Cash, Hoarding and the Underground Economy

by

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Abstract: We further refine the Modified-Cash-Deposits-Ratio (MCDR) approach, developed by Pickhardt and Sardà (2011, 2012) with a view to analyze size and causes of the cash using section of the underground economy. Among other things, we address the issue of cash hoarding. Findings include that the size of hoarded currency in Germany, about 40 to 110 billion Euro in 2009 according to recent estimates, may have reduced the size of the cash using underground economy in Germany, *ceteris paribus*, from about 8.5 to 2 percent in 2009, according to the MCDR approach.

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1 Introduction

Estimates of the size and scope of underground economies[3] are often carried out by using a so-called 'monetary method'. A central assumption of all monetary methods rests on the assertion that everyone involved in underground economic activities has a strong preference to conceal these activities and, therefore, prefers to use cash (currency) in all underground economy transactions. Hence, *ceteris paribus* the demand for cash should be higher the larger the size of the cash using underground economy.

This idea was pioneered by Cagan (1958) and later Gutmann (1977), Feige (1979, 1989), Tanzi (1980, 1982, 1983), Klovland (1980, 1984), Bhattacharyya (1990), Escobedo and Mauleón (1991) and others developed variants of the monetary method. More recently, however, Breusch (2005a,b) and Ahumada et al. (2007, 2008) have shown that many of the estimates using either the Tanzi or Klovland method suffer from serious econometrical or mathematical shortcomings. Therefore, results obtained from these methods may provide misleading information to policy and law makers. Pickhardt and Sardà (2011, 2012) have made a first attempt to address these issues by developing the Modified-Cash-Deposits-Ratio (MCDR) approach, which they have applied to Germany and Spain, respectively. Moreover, Berger et. al (2012) have applied the approach to Greece.

The purpose of the present paper is to further refine the MCDR approach by incorporating cash hoarding and to discuss in some detail implications of the MCDR approach with a view to identify possible applications and limitations. The remainder of this paper is organized as follows. In the next section we briefly review essential aspects of the MCDR approach and

[3] Here we use the term „underground economy" interchangeable with terms such as shadow economy, hidden economy, black economy, etc. (see also Kazemier 2006; Pickhardt and Sardà 2011).

discuss relevant assumptions. In section three we extend the MCDR approach by incorporating estimates of hoarded currency. The final section concludes.

2 The MCDR Approach

In this section we briefly reconsider essential aspects of the MCDR approach. In particular, we first deal with the theoretical and econometrical background and then discuss the underlying implications and assumptions of the approach in some detail.

2.1 Motivation and Background

As noted, the MCDR approach was primarily developed with a view to avoid econometrical and mathematical problems that were discovered some years ago with respect to the popular monetary approaches of Tanzi (1980, 1982, 1983) and Klovland (1980, 1984). Additional motivations were related to: (i) the possible inclusion of cash using illicit economic activities not caused by tax pressure, (ii) simplifying plausibility testing and, (iii) raising the level of transparency (see Pickhardt and Sardà 2011, 2012).

Essentially, the MCDR approach follows a 'back-to-the-roots path' by first going back to the pure calculation method of Peter M. Gutmann (1977). Among other things, Gutmann's approach rests on the assumption that over time agents in the legal economy wish to maintain a constant ratio λ of currency to sight deposits.[4] Unfortunately, however, for many industrialized countries this assumption does not seem to hold as the growth rates of sight deposits substantially exceeded those of cash or currency during the last decades. As a consequence, the original Gutmann approach may lead to a negative size of the underground economy, which does not seem to be plausible. Pickhardt and Sardà (2011, 149-150), therefore, replace the aforementioned assumption by the equally strong assumption that "all

[4] Gutmann (1977, 27) writes: „The amount of currency required for legal transactions in 1976 is assumed the same percentage of demand deposits as in 1937-41."

currency in circulation in the base year, C_0, represents the entire cash agents wish to hold in any year after the base year for the set of legal transactions they prefer to carry out in cash." Otherwise, the remaining assumptions of the Gutmann approach continue to hold. By formalizing these assumptions and after some rearranging the authors derive the following equation,

$$\frac{C_t - C_0}{C_0 + D_t} = \frac{Y_{Ut}}{Y_{Lt}}, \tag{1}$$

with C_t denoting currency in circulation outside banks (MFIs) at the end of the year, C_0 denoting currency in circulation outside banks at the end of the base year or base period, D_t denoting sight or demand deposits held by domestic non-banks (non-MFIs) at the end of the year, Y_{Ut}/Y_{Lt} denoting the relative size of the cash using underground economy and t denoting the time index. Also, by assumption, we have $C_0 = C_{Lt}$, and, thus, $C_t - C_0 = C_{Ut}$, where C_L denotes currency used for transactions in the legal economy and C_U denotes currency used for transactions in the underground economy.

Equation (1) states that the relative size of the cash using underground economy (r.h.s. of (1)) can be measured by the ratio of currency used for underground economy activities (C_U) and money used in the legal sector of the economy ($C_L + D = M_L$). Moreover, equation (1) generates a positive size of the underground economy for many industrialized countries and, therefore, solves a fundamental problem of the original Gutmann approach.

