase of consumption by 100 billion euro that is an increase in logs by 0.01764 raises cash in circulation by 1.68 billion euros. Moreover, an increase of the interest rates by one percentage point reduces the cash in circulation by 5 billion euros, Hence, the influence of shadow economy in terms of changes in percentage points relative to GDP seems to be as important as a percentage point change in the interest rate. However, these magnitudes are significantly lower than those of a one percent change in private consumption.

As a robustness check and kind of sensitivity analysis, we divide the whole cross section of countries into the big four countries France, Germany, Italy, Spain (*Big 4*) and the rest of the smaller euro area countries (*other countries*). We concentrate on the DOLS (with weighting) estimates with fixed effects. In table 4 the third column indicates the panels considered where for comparison purposes "*all countries*" replicates the estimates of table 3. Interestingly, the result that the medium denominations are positively influenced by the shadow economy (given the effects of the control variables) seems to be driven by the smaller euro area countries. For the panel including France, Germany, Italy and Spain, the *bm* coefficient is significant, but with the wrong negative sign. Turning to the large denominations, *bm* is in any case negative. The estimated coefficients of the small denominations are mostly not significant. Within no country grouping are we able to explain the use of the small denominations in a meaningful way with the included variables and effects.

Table 4: Pooled cointegrating relationships: different country groupings

Variable	Specifi-cation	Panel	Explanatory variables			
			bm	in	lcons	R^2
cash	c	All countries	7.1***	-5.0***	95.0***	0.92
cash	c	Big 4	-23.3*	-30.7*	484.0***	0.91
cash	c	Other countries	4.9***	-4.6***	0.9	0.90
cash_la	c	All countries	-5.0***	-32.2***	-5.0***	0.87
cash_la	c	Big 4	-20.1***	-23.3***	-63.7	0.91
cash_la	c	Other countries	-0.9	-1.2*	4.1	0.84
cash_mi	c	All countries	4.8***	-4.7***	54.7***	0.88
cash_mi	c	Big 4	-7.3	-10.4	332.0***	0.90
cash_mi	c	Other countries	6.2***	-2.4**	20.7**	0.84
cash_sm	c	All countries	-0.2	0.2	2.7	0.83
cash_sm	c	Big 4	-3.3	-4.6*	151.0***	0.96
cash_sm	c	Other countries	0.1	-0.3	10.2***	0.84

Notes: Unbalanced panel; pooled DOLS Panel dynamic Least Squares with fixed 1 lead and 1 lag; equations deterministics c as fixed effects using cross-section weights; *** (**, *): 1 (5, 10) percent significance level.

4.2 The euro area and non-euro area countries

In this section, we repeat the same analysis for eight non-euro area countries (Australia, Canada, Japan, Norway, Sweden, Switzerland, UK, US) to which we add the total euro area in a second step. For the eight countries, the annual sample can be extended to include the 1990s. In this setup, the cumulated net issues equal currency (banknotes) in circulation (including vault cash). Once again and for every country, we distinguish between small, medium and large denominations. The decision is done on a country-by-country basis.[9] In any case, we qualify at least one denomination as large, medium and small, respectively (see table 5). As in section 3.1, we control for transaction balances and opportunity costs by including private consumption and a short-term nominal deposit interest rate. The data are from the AMECO database and the respective national central banks. Panel unit root and cointegration tests unambiguously show that all variables are I(1) and that there exists (at least) one cointegration relationship (not shown, but available upon request).[10]

Table 5: Small, medium and large denominations: non-euro area countries

	Small	Medium	Large
Australia	AUD 10, 5	AUD 50, 20	AUD 100
Canada	CAD 10, 5, 2, 1	CAD 50, 20	CAD 100
Japan	JPY 2000, 1000, 500	JPY 5000	JPY 10000
Norway	NOK 100, 50	NOK 500, 200	NOK 1000
Sweden	SEK 50, 20, 10, 5	SEK 500, 200, 100	SEK 1000
Switzerland	CHF 20, 10, 5	CHF 100, 50	CHF1000, 500, 200
United Kingdom	GBP 5, 1	GBP 20, 10	GBP 50
United States	USD 10, 5, 2, 1	USD 50, 20	USD 100

Notes: own table.

