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Determinants of the Demand for Cash in Peru: A Non Linear Approach

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Determinants of the Demand for Cash in Peru: A Non Linear Approach[1]

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Abstract

This paper estimates the main determinants of the demand for cash in Peru from 2002 to 2013. Cash data is analyzed in two levels: considering an aggregate level, where all the notes circulating in the economy are included; and considering the type of denomination. Two sub-groups were defined: lower denomination notes (S/. 10, S/. 20 and S/. 50), and higher denomination notes (S/. 100 and S/. 200). We construct a model of the demand for cash following Adam (2000). For each sub-group, we estimate a non-linear relation with the Markov switching model method (MSM). The MSM estimation shows that the analyzed period has two different regimes. Depending on the sub-group and the regime analyzed, the results differ. The general conclusion is that low denomination notes are highly correlated with transactional variables and in a lower degree with interest rates. Meanwhile, the demand for high denomination notes is positively correlated with the ratio of dollarization and the informal sector of the economy. These results are consistent with the Cash Usage Surveys taken by the Central Bank in 2008 and in 2012.

Classification JEL: E41, E51 y E52

Key Words: Cash, money demand, dollarization, informality, *Markov switching* model.

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1. Introduction

Cash is the main instrument used by the public in payments and savings in Peru, according to the results of the cash survey developed by the central bank in 2012. In that year, cash represented about 84 per cent of the households and small businesses payments and near 95 per cent of their savings.

Importance of cash remains high, although it is diminishing as the use of alternatives instruments of payment -as debit cards, credit cards, interbank transferences, m-banking and capital market instruments- grow.

In recent years, cash has showed a sustained growth, higher than GDP and inflation rates, which can be explained due to the existence of factors other than those associated with transactional reasons.[3]

Informal and illegal transactions, a substantial part of the Peruvian economy not included in the GDP statistics, are intensive in the use of cash (Loayza, 2008; Hernández, 2005). Low levels of financial development (Ramirez, 2012 and Choy, 2013), and a dedollarization process are variables that must be included in the analysis of cash (Rossini and Vega, 2007, Castillo and Winkelried, 2007).

This paper estimates the determinants of the demand for cash from 2002 to 2013. These determinants are based on transactional, store of value and technological factors. There are three versions of the estimated model. The first one estimates the total demand for money at an aggregate level, and includes all the denominations. The second version estimates a model for low denomination notes (considering denominations of S/. 10, S/. 20 and S/. 50); and the third version estimates a model for high denomination notes (considering denominations of S/. 100 and S/. 200). Each version of the model is estimated with two different techniques: a linear one with ordinary least squares (OLS), and a non-linear estimation using a *Markov switching model* (MSM).

The results show that exists a non-linear relationship between cash and its determinants, and that there are two regimes in the analyzed period. An analysis by denominations indicates that notes of small value have a better adjustment with transactional variables and in a lesser extent with the interest rate. On the other hand, notes of higher value have a positive relation with the degree of financial dedollarization and with the degree of economic informality. These results of the econometric model are consistent with the cash surveys that the central bank made in 2008 and 2012.

The paper is organized in five sections. The first section introduces the theme. The second one reviews the literature on the demand for cash. The third section analyzes the demand for cash in Peru. The fourth one presents the econometric models and its estimates, and the last section concludes the paper.

[3] Data on countries is found in: *World Payment Report*, 2012.

2. Literature Review

2.1 Theoretical relationships among money demand, product, inflation and interest rates

Models of money demand (M^d) can be represented in the general form of:

$$M^d = P\,L(Y, i, t) \qquad (1)$$

In which the variables are the number of transactions (Y), the interest rate (i), the price level (P) and the technology (t)[4].

Inventory models of money demand emphasize the medium of payment function of money (*Baumol*, 1952; Attanasio, Guiso y Jappelli, 1998; and McCallum and Goodfriend, 1987); while in portfolio models, the demand for money is dependent on wealth and on the relative return with other financial and real assets[5] (Tobin, 1956; and Friedman, 1956).

More recent models of the demand for money as MIU (money in the utility function), and cash in advance models (CIA), introduce wealth and intertemporal restrictions in saving and consumption decisions (Walsh, 2010).

A lot of the empirical research has been made on the relation of money, prices, product and interest rates, in the short run and in the long run.[6]. McCandless and Weber (1995) found a long run correlation between money supply growth and inflation with values from 0,92 to 0,96 in a 30 year period of and considering 110 countries, giving empirical support to the quantitative theory of money. This result is supported by the work of Berentsen, Menzio and Wright (2008).

McCandless and Weber (1995) found no correlation between money growth and real product growth. However, these results aren't robust along the sample periods. Short run dynamic between money, product, inflation and interest rates is not the same among all countries and during all periods. This dynamic is dependent on agent's behavior and on the policies implemented by governments. In the United States of America, considering quarterly data from 1967.1 to 2008.2, shows a positive correlation between base money (defined as M0, cash maintained by the public plus reserve requirements) and real GDP (past and future), however, from 1984 correlation is negative between future M0 and real GDP.