This notwithstanding, equation (1) rests on some rather strong assumptions. For example, according to (1) it is assumed that the *nominal* amount of currency in circulation outside banks at the end of the base year or period represents the entire amount of currency agents wish to hold for legal transactions during each and every subsequent period. Hence, in (1) the distorting effect of inflation is ignored. Yet, the inflation effect may be incorporated by

adjusting C_0 in each year with the prevailing inflation rate, as measured by the consumer price index (CPI). Effectively, this amounts to assuming that agents wish to hold a constant *real* value stock of currency for legal transactions during all periods under consideration. Likewise, according to (1), changes in the population size would have no influence on C_0, but would be reflected in both C_t and D_t, and may thus lead to some distortions over time. To address this issue, C_0 may be adjusted over time with an index that reflects population developments. This procedure then implies the assumption that on average agents wish to hold a constant *per capita* real value stock of currency for legal transactions during all periods under consideration. In Pickhardt and Sardà (2011, 2012) these changes are denoted as auxiliary modifications one (*mod1*) and two (*mod2*), respectively.

In addition, in both the German and the Spanish case distortions caused by the introduction of Euro coins and notes on January 1, 2002 have been taken into account by an econometric estimation, which in the German case was based on a slightly modified version of the method proposed by Seitz (1995). With respect to the German case the results of this estimation were also used for estimating the amount of currency held outside Germany (*mod3*). Regarding equation (1) both changes require an adjustment of C_t, and the latter also an adjustment of C_0. Then, by taking all adjustments into account, Pickhardt and Sardà (2011) obtain the following equation,

$$\frac{INFC_t - INPIC_{0t}}{INPIC_{0t} + D_t} = \frac{Y_{Ut}}{Y_{Lt}}, \tag{2}$$

where $INFC_t$ denotes forecasted currency in circulation outside banks, inside Germany, and $INPIC_{0t}$ denotes the inflation and population adjusted amount of currency that was in circulation outside banks, inside Germany, at the end of the base year or base period. In the Spanish case, however, it is assumed that no substantial amounts of Pesetas were held outside

Spain, and, therefore, no such adjustment was necessary (see Pickhardt and Sardà 2012). Equation (2) then amounts to,

$$\frac{FC_t - PIC_{0t}}{PIC_{0t} + D_t} = \frac{Y_{Ut}}{Y_{Lt}}. \qquad (2')$$

Application of (2) and (2') yields a time series of the size of the cash using underground economy in Germany and Spain, which are denoted as G3 and S2 in Pickhardt and Sardà (2011, 2012), respectively.

Moreover, while the former work focuses primarily on developing the theoretical background of the MCDR approach, the later exposes the S2 profile, as the dependent variable, to an econometric estimation procedure. Provided that this procedure yields a regression with reasonable diagnostic statistics, not only the creditability of the relevant MCDR underground economy profile is supported, but also essential causes of the latter are identified. To this extent, even policy conclusions may be derived with the MCDR approach. For example, based on the results of the econometric estimation procedure Pickhardt and Sardà (2012) conclude that a growth and competitiveness enhancing macro policy, combined with a fundamental labor market reform, and accompanied with less tax pressure and an intensified fight against criminal activities, in particular illicit drug related crimes, is best for fighting the cash using underground economy in Spain.

2.2 Discussion

The brief sketch of the MCDR approach in the preceding subsection provides an introduction to its essential elements. This subsection aims at a deeper discussion of its assumptions and implications with a view of going beyond earlier discussions of the approach. A good starting point for the discussion are the auxiliary modifications four to seven mentioned by Pickhardt

and Sardà (2011, p. 153), which they did not address due to a lack of data. These modifications concern: cash hoarding by national non-banks (*mod4*), changing cash use preferences of national non-banks (*mod5*), the use of deposits for underground economy transactions (*mod6*), and the benchmarking procedure (*mod7*), i.e., the choice of the base year or period, respectively.

2.2.1 *Hoarded Currency*

Non-banks may hold currency not only for transaction purposes but also for hoarding purposes. This notwithstanding, it is difficult to explain cash hoarding in the legal economy with behavior patterns of *homo economicus*. In addition, there is little empirical evidence about actual motivations for keeping cash hoards (see van Hove and Vuchelen 1994). Yet, precautionary motives caused by a fundamental distrust in the banking system or safety measures in case of a loss of debit and/or credit cards might be plausible motivations for holding cash hoards in the legal economy. In any case, however, there is ample anecdotal evidence that cash hoards do exist in the legal economy.

In contrast, with respect to the cash using underground economy, cash hoarding may well be explained by rational behavior. For example, cash hoards may emerge from saving motives because interest bearing demand deposits are by definition not considered as a feasible option. In addition, cash hoards may be build up with a view to create larger amounts of cash, which could then be easier handled by the money laundering branch of the underground economy. To this extent, agents engaged in the cash using underground economy may well have a much stronger motivation for keeping cash hoards, which was already noted by Cagan (1958).

Bartzsch et al. (2011a,b) have recently conducted two comprehensive studies on the foreign demand for Euro banknotes issued in Germany, which also generate cash hoarding

data for Germany. In section three we use their data to further refine the MCDR approach by applying auxiliary modification four.