The pooled cointegration equations are again estimated by DOLS with fixed effects (see table 6). Private consumption as well as the cash variables are in logarithms (*l*), interest rates and the shadow economy enter the equations in percentage terms. Consequently, we report true (semi-)elasticities. Three main conclusions emerge: First, for no cash group are we able to establish a meaningful cash demand equation. This result also holds if we restrict the sample to the period since 2002 as in section 3.1. Second, the results do not differ whether including or excluding

[9] See for a such a procedure Amromin & Chakravorti (2009) and Fischer et al (2004).

[10] Exceptions of the rule that the null of a unit root in the levels of the variables is rejected are in some cases interest rates and the shadow economy estimate. However, as the null of a unit root is unambiguously rejected for the (logarithmic) change in all the variables, we classify the variables as I(1).

the whole euro area. Third, the shadow economy variable is either not significant or has the wrong sign. In this respect, aggregating all euro area countries obviously cushions the different national behaviours. However, it is important to notice once again that the national net issues of countries within a currency union do not correspond to the national cash in circulation. The disappointing result for the non-euro area countries is in line with papers which do not find a reliable and significant relationship between the shadow economy and cash holdings (see, e g, Bartzsch & Seitz, 2016; Flannigan & Parsons, 2018; Takala & Virén, 2010). It also matches the statements in this respect mentioned in the introduction.

Table 6: Pooled Cointegration relationships: non-emu countries with/without euro area

Variable	Specifi-cation	Panel	Explanatory variables			
			bm	in	lcons	R^2
lcash	c	without euro area	-0.06***	-0.02*	0.78***	0.99
lcash	c	including euro area	-0.08***	-0.01*	0.74***	0.99
lcash_la	c	without euro area	-0.15***	-0.02	0.55***	0.99
lcash_la	c	including euro area	-0.17***	-0.02	0.46***	0.99
lcash_mi	c	without euro area	-0.02*	-0.01	0.93***	0.99
lcash_mi	c	including euro area	-0.02**	-0.01	0.90***	0.99
lcash_sm	c	without euro area	-0.01	0.01**	0.33***	0.99
lcash_sm	c	including euro area	-0.01	0.01*	0.32***	0.99

Notes: Unbalanced panel; sample 1992-2017; pooled DOLS Panel dynamic Least Squares with fixed 1 lead and 1 lag; equations deterministics c as fixed effects using cross-section weights; *** (**, *): 1 (5, 10) percent significance level.

5 Summary and conclusions

The paper analyzed the importance of the shadow economy for the cash holding in the different euro area countries. Estimates of the shadow economy are only available on an annual basis. Therefore, panel approaches are sensible, e.g. panel unit root and panel cointegrating tests as well as panel estimation methods. To assess the relationship between cash and the shadow economy, it was necessary to control for other motives for holding cash and national peculiarities. To test for robustness different cash breakdowns and two different country groups are considered and a multitude of statistical tests and econometric procedures are performed. Given that some results are sensitive to the concrete specification and the presence of estimation uncertainty it may be concluded that, if at all and in euro area countries, it is the medium denominations which might be influenced positively by shadow economic activities. And obviously this result is driven by the smaller countries. For the four big euro area countries, we did not get a significant positive coefficient of the shadow economy variable. Furthermore and unfortunately, extending the approach to important western economies and including in the panel the euro area as a whole does not allow to establish a meaningful relationship.

The paper also demonstrates (like many others) that it is difficult to establish such a relationship against the background of the special characteristics of cash and the shadow economy. With respect to cash, we do not know exactly where it circulates, for what purposes it is held and who holds it. In this sense private consumption or disposable income may not be the best proxies for the transaction variable. Moreover, precautionary savings in cash are not addressed. This could be especially important around the financial and economic crisis 2008/09 or during the euro crisis 2012/2013. Furthermore, the shadow economy is a construct which by definition is hard to capture and to estimate. All in all, it seems that cash is probably used to a smaller extent in the context of shadow economic activities than is often suspected and that abolishing or limiting cash would not be as effective as desired in curbing crime (Mai, 2016; Schneider & Linsbauer, 2016).

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