Montoro, Castillo and Tuesta (2007) study for the Peruvian economy considering quarterly data from 1994 to 2005 found that correlations between inflation and short term interest rate for the whole period is 58,4. Furthermore, they found a value of 17,9 before the implementation of the inflation targeting regime (IT) (1994.1-2001.4) and of -6,5 after the implementation of IT. Correlation between inflation and M0 growth rate is 51,5 for the entire period, with a value of 69 before the implementation of IT and of 5,2 after the IT implementation. These results show that relationships are highly dependent on the studied periods which difficult the identification of a general dynamic in the sample. Exchange

[4] *L (Y, i, t)* is demand of real balances.
[5] Relative return of money depends on the services that it gives.
[6] We follow Walsh (2010), Ch. 1.

rate variations are positively correlated with inflation before the IT implementation with a value of 53,8, while in the period after the IT implementation the correlation is -4,8.

2.2 Determinants of the demand for cash: The Evidence

Lately, many studies have consistently reported relatively high rates of cash growth well above the growth of nominal GDP (Williams, 2012; Amorin and Chakravorti, 2009 and Fisher, Köhler and Seitz, 2004). There has been also a significant grow in non-cash payment instruments, like debit and credit cards, interbank transferences, electronic money, and others. Williams (2012) and Amromin and Chakravorti (2009) show a process of cash substitution for more secure and rapid means of payment, although in relative terms cash is still the predominant means of payment for transactions in most countries (World Payment Report, 2012).

Williams (2012) analyzed the period 1989-2012 in USA and divided cash in two denomination groups: small denomination notes, with a value lower or equal than US$ 50, associated to transactional motives; and large denomination notes, identified by the note of US$ 100, associated to its use as store of value. He showed that the demand for cash in lower denomination notes is highly correlated with the GDP; while the US$ 100 notes are not. There was evidence found during the banking crisis of 2008 that lead the authors to believe that the demand for the US$ 100 notes was associated with its use as store of value or with a precautionary motive.

Amromin and Chakravorti (2009), using a panel data type of model estimated the relation between cash and the GDP for several countries during the period 1988-2003. The results showed that the ratio of cash over GDP has been heterogeneous among countries. The ratio in the United Kingdom was relatively stable and it was between 3,5 per cent and 3,4 per cent; while in Japan the ratio increased from 6,3 to 9,2 per cent in the same period. Williams (2012), and Amromin and Chakravorti (2009) found that the correlation between cash and the GDP doesn't have the expected long term values, with value below one, indicating a short term dynamic of the velocity in circulation during the period.

Amromin and Chakravorti (2009), like Williams (2012), found that low denomination notes are not affected by the interest rates; on the contrary, high denomination notes have a positive elasticity with the interest rates, in particular for currencies where international trading is not significant.

Fischer, Köhler and Seitz (2004) study the demand for cash for the Eurozone during 1980-2001, and divide cash in two groups: small denomination notes and large denomination notes. They found evidence that lower denomination notes have a negative correlation with non-cash payment instruments.

Cusberg and Rohling (2013) studied the effect of the financial crisis of 2008 on the demand for cash in Australia. The authors found that this demand increased significantly in the last quarter of 2008 (12 per cent), mainly due to the raise in the demand for large denomination notes. This raise was associated

with the reduction of the interest rates, but mainly with precautionary motives[7] originated because of the uncertainty on the financial health of banks during the crisis period.

Hancock and Humprey (1998), show different patterns of cash usage in developed countries, despite similar availability of payment instruments besides cash. Humprey (2010), found that the major differences in cash usage between Europe, the US and Japan were not related to price or cost differences. They were explained for institutional environment, geographical size or culture. It explaines why Japan uses twice cash as more than Europe and six times as much as the US[8]. Borzekowski, Kiser and Ahmed (2006), based on a survey of consumers, showed that debit cards usage in EPOS (electronic point of sale) have increased in 20 per cent at year from 1996, and transactions with checks, credit cards and cash retirement in ATM have increased very little. Also, these authors observed that households with higher education use in greater extent debit cards, thus 60 per cent of agents with a university degree use debit cards.

Drehmann and Goodhart (2000) stated an extended use of large denomination noted for illicit activities. Rogoff (1998) added that in OECD countries about 50 per cent of cash is used by the informal and illegal economy, mainly in high denomination notes. According to this author, *seigniorage* gains for the central bank for the emission of large denomination notes can be outweighed by taxes losses. As a result, Rogoff proposed to bane big transactions in cash and to eliminate the large denomination notes. Giavazzi[9], pointed out that to bane large denomination notes only gives as a result its substitution to other instruments.