2.2.2 *Non-cash Payment*

In this subsection we shall deal with auxiliary modifications five and six jointly. To begin with, recall that the MCDR approach implies by assumption that any additional spending in the legal economy that goes beyond $INPIC_0$ (PIC_0) is carried out via demand or sight deposits and, thus, fully handled via non-cash involving payment methods such as checks, debit cards, and credit cards. Put differently, new non-cash payment methods pose a problem for the MCDR approach only if they effectively lead to a partial replacement of $INPIC_0$ (PIC_0) or, alternatively, if over time more currency is used for legal transactions than indicated by $INPIC_0$ (PIC_0).

Therefore, with respect to the applicability of the MCDR approach, the important question is how to verify whether or not agents in the legal economy use over time and on average a stable real per capita amount of currency to carry out those legal transactions they wish to handle in cash. Despite some anecdotal evidence, there is, unfortunately, a fundamental lack of useful time series data on this topic. This notwithstanding, over time economic growth, technical progress, innovations, etc. may lead to fundamental changes of individual cash payment preferences. It is important, however, to recognize that these changes may have opposite effects.

For example, economic growth may make many households much richer over time, which in turn may prompt these households to source out part of their household production to market exchanges. Going out for lunch or dinner rather than cooking at home, using a laundry rather than doing all washing at home, taking a hair cut at a hair dresser rather than at home, using market based leisure activities rather than staying at home, are just a few examples.

Even if some of these market exchanges are paid via non-cash payment methods, others are paid in cash and, thus, might cause an increase of cash used for legal transactions. In contrast, however, technical progress, economies of scale and scope, etc. may, among other things, make many products much cheaper, which would reduce the need for cash. Hence, subject to a lack of useful time series data on the cash use of domestic non-banks, with respect to the MCDR approach it is assumed that all conceivable influences on $INPIC_0$ (PIC_0) balance over time.

Another issue is the use of demand deposits for underground economy transactions, such as fraud and the like. These cases amount to the implicit assumption that the MCDR figures no longer cover just the cash using section of the underground economy. Technically, in both (2) and (2'), this notion implies, $D_t = D_{Lt} + D_{Ut}$, and, therefore, we get,

$$\frac{INC_{Ut} + D_{Ut}}{INPIC_{0t} + D_{Lt}} = \frac{Y_{Ut}}{Y_{Lt}}, \tag{3}$$

$$\frac{C_{Ut} + D_{Ut}}{PIC_{0t} + D_{Lt}} = \frac{Y_{Ut}}{Y_{Lt}}, \tag{3'}$$

respectively, where D_{Lt} denotes demand deposits used for legal transactions, D_{Ut} denotes demand deposits used for, or generated by, underground economy transactions, both at the end of the year. But again, there is currently no time series data or estimation method that allows for obtaining data on either D_{Ut} or D_{Lt}.

Barter exchanges are another important issue with respect to non-cash payment methods, as they may be used in underground economy transactions instead of cash. For example, barter exchanges may have played an important role for underground activities in Germany after World War II and until the 1950s, because many markets did not yet exist or were still

underdeveloped. But even in more recent times barter exchanges may play an import role in some industries. The market for recorded music and movies is a good example. To copy a music CD or MP3 file for a friend in exchange for another copied CD or simply a favor may be regarded by many people as some sort of petty crime. Yet, if such beliefs are fairly common within the population and even internet based platforms are available, allowing for a wide distribution of these barter exchanges, a whole industry might get into trouble.

Finally, money laundering is an important issue that may have a non-negligible impact on (2) or (2'). In the present context, the money laundering branch of the underground economy essentially ensures that a large number of small retail cash proceeds from activities such as illegal drug consumption or illegal prostitution can be channeled into (allegedly) legal investment projects.[5] Provided that this sort of money laundering takes place domestically, in (2) or (2') it would reduce C_{Ut} by dissolving hoards of cash held in the underground economy and would increase D_t, thereby reducing the size of the cash using underground economy according to the MCDR approach.

2.2.3 *Benchmarking*

Arguably the most important issue with respect to all monetary approaches is the benchmarking procedure, because it is this procedure that inevitably introduces some arbitrariness to the underground economy estimates. Regarding the MCDR approach the benchmark assumption for both the German and Spanish case has been 'zero percent of cash using underground economy in 1960'. As demonstrated by Pickhardt and Sardà (2011, p. 155), choosing a different base year leads to different values and choosing a different (positive) initial percentage of the underground economy would also lead to different values with respect to the size of the underground economy. Moreover, contrary to conventional

[5] Note that money laundering for terrorist financing may work the other way round, i.e., either small amounts of legal cash (e.g. donations) or even large sums are channeled into illegal terrorist projects.

beliefs, Ahumada et al. (2008) have demonstrated that estimates using the Tanzi method also require a benchmark value, if short-run models, which include the lagged dependent variable, are used.

It is for this reason that any estimate of the size of the underground economy that rests on the MCDR approach or another monetary method carries some arbitrariness. Therefore, interpretations of estimated underground economy figures, in particular with respect to economic policy recommendations, should take these aspects into account and special attention should be given to the benchmark selection procedure.

For example, the MCDR benchmark 'zero percent of cash using German underground economy in 1960' was chosen for the following reasons. First, in 1958 the Deutsche Mark became convertible and the federal state of Saarland became part of Germany again. Second, the macroeconomic environment in 1960 was rather favorable, with full employment and a booming economy. Third, many cash using underground activities such as illegal soft and hard drug dealing, illegal prostitution, human trafficking, etc. either did not exist or were on a rather small scale. Fourth, as noted, during the 1950s many underground economy activities may have been based on barter exchanges, rather than on cash involving market exchanges. In this context it is worth emphasizing that the MCDR benchmark assumption does not imply that there was no underground economy in 1960, but that the cash using section of the underground economy was negligibly small.

Also, regarding the Spanish case, all aspects mentioned above apply as well, except for the first one. In addition, in 1960 Spanish taxes in total where on rather low levels and potential unemployment problems were solved via emigration.

Furthermore, the benchmarking problem also applies to non-monetary approaches, notably the popular MIMIC approach (e.g. see Pickhardt and Sardà 2006). As the MIMIC approach generates only an index, a benchmark obtained from a different source, often a monetary

method, is required to calibrate the index. Obviously, if there are alternative potential benchmarks to choose from, the actual size of the underground economy is essentially determined by the benchmark choice of the researcher and only the development of the underground economy over time is determined by the MIMIC estimation procedure. This may have important implications for the policy recommendations that are given based on results obtained from a MIMIC approach.

2.2.4 *MCDR and other Monetary Approaches*

Recently, Cebula and Feige (2011, 2012) have developed an alternative modification of the Gutmann (1977) approach, which they apply to U.S. data. Their first modification consists of taking into account that U.S. currency may be held abroad. The second modification they suggest consists of taking into account "technological innovations in the financial industry that significantly reduce the volume of 'checkable deposits' (D)",[6] which effectively modifies Gutmann's original assumption that the ratio of currency to deposits remains constant over time (see section 2.1).

The third modification deals with the benchmark procedure. Their original benchmark is 'zero unreported income in 1940' and they introduce two alternative benchmark values that come from independent audit based estimates of unreported income for the years 1988 and 2001, conducted by the Internal Revenue Service (IRS). The fourth modification they propose is a relaxation of Gutmann's assumption that currency is the exclusive medium of exchange in the underground economy. As an alternative they assume, based on IRS audit data, that 20 percent of all unreported income transactions are paid by check and just 80 percent by cash. Finally, the fifth modification is a relaxation of Gutmann's assumption of equal velocities in the legal and underground sector of the economy. They suggest instead that the income

[6] According to Cebula and Feige (2011, p. 7), the term 'checkable deposits' refers to demand deposits plus other checkable deposits.

velocity in the underground economy is higher than in the legal economy, which would *ceteris paribus* lead to a larger size of the underground economy, but they do not apply this last modification to the actual calculation procedure.

Hence, in comparison with the MCDR approach, the main difference occurs with respect to Gutmann's assumption that the currency to deposits ratio stays constant over time. In the MCDR approach Gutmann's assumption is replaced by the alternative assumption of a constant average (per capita, *mod2*) amount of (real, *mod1*) currency that is held for legal transactions, whereas Cebula and Feige (2011, 2012) adjust the amount of deposits D_t, but otherwise maintain Gutmann's assumption. Mathematically, this difference is shown in the appendix. It follows from this mathematical difference that *ceteris paribus*, (i) the Cebula and Feige approach leads to lower (higher) values for the cash using underground economy than the MCDR approach, if deposits are increased (decreased), (ii) the Cebula and Feige approach cannot handle the case where cash hoards are transferred into demand deposits, because this would lead to an unwarranted increase of cash held for legal transactions.

With respect to the popular monetary approaches of Tanzi (1980, 1982, 1983) and Klovland (1980, 1984) the main difference with the MCDR approach is that the amount of currency held for underground economy transactions, C_U, is simply calculated in the MCDR approach (i.e. the nominator of (2) or (2')), but econometrically estimated with a currency demand function in both the Tanzi and Klovland approaches.[7] This difference shows another advantage of the MCDR approach. In comparison with a currency demand estimation, more variables that directly explain the underground economy development may be included, if the MCDR underground economy profile is directly exposed to an econometric estimation. This in turn may allow for deriving more refined policy recommendations.

[7] Among other things, Tanzi considers a relative measure, *C/M2*, as the dependent variable, whereas Klovland considers an absolute measure, real currency *C/P*, as the dependent variable, in their respective currency demand estimations, where *C* denotes nominal currency, *M2* is the conventional monetary aggregate and *P* denotes the price level.