Fischer, Köhler and Seitz (2004) analyzed the effect of informal economy on the demand for cash. They proposed to use the ratio of taxes over GDP as a proxy of informality and alternatively the rate of unemployment (that incentives informality). Humphrey (2010) proposed to estimate the use of cash associated to illicit activities through the comparison of changes in consumption of electricity (associated to GDP formal and informal) with changes in declared incomes and taxes. Judson and Porter (2004) found a positive relationship between cash usage and small businesses.

Vega (2005) and Armas and Grippa (2007) noticed that in dollarized economies, like the Peruvian, an additional source of the demand for cash came from the dedollarization process. In Peru, there is a context of appreciation of the domestic currency since 2001. Vega (2005) cautioned on the effects that the dedollarization process could have on cash management. Finally, Boeschoten (1998) included other factors that determine the demand for cash like: age, education, sex, among others; while Van der Horst and Matthijsen (2013) included psychological factors.

[7] The demand for money due to precautionary reasons according to *Keynes* has a different meaning, and consists in the demand for money used to make unexpected expenditures.
[8] P. 1732.
[9] Rogoff(1998)

3. Data on Cash Usage and Cash Evolution in Peru

3.1 Aggregated Cash

In the analyzed period, there has been an increasing use of cash and other means of payment that exceed the growth rates of GDP. Graph N° 1 shows the cash on nominal GDP ratio in the period 2002-2012. This ratio grew from 28 per cent in 2002 to 55 per cent in 2012. On the other hand, the growing rate of alternatives means of payment and savings has led to a fall in the currency over total domestic currency liquidity ratio (monetization ratio[10]), from 40 per cent in 2003 to 26 per cent in 2012.

Graph N° 1
Cash on GDP ratio and cash on domestic currency liquidity ratio
(percentage)

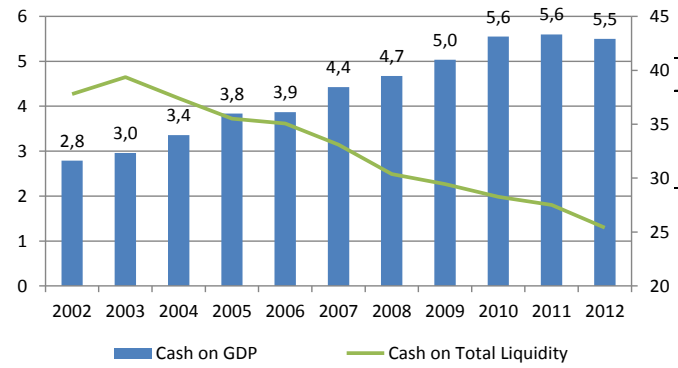


Table N° 1
Correlation among currency, GDP and inflation

Period	1981-2012	1981-2002	2003-2012
Var % Currency-Inflation	1,00	1,00	0,16
Var % Currency-Var% real GDP	-0,44	-0,42	0,78
Var % Currency-Var% nominal GDP	1,00	1,00	0,55

Source: Central Reserve Bank of Peru

The correlation between currency and nominal GDP (Table N° 1) is consistent with the hypothesis of money neutrality in the long run (Montoro, Vega and Tuesta, 2006). However, if we consider a shorter period, between 2003 and 2012, the correlation between currency and nominal GDP was 0,55; and the correlation between currency and inflation was only 0,16 showing that the real GDP has been the main variable to explain the correlation between currency and nominal GDP[11].

Between 2003 and 2012, the relation between money and nominal GDP has not been constant. The drops in the velocity of circulation of money are explained mainly by the dedollarization process and to some extent by the lower interest rates.

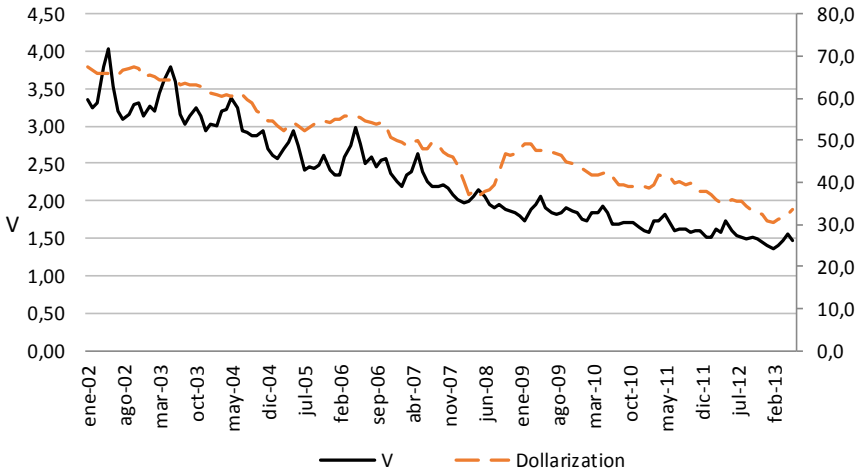
Graph N° 3 shows a weak relation between the velocity of money (V) and nominal interest rate (i), while Graph N° 2 shows a close relation between the velocity of money (*V*) and dollarization ratio. The greater is the preference for domestic currency and the monetization ratio, the lower the dollarization ratio is.

[10] Monetization ratio is the inverse of the velocity of circulation of money (V), V = PY/M; where PY = nominal GDP and M = currency. This ratio has been decreasing between 1981 and 1990, and increasing in the period from 1991 and go on

[11] Inflation rate does not explain *V* behavior in this period. Humala (2006) pointed out the importance of the implementation of inflation targeting from 2002.

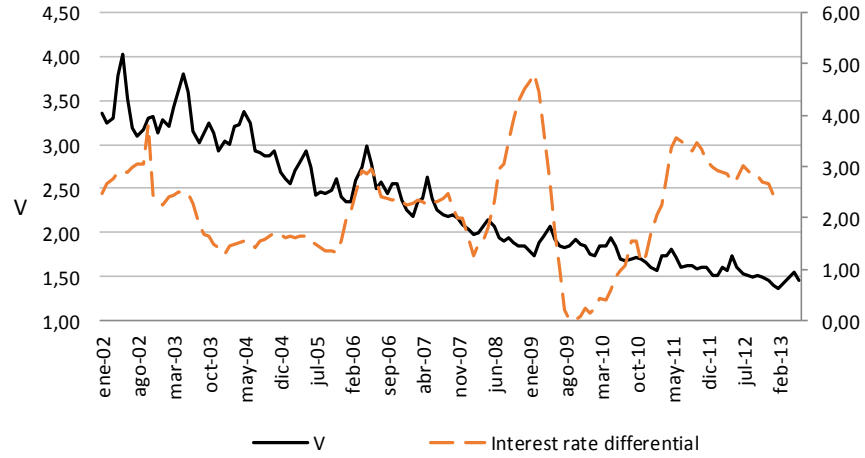
Graph N° 2

Velocity of circulation of currency and dollarization ratio



Graph N° 3

Velocity of circulation of currency and interest rate



Source: Central Reserve Bank of Peru, Weekly Report.

Montoro (2006) distinguished three types of dollarization: financial, related to its function as store of value; transactional, related to its medium of exchange function; and price dollarization, related to its function as a unit of account.

The Peruvian experience of dollarization is basically financial[12] and the use of dollars for cash payments is very limited, as stated by Rossini (2006) and Armas, Grippa, Quispe and Valdivia (2001). Payments denominated in dollars belong basically to credit and debit cards, credit transfers and checks. Financial dollarization is still high although it has fallen from 66 per cent in 2002 to 33 per cent in 2013[13].

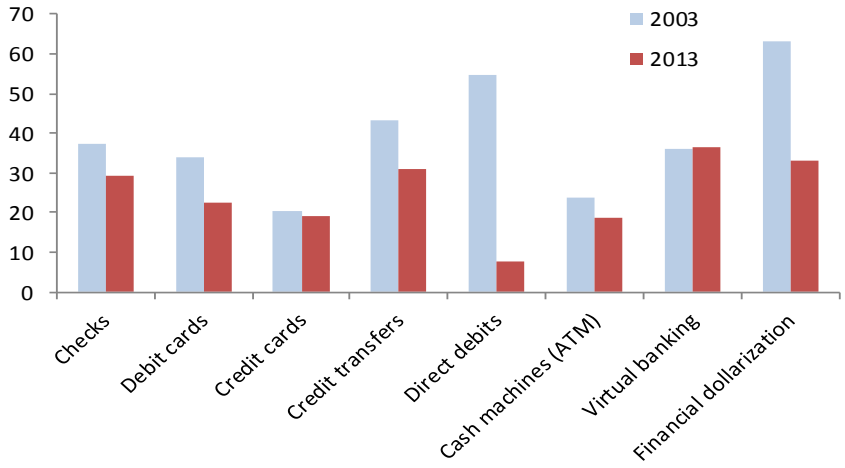
Although there is no statistics on price dollarization, there is evidence that many prices of real estate, cars, domestic appliances and rentals are expressed in US

[12] Calculated as the ratio between foreign currency liquidity and total liquidity of the banking system, as defined by the Central Bank.

[13] BCRP (2012), mention some policies implemented recently to diminish dollarization.

dollars[14]. Montoro (2006) estimated that about 30 per cent of goods and services prices of the consumer price index were expressed in US dollars from January 1995 to August 2004. This number falls to 13 per cent from September 2004 to December 2005, and probably would have continued to fall in the subsequent years.

Graph N° 4
Payment and financial dollarization: 2003-2013



Source: Central Reserve Bank of Peru.