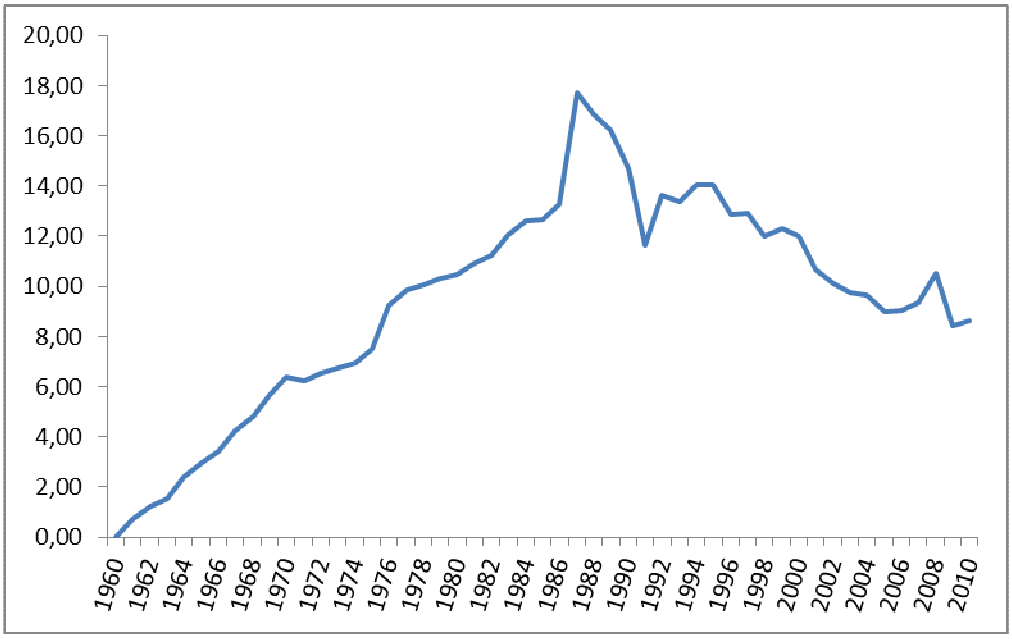
3 New MCDR Estimates for the German Underground Economy

In this section we provide up-dated figures for the size of the cash using German underground economy and further refine the MCDR approach by taking recent estimates on the extent of cash hording in Germany into account.

3.1 Evidence for 2009 and 2010

The German underground economy profile G3, provided by Pickhardt and Sardà (2011, p. 151-152), covers the period 1960 to 2008 and by applying (2) with data for 2009 and 2010 we can extend the G3 profile to the period 1960 to 2010. Figure 1 shows the G3 profile for this latter period and Table 1 shows relevant calculation data for the post reunification period 1992 to 2010. Note, however, that during the period 1987 to 1991 the G3 profile may not fully reflect the development of the cash using German underground economy due to withholding tax effects and the German reunification (see Pickhardt and Sardà 2011, 155-156).

Figure 1: G3 profile (1960 – 2010)



Note: Own calculation.

Inspection of Figure 1 and Table 1 shows that the size of the cash using German underground economy slightly decreased since 2008. Moreover, data provided in Table 1 suggests that this decline is due to the comparatively strong increase in deposits. But, of course, the years 2008 to 2010 are also affected by the world wide economic crisis.

Moreover, by dividing column two ($INPIC_0$) of Table 1 with the relevant annual population data, we obtain the amount of currency each agent would hold on average at the end of the year for transactions in the legal economy. For example, at the end of 2010 (2009, 2008) this amounts to 742.6 (730.3; 722.6) Euro.

Table 1: Relevant data for calculating G3 (1992 to 2010)

$INFC_t$	$INPIC_{0t}$	D_t	C_{Ut}	M_{Lt}	Year	*G3*
82,846,343,844	44,278,218,606	239,000,000,000	38,568,125,238	283,278,218,606	**1992**	13.61
87,773,897,349	46,449,261,498	263,000,000,000	41,324,635,851	309,449,261,498	**1993**	13.35
93,260,561,978	47,842,037,505	276,000,000,000	45,418,524,472	323,842,037,505	**1994**	14.02
97,439,675,255	48,832,566,672	297,000,000,000	48,607,108,583	345,832,566,672	**1995**	14.06
100,351,926,365	49,656,819,360	345,000,000,000	50,695,107,005	394,656,819,360	**1996**	12.85
102,819,687,122	50,618,187,010	353,000,000,000	52,201,500,111	403,618,187,010	**1997**	12.93
106,170,377,324	51,079,364,224	409,000,000,000	55,091,013,100	460,079,364,224	**1998**	11.97
109,381,786,133	51,449,284,263	420,000,000,000	57,932,501,870	471,449,284,263	**1999**	12.29
111,805,128,774	52,267,908,942	443,000,000,000	59,537,219,832	495,267,908,942	**2000**	12.02
115,230,631,800	53,416,830,779	526,000,000,000	61,813,801,021	579,416,830,779	**2001**	10.67
118,058,779,537	54,213,896,534	576,000,000,000	63,844,883,004	630,213,896,534	**2002**	10.13
121,063,748,103	54,778,545,502	624,000,000,000	66,285,202,601	678,778,545,502	**2003**	9.77
123,425,252,319	55,671,144,548	647,000,000,000	67,754,107,772	702,671,144,548	**2004**	9.64
126,266,811,764	56,728,633,761	717,000,000,000	69,538,178,003	773,728,633,761	**2005**	8.99
130,270,017,850	57,598,520,036	748,000,000,000	72,671,497,814	805,598,520,036	**2006**	9.02
137,241,491,631	58,745,111,452	780,000,000,000	78,496,380,179	838,745,111,452	**2007**	9.36
153,340,722,350	59,257,851,951	835,000,000,000	94,082,870,399	894,257,851,951	**2008**	10.52
151,753,268,600	59,738,889,765	1,029,489,000,000	92,014,378,835	1,089,227,889,765	**2009**	8.45
161,087,038,300	60,710,276,269	1,104,387,000,000	100,376,762,031	1,165,097,276,269	**2010**	8.62

Note: Own calculations. All variables are denoted in Euro, except columns year and G3, with the later denoted in percent of official GDP.