Since 2002, the value of notes in circulation has grown at an average rate of 18 per cent[15], well above nominal GDP which annual growth rate was about 10 per cent in the same period[16]; meanwhile, payments with instruments substitutes of cash, like debit and credit cards, grew in the same period to annual rates higher than 22 per cent (Table N° 2).

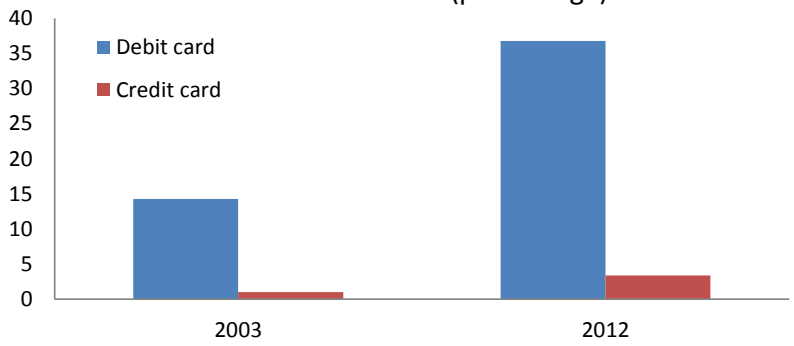
Increased bancarization had a positive effect on the demand for cash and other payment instruments, mainly on the usage of debit and credit cards. From 2002 to 2013 the average growth rate of checks was 5,5 per cent; of debit cards was 32 per cent (cash withdrawal 32 per cent and payments 25 per cent); of credit cards was 25 per cent (cash withdrawal 33 per cent and payments 22 per cent), of credit transfers was 17 percent, of direct debits was 16 per cent; and of virtual bank was 50 per cent[17]. Debit and credit cards register growth rates above nominal GDP and currency rates[18]; while checks register the lowest growth rates

[14] Montoro (2006) state that in many cases the financial dollarization contributes to Price dollarization. For example, credit dollarization affects the prices of products associated to the activities financed by these credits.
[15] The average value of domestic notes in the economy increased from S/. 43 in 2002 to S/. 64 in 2013 (average annual growth rate of 3,5 per cent).
[16] As it is stated in this document, the use of cash in transactions could be higher than the reported in the circulation over GDP rate. In economies in which the GDP reports is not elevated, the informal sector is often quite relevant. For instance, in certain European economies the informal sector represents almost 19 per cent of the GDP; in the United States it represents around 9 per cent; and in Peru it represents more than 50 per cent (Schneider, 2006).
[17] Internet payments, corporate software, consumer's software and mobile banking.
[18] Nominal GDP grows from 2002 to 2013 on average 9,9 annual per cent while currency grows 17,9 on annual average.

in the period 2002-2013. Internet and phone banking have had a very high increase in percentage rates although its share is still very low.

According to BCR statistics, debit and credit cards are used increasingly for cash retirements. In 2012, monthly cash withdrawal through debit cards was about 37 per cent of currency on circulation and through credit cards was about 3 per cent, representing in 2012 an annual increase of cash withdrew from ATM´s of 3,2 times the average cash outstanding in 2011[19].

Graph N° 5
Average monthly cash withdrawal over currency on circulation (percentage)



Source: Central Bank.

The causes of the poor development in cash alternatives are diverse: public's preferences, banking infrastructure, educational factors and relative costs. Cash is anonymous, liquid and the only payment instrument in places where the presence of financial intermediaries is scarcely developed. Telecom (2013), Ramirez (2012), Choy (2013), ASBANC (2013)[20], Ayllón, Chávez and Vega (2010), and Perea, Tuesta and Ugarte (2012) report different factors and explanations for the preference of cash in most transactions. Mastercard Advisor´s (2013a) and Mastercard Advisor´s (2013b) report that 95 per cent of payment transactions in Peru are on cash (75 per cent in value). Recently, ASBANC reported that 70 per cent of car sales are made in cash and only 30 per cent through a credit bank[21].

Informality and illegal activities in the Peruvian economy are other important factors that explain the demand for cash. Schneider (2004), Loayza (2008) and De Soto (1989) report this problem. According to these authors about 50 per cent of production is informal. Medina and other (2007) estimated that the gold production in 2006, concentrated in Madre de Dios, Puno and the Central South of Peru, is between US$ 6,2 and US$ 4,6 billion each year[22]. The Banking

[19] Peru21-http://peru21.pe/mis-finanzas/que-no-usar-tarjeta-credito-retirar-efectivo-2119661
[20] Gestión, November 2013.
[21] Gestión, August 31, 2013.
[22] According to these authors, informal mining has presence in 12 departments, and include an economic chain that includes small producers, collectors, traders and local exporters.

Association in Peru (ASBANC) has estimated that about S/. 66 billion (12 per cent of the International Reserves) are involved in money laundering activities[23].

3.2 Cash by Denominations

According to the Central Bank Survey[24] of Cash[25] Usage of 2012, 84 per cent of weekly payments made by individuals and small companies are in cash; while 6,9 per cent are made with debit cards, 6,1 with credit cards and 1,9 with interbank transferences. Compared to the survey of 2008, the percentage falls 10 percentage points, from 94 per cent in 2008.

Table N° 2
Frequent use of notes for transactions [1/]
(weekly)

Denomination	Number	%	Value	%
S/. 10	45	41,67	S/. 450	13,1
S/. 20	34	31,48	S/. 680	19,8
S/. 50	16	14,81	S/. 800	23,3
S/. 100	11	10,19	S/. 1 100	32,1
S/. 200	2	1,9	S/. 400	11,7
Total	108	100	S/. 3 430	100

1/ Persons and small business.

Source: Central Bank Survey of Cash, 2012

Table N° 3
Outstanding notes in circulation
(percentage of total)

Denomination	Number	Value
	%	%
S/. 10	18,1	2,9
S/. 20	18,1	5,8
S/. 50	19,3	15,5
S/. 100	41,9	67,3
S/. 200	2,6	8,5
Total	100	100

Source: Central Bank statistics.

Table 2 shows the results of the survey of cash usage by denominations. In this table, we can see that 33 per cent of cash transactions, made by individuals and small businesses, use notes of S/. 10 and S/ 20; 23 per cent use notes of S/. 50; and 44 per cent use higher denomination notes of S/. 100 and S/. 200.

The structure of notes showed above in Table 2, however, differs of the outstanding value of notes by denominations, where higher value notes are predominant. Thus, in June 2013, the value of notes in circulation of S/. 10 and S/. 20 was only 9 per cent; of S/. 50 was 16 per cent; and of 76 per cent for notes of S/. 100 and S/. 200.

The BCRP survey found that 56 per cent of lower denomination notes - S/. 10, S/. 20 and S/. 50- Is used by individuals and small businesses in their

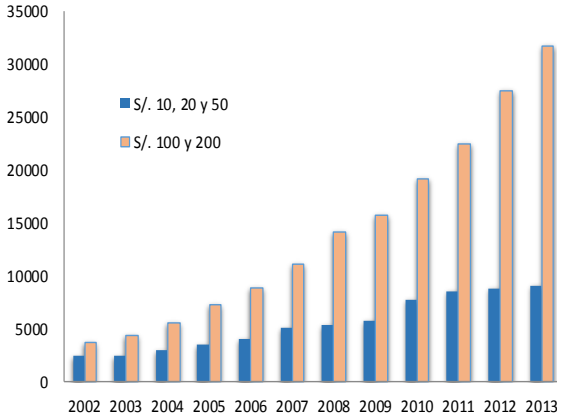
[23] The banking supervisor (SBS) define asset laundry as those activities made for one or more persons or enterprises that seek to hide or disguise the illicit origin of goods or assets associated to illicit activities.

[24] Survey was elaborated by Instituto Cuanto S.A. in 2012 for the Central Reserve Bank. Our analysis in this paper refers only to notes that represent about 97 per cent of currency in circulation, and cover the period 2002-2012.

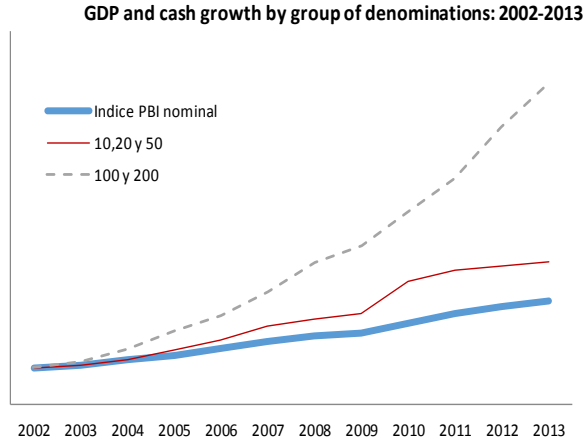
[25] The legal currency in Peru is the new sol that was created in 1991. Today the monetary cone has 12 denominations: 7 coins and 5 notes. The note of the highest denomination has a value of S/. 200 (about US$ 70) and the coin with the lowest value has a value of S/. 0,05. The structure and security features of the notes and coins can be seen in Ramirez (2011).

transactions[26] that it is not according to the value in circulation of these denominations that in 2012 represented only 24 per cent of the total value. That situation reflect the existence of a currency demand for higher denominations that are not showed in the survey, and that would be associated to the demand as a store of value, high value transactions, or transactions associated to illegal or informal activities[27].

Graph N° 6
Denominations by group: 2002-2013 in millions)



Graph N° 7
GDP and cash growth by group of denominations: 2002-2013



As show in Graph N° 6, since 2002 denominations of small denomination notes (S/. 10, S/. 20 and S/. 50) have grown at lower rates than large denomination notes (S/. 100 and S/. 200).