Data in column one (*INFC*) of Table 1 also allows for a comparison with the 'domestic circulation' values obtained by Bartzsch et al. (2011a,b). For example, in 2009 these values range from 40 to 205 billion Euros, subject to the underlying approach. But half of the

estimates range between 130 and 180 billion Euros, which compares fairly well with the independently obtained MCDR amount of 151.75 billion Euro according to Table 1.

Moreover, Table 2 provides some additional time series data obtained from the seasonal methods for estimating the demand for Euro banknotes issued in Germany (see section 2.2.2 of Bartzsch et al. 2011b). This method is of interest as it allows for distinguishing cash held for domestic transactions and cash held for hoarding purposes.

Table 2: Currency in Circulation in Germany (2002 to 2009)

Year	*Transaction*	*Hoarding*	*Domestic Circulation*	$G4_{UH}$	$G4_{LH}$
2002	45.9	9.1	55	8.69	10.28
2003	45.9	12.2	58	7.97	9.94
2004	49.3	15.7	65	7.41	9.86
2005	47.3	22.7	70	6.05	9.26
2006	51.1	23.9	75	6.05	9.30
2007	56.4	28.6	85	6.95	9.69
2008	72.4	32.6	105	6.88	10.92
2009	58.2	36.8	95	5.07	8.74

Note: Transaction denotes currency held for transaction purposes, Hoarding denotes currency held for hoarding purposes and Domestic Circulation denotes currency in circulation inside Germany, with all three in billions of Euros. Data refers to the end of the year, was kindly provided by Franz Seitz in March 2012, and is based on the seasonal methods of Bartzsch et al. (2011b, pp. 9-21). $G4_{UH}$ denotes the hoarding adjusted size of the cash using German underground economy in percent of GDP, if all hoarded cash (column three) is held in the underground economy and $G4_{LH}$ denotes the same, if all hoarded cash is held in the legal economy (own calculations).

Inspection of Tables 1 and 2 reveals that the data of currency held for legal transactions (columns two in both tables) is surprisingly similar, given that the data has been generated with two entirely different methods. Differences in 2005 and 2008 are obviously due to the fact that the results shown in Table 2 are more sensible to specific influences in each year.[8] For matters of convenience, results presented in columns $G4_{UH}$ and $G4_{LH}$ of Table 2 are discussed in the following section.

[8] Data for 2009 in Table 2 should be identical with relevant data in Table 2 of Bartzsch et al. (2011b, p. 37) and, therefore, with Table 3, column 3. Existing differences are entirely due to rounding effects.

3.2 Hoarding

As noted, recent estimates of cash hoarding in Germany by Bartzsch et al. (2011a,b) allow for addressing auxiliary modification four of the MCDR approach. Table 3 shows relevant results of the two studies for 2008 and 2009. Subject to the approach that is used, the stock of hoarded cash ranges from 40 to 110 billion Euro in 2009.

The incorporation of hoarded cash into the MCDR approach requires a correction of some variables used in (2) or (2'). The actual correction procedure depends on whether the calculated amount of hoarded cash is held: (i) entirely in the underground economy, (ii) entirely in the legal economy, or (iii) to some extent in both sections of the economy. Subject to the discussion in the preceding section it is most likely that option (iii) is true. But since we do not know the exact proportions, for illustrative purposes alone, we assume that two thirds of the hoarded cash amount is held in the underground economy and one third in the legal economy.

Technically, option (i) amounts to correcting the C_t value in (1), or the $INFC_t$ value in (2) or the FC_t value in (2'). Regarding the German case, we have to adjust $INFC_t$ in (2) by deducting the hoarded cash amount, which yields the $HINFC_t$ figures shown in Table 3 (see appendix for mathematical details). Application of (2), with the $HINFC_t$ figures rather than the $INFC_t$ ones, yields the $G4_{UH}$ underground economy sizes provided in Table 3. In contrast, option (ii) essentially amounts to a correction of the denominator in (1), (2) or (2'), by deducting the hoarded cash amount (see appendix for mathematical details), which yields the $G4_{LH}$ underground economy sizes shown in Table 3. Option (iii) is a mix of the former two procedures, subject to the assumed distribution of the hoarded cash amount, and yields the $G4_{LUH}$ underground economy sizes shown in Table 3.

Table 3: G4 Estimates

	2008		2009	
Hoarding	*20*	*40*	*70*	*110*
HINFC$_t$	*133.34*	*111.75*	*81.75*	*41.75*
G4$_{UH}$	8.28	4.78	2.02	[-1.65]
C$_{LT}$	*39.3*	*19.7*	---	---
G4$_{LH}$	10.76	8.77	---	---
G4$_{LUH}$	9.1	6.07	4.3	1.78

Note: Hoarding is denoted in billion Euro (end of the year) and taken from Bartzsch et al. (2011a,b), Tables 11 and 2, respectively. HINFC denotes hoarding adjusted, inside Germany forecasted currency held outside banks at the end of the year in billion Euro (own calculation). G4$_{UH}$ denotes the hoarding adjusted size of the cash using German underground economy in percent of official GDP, if all hoarded cash is held in the underground economy (own calculation). C$_{LT}$ denotes cash held in the legal economy for transaction purposes, in billion Euro (own calculation). G4$_{LH}$ denotes the hoarding adjusted size of the cash using German underground economy in percent of official GDP, if all hoarded cash is held in the legal economy (own calculation). G4$_{LUH}$ denotes the hoarding adjusted size of the cash using German underground economy in percent of official GDP, if two thirds of hoarded cash are held in the underground economy and one third is held in the legal economy (own calculations). "---" denotes that a calculation is not possible.

Inspection of the G4 results in Table 3 makes it clear that taking domestic cash hoarding into account may either reduce or increase the size of the cash using German underground economy. Also, the 2009 cash hoarding estimates show a rather wide range and for this reason alone it is hard to assess which of the G4 values may best reflect the true size of the cash using German underground economy in 2009.

This notwithstanding, and provided that the MCDR figures are otherwise close to the true values, it seems to be fairly evident that the 110 billion Euro hoarding estimate is compatible with the MCDR approach, only if option (iii) applies and a substantial amount of hoarded cash is held in the underground economy. Regarding the other two options, the 110 billion estimate leads either to a negative size of the cash using German underground economy or to a negative amount for cash transactions in the legal economy C_{LT}, so that the size of the underground economy cannot be calculated (see Table 3). The same is true for the 70 billion Euro estimate, if it is assumed that all or a large fraction of the estimated amount of hoarded cash is held in the legal economy.

Alternatively, one might take a second look at the results of a representative household survey on banknotes hoarded by adults (i.e. people aged over 14) in Germany, conducted in

2008 on behalf of the European Central Bank (see Bartzsch et al. 2011a, p. 23; Table 3, column 2008). As noted by Bartzsch et al. (2011a), the results may underestimate the true size of cash hoarding in Germany. However, the results may be regarded as a rough indicator for the amount of cash hoarded in the legal economy, as it is particularly unlikely that people report cash hoards held for, or stemming from, underground economy activities. Hence, if we assume that cash hoarded in the legal economy, C_{LH}, amounts to about 20 billion Euro in 2009, then the estimates of 40 and 70 billion in terms of C_H seem to be the most plausible in terms of section 2.2.1 and the comments on the 110 billion Euro estimate made above. Moreover, based on the assumption C_{LH} = 20 billion Euro, cash hoards held in the underground economy, C_{UH}, amount to 20 or 50 billion Euro, respectively. This distribution of the total amount of hoarded cash, C_H, would generate a size of the cash using German underground economy in the range of 3.93 to 6.74 percent of GDP for 2009, according to the MCDR approach.

Finally, Table 2, columns $G4_{UH}$ and $G4_{LH}$, provide some time series data on the hoarding adjusted size of the cash using German underground economy for the period 2002 to 2009, which is based on cash hoarding data obtained from the seasonal methods (see Bartzsch et al. 2011b and column three of Table 3) and the application of options (i) and (ii), respectively. The results are by and large in line with the observations already made above.

In summarizing, the G3 values for 2002 to 2009 (Table 1) do not require any correction, if it is assumed that almost all of the hoarded cash is held in the legal economy. In contrast, if it is assumed that almost all of the hoarded cash is held in the underground economy, the size of the latter is much lower than the G3 values suggest. In this context, it is worth noting that any estimate of cash hoards held in the underground economy essentially amounts to an estimate of accumulated past profits from underground economy activities. Most likely, however, cash hoards are held in both the legal and underground section of the economy and anecdotal

evidence suggests that the hoarding corrected size of the cash using German underground economy has ranged between four and seven percent of GDP in 2009, according to the MCDR approach.

4 Concluding Remarks

Recent estimates concerning currency hoarding in Germany allow for further refinements of the MCDR approach for calculating the size of the cash using German underground economy. In a first step, we have up-dated existing estimates and have obtained values for the size of the cash using German underground economy in 2009 and 2010. Next, we have used available estimates of currency hoarding in Germany for 2008 and 2009 and demonstrated how these data would affect the size of the German underground economy according to the MCDR approach. In particular, in the most extreme setting, we showed that the size of the cash using German underground economy may have ranged in 2008 (2009) between 8.28 (2.02) and 10.76 (8.77) percent, with 10.52 (8.45) percent of official GDP as the previously calculated size.

In addition, we have discussed the assumptions and implications of the MCDR approach in more detail than in previous work. However, it must be emphasized that the criticism put forward by Thomas (1999) and various other authors against the original Gutmann (1977) approach are by and large still valid with respect to the MCDR approach. Yet, the hoarding adjustment which we did here and previous work on the extent of the cash using Spanish underground economy shows two fundamental advantages of the MCDR approach. First, it can accommodate practically any number of additional modifications, while maintaining its transparency, provided that relevant data is available. Second, exposing the obtained underground economy profiles to econometric estimation procedures may not only add to their creditability. In fact, it may also allow the researcher to investigate the causes of the

underground economy in a more comprehensive way than this is would be possible with the Tanzi, Klovland or MIMIC method.

Appendix

Part A of the appendix deals with the technical incorporation of hoarding into the MCDR approach and part B deals with the technical differences between the MCDR approach and the approach of Cebula and Feige (2011, 2012).