The high growth rates of cash have led to a raise of the monetization ratio in the Peruvian economy. Between 2002 and 2012, the nominal GDP growth was on average 16 per cent by year, while low denomination notes (S/. 10, S/. 20 and S/. 50) growth on average 28 per cent, and high denomination notes (S/. 100 and S/. 200) at an annual average rate of 70 per cent.

The BCRP cash survey of 2012 indicates that 95 per cent of the savings of Peruvian families are held in cash, which shows a high use of cash for saving purposes. The informal economy is another major component of the demand for cash. Schneider (2006) and Hernández (2005) estimated that this sector represents between 50 and 60 per cent of the Peruvian GDP. According to Rogoff (1998), the demand for cash is increasingly associated with illegal activities. Informal and illegal activities are generally omitted variables that are not incorporated in the GDP statistics, causing difficulties in the empirical studies of the relation between cash and GDP.

According to cash survey of 2012, 84 per cent of the payments of individuals and small businesses are made in cash (versus 94 per cent in 2008), 16 per cent are made with alternatives payments instruments as debit cards (6,9 per cent) or credit cards (6,1 per cent). Central bank's statistics show that the use of credit card for cash retirements has increased from 19 per cent of total

[26] Fisher, Khöler and Smetz (2004) estimated a demand for cash for transactions in Europe between 25 and 35 per cent (p. 72).
[27] It is reasonable to assume that cash is used for transactional motive mainly by persons and small business; and in a lesser extent by medium and large business that prefer alternative and more secure instruments of payments.

transactions in 2003 to 37 per cent in 2013. Debit cards use for cash retirements represents about 95 per cent of these transactions[28]. This is an evidence of the high preference of cash or the lack of payment alternatives to make retail payments. Wakamori and Welte (2012) documented the preference of cash usage for low value transactions in Canada.

The recent introduction of electronic money in Peru through the use of cell phones[29] has the potential to incorporate the rural and unbanked zones into the financial industry, considering the high penetration of mobile phones in Peru (more than 1 cellular per inhabitant). Nonetheless, the experience of Kenya shows that these financial innovations lead to a higher use of cash as Tarazi and Brelof (2010) showed. In general, the use of financial innovations reduces the demand of cash in the form of small denomination notes (BIS, 2012). In Japan, Kitamura, Oomori and Nishida (2010) and Fujiki and Tanaka (2007) found that the growth of electronic money in the last decade has not had a substantial impact on the use of notes and coins; although the effect has been greater in low denominations coins (replaced by electronic wallet).

4. Some Estimations for Peru´s Demand for Cash: 2002-2013

4.1 Model of Demand for Cash

Following Adam (2000) we assume a cash function where money, new soles and dollars, enter directly in the utility function of a representative agent (MIU *model*) with cash restriction (CIA *cash in advance model)* and a given technology of transactions.

$$U_t = \sum_{s=t}^{\infty} \beta^{s-t}(u(c_s), v(\frac{M_s}{P_s}, \frac{E_s M_s^*}{P_s})) \quad (1)$$

c represents real consumption, *M* represents cash in new soles, *M** cash in US dollars, *P* the price level and *E* the nominal exchange rate. Both cash in new soles and US dollars are substitutes in the liquidity services of the representative agent.

We assume by simplicity that there are no foreign bonds, then the intertemporal budget restriction is given by (a point above the variable refers to time derivative):

$$c_t = y_t - \tau_t + r_{t-1}^b b_{t-1} + \frac{i_{t-1}^d D_{t-1}}{P_t} - \frac{\dot{M}_t}{P_t} - \frac{E_t \dot{M}_t^*}{P_t} - \frac{\dot{D}_t}{P_t} - \dot{b}_t \quad (2)$$

(y-τ) is the disposable real income, *b* are real bonds and r^b its real return, *D* are deposits that earns a i^d interest. Wealth restriction is given by:

$$w_t = \frac{M_t}{P_t} + \frac{E_t M_t^*}{P_t} + \frac{D_t}{P_t} + b_t \quad (3)$$

[28] Weekly Report, Central Bank of Peru.

[29] In Peru, mobile banking can be used with a low gamma standard and prepayment phones. While the coverage of banking services in Peru is only 30 per cent of the population, however, the coverage of mobile phones is 117 per 100 inhabitants.

Maximizing (1) subject to (2) and (3) we obtain the demand for cash in new soles in the standard form:

$$\frac{M^d}{P} = l(y^*, w, \pi, i^d, i^b, e) \quad (4)$$

The demand for cash depend of expected income, wealth and asset prices, including the expected exchange rate[30], and transactions technology, *t*, that is assumed constant.