A)

Let C_H be the observed or estimated total amount of cash hoarding by domestic non-banks and let C_T be the total amount of cash used for domestic transactions, where here and in the following all variables refer to the end of the year, but for simplicity alone we suppress the time index *t*. Then, the total amount of cash held outside banks, *C*, may be defined as,

$$C = C_T + C_H. \tag{A1}$$

Note that (A1) implies that cash may now be held for two purposes, transactions and hoarding. Further, since cash may be used both in the legal and underground sector of the economy, we may restate (A1) as,

$$C = C_L + C_U = C_{LT} + C_{LH} + C_{UT} + C_{UH}, \tag{A2}$$

with $C_T = C_{LT} + C_{UT}$ and $C_H = C_{LH} + C_{UH}$ and where C_L denotes cash held in the legal economy, C_U denotes cash held in the underground economy, C_{LT} denotes cash used for transactions in the legal economy, C_{LH} denotes hoarded cash in the legal economy, C_{UT} denotes cash used for transactions in the underground economy, and C_{UH} denotes hoarded cash in the underground economy.

Based on (A2), option (i), i.e. all hoarded cash is held in the underground economy, amounts to $C_{LH} = 0$ and, thus, we get $C_{LT} = C_L = C_0$. Moreover, regarding the nominator of (1) we are interested in obtaining C_{UT}, which according to (A2) and option (i) is now defined as, $C_{UT} = C - C_0 - C_{UH}$. However, option (i) does not affect the denominator of (1) and, therefore, with respect to option (i) equation (1) is modified to,

$$\frac{C - C_0 - C_{UH}}{C_0 + D} = \frac{Y_U}{Y_L}. \tag{A3}$$

In contrast, if option (ii) holds, i.e. all hoarded cash is held in the legal economy, we get $C_{UH} = 0$ and, thus, $C_U = C_{UT}$, and $C_{LT} + C_{LH} = C_L = C_0$. Hence, the nominator of (1) is now unaffected, with $C - C_{LH} = C_{LT} + C_{UT}$ and $C_0 - C_{LH} = C_{LT}$, or simply $C - C_0$. However, option (ii) now affects the denominator of (1) due to $C_0 - C_{LH} = C_{LT}$ and, therefore, with respect to option (ii) equation (1) is modified to,

$$\frac{(C - C_{LH}) - (C_0 - C_{LH})}{(C_0 - C_{LH}) + D} = \frac{Y_U}{Y_L}. \tag{A4}$$

As option (iii) is just a mix of options (i) and (ii), we can use a simplified version of (1),

$$\frac{C - C_0}{C_0 + D} = \frac{C_U}{M_L} = \frac{Y_U}{Y_L}, \tag{A5}$$

and incorporate hoarding by stating,

$$\frac{C_U - C_{UH}}{M_L - C_{LH}} = \frac{Y_U}{Y_L}. \tag{A6}$$

B)

As noted in Pickhardt and Sardà (2011, p. 149), the original Gutmann (1977) approach can be restated as,

$$\frac{C - \lambda \cdot D}{\lambda \cdot D + D} = \frac{C - C_{L0} \cdot \frac{D}{D_0}}{C_{L0} \cdot \frac{D}{D_0} + D} = \frac{Y_U}{Y_L}, \tag{A7}$$

where λ denotes the fixed cash to deposits ratio C_{L0}/D_0 of the base year or period. Then, the main modification on which the MCDR approach rests consists of replacing Gutmann's assumption that agents wish to hold a fixed ratio of cash to deposits over time by an equally

strong alternative assumption, as noted in the main text. Technically, this amounts to removing the ratio D/D_0 from equation (A7), so that equation (1) of the main text emerges,

$$\frac{C - C_0}{C_0 + D} = \frac{Y_U}{Y_L}. \tag{A8}$$

In contrast, Cebula and Feige (2011, 2012) maintain Gutmann's original cash to deposits assumption, but adjust demand deposits D by taking into account that in the U.S. "checkable deposits were swept into money market deposits". Hence, in the U.S. the cash to deposits ratio was raised due to innovations in the financial industry, which caused a downsizing of checkable deposits essentially unrelated to underground economy activities. Technically, the main modification of Cebula and Feige (2011, 2012), therefore, is to replace D in (A7) by $D_{adj.}$, with $D_{adj.} > D$. This procedure yields,

$$\frac{C - C_{L0} \cdot \frac{D_{adj.}}{D_0}}{C_{L0} \cdot \frac{D_{adj.}}{D_0} + D_{adj.}} = \frac{Y_U}{Y_L}, \tag{A9}$$

and a comparison of (A8) with (A9) shows the main difference of the two approaches.

Also, to illustrate the first claim made in the main text of section 2.2.4, assume the following numerical values: C = 150, C_0 = 60, $D = D_{adj.}$ = 1000, C_{L0} = 15, D_0 = 250, for (A8) and (A9), which should yield a size of the cash using underground economy of 8.49 percent in both cases. Then, $\Delta D = \Delta D_{adj.}$ = 100 (-100) yields 7.76 (9.38) percent in case of the MCDR approach, but 7.20 (10.06) percent in case of the Cebula and Feige approach.

With respect to the second claim (see section 2.2.4) note that in (A9) any increase in deposits ($\Delta D_{adj.} > 0$) inevitably leads to an increase in cash used for legal transactions, i.e., the term $C_{L0} * (D_{adj.}/D_0)$, which is unwarranted if cash hoards are transformed into deposits.

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