Following Amromin and Chakravorti (2009) the lineal specification of the above model is:

$$CIR_t = \propto + \beta_1 GDP_t + \beta_2 Debit\_Cards_t + \beta_3 ATM_t + \beta_4 Bank\_Agencies_t + \beta_5 Interes\_Rates_t + \beta_6 Dollarization_t + \beta_7 Informality_t + \beta_8 TREND_t + \varepsilon_t \quad (2)$$

The demand of cash (CIR) depends on the transaction level (nominal GDP); alternative payment instruments (Debit_Cards); banking infrastructure (ATMs and Bank_Agencies); technological innovations (TREND); opportunity cost of holding cash (Interest_Rates); alternative financial assets (Dollarization); and informality.

The estimation of the model uses three different cash aggregates. First, we estimate the model with the data of total cash, to model the average behavior of cash with respect to each one of its determinants. Secondly, we try to separate the two principal functions of money: as a medium of payment and as a deposit of value (or asset substitute). In this direction, we estimate two separate models for data of cash of lower denominations notes, CIR_small (S/. 10, S/. 20 and S/. 50) and data of cash for higher denomination notes, CIR_big (S/. 100 and S/. 200).

The first variable used in the model to explain the demand for cash is the nominal GDP, associated basically to the transactional motive. The high correlation between these variables is showed in Table 1 and in Graph N° 7. However, as showed in Graph N° 7, the correlation between these variables rise when we consider lower denomination notes, in line with the transactional motive[31].

The demand for cash is affected for payment substitutes, that we proxy with the number of debit cards (Debit Cards)[32]. Expected sign of this variable is negative[33]. There are not main differences expected in the coefficients of debit cards between the categories of cash in which the money was divided. The number of transactions of POS is not used as proxy of other medium of payments, because the data is not complete in the period of analysis.

[30] Regressors are potentially endogenous. Johansen (1992) uses conditional demands derived from a generalized error correction model.
[31] We do not use private consumption as a proxy of transactions due to its volatility. We do not use either a retail sales indicator, because data is not available.
[32] We discard the use of the variable "number of credit cards" because this variable is highly correlated with the variable "number of debit cards".
[33] Constant fee charges for the use of these instruments are assumed.

As proxy of technology of transactions we use the number of Automated Teller Machines (ATMs), the number of banking offices (Bank_Agencies) and a TREND variable[34] that assumes that the innovations are linear.

The number of ATMs and the number of bank agencies have grown substantially in recent years reflecting the development of physical and financial infrastructure. According to ASBANC, between 2002 and June 2013, the number of ATMs grew from 4 to 22 per one hundred thousand inhabitants, while banking offices grew from 3 to 6 per one thousand inhabitants[35].

The expected sign of the coefficients of these variables are not clear. An increasing number of ATMs can imply a lower demand of cash (lower precautionary demand) but also can imply a higher demand for cash considering that the access cost diminish respect to other payment alternatives. In regard of banking offices, the theory is ambiguous. Higher numbers of bank agencies can increase the demand for cash to supply these agencies; on the other hand, it can decrease the demand for cash assuming that the cost to be without cash lowers. In terms of categories of cash, there are not expected differences between categories.

We use two variables associated to the demand for cash as store of value or speculation[36]: interest rate on domestic deposits (Interest_Rates)[37] and the coefficient of dollarization (Dollarization), both variables measure the opportunity cost of money in terms of these two assets. The sign of the interest rate it is expected to be negative. In terms of denominations it is expected a greater effect of the interest rate on higher value notes (CIR_big), associated to the reserve of value function of money.

The variable of dollarization is expected to have a negative effect on cash, assuming that there is a degree of substitution between domestic and foreign money, although the effect would be greater for higher denominations notes (CIR_big).

The coefficient of dollarization falls from 67 per cent in 2002 to 35 per cent in 2013.

Also, a *proxy* of the informality is included in the estimation of the demand for cash. The inclusion of this variable is justified for two reasons: much of these economic activities are not part of GDP and their income elasticity to GDP is expected to be higher than the GDP income elasticity.

The variable used for informality is the ratio of number of independent workers on employed PEA (Economically Active Population) in Lima Metropolitana (INFORM) as known as ratio of auto-employment (Loayza, 2007). A positive effect

[34] See Fischer, Köhler and Seitz (2004) for a discussion on other variables used to measure technological change in the banking industry.
[35] Banking offices growth was limited by the surge of correspondent banking agents from 2005.
[36] Differentials between domestic and foreign interest rates are a proxy for the expected depreciation of domestic currency (according to UIP).
[37] As a proxy of interest rates we use the TIPMN that is the passive interest rate in new soles that represent the average interest rate of the outstanding deposits. The FTPMN is the average passive interest rate of deposits in the last 30 days.

of this variable on cash is expected; although with differences by type of denomination (lower value notes o higher value notes).

Some papers include the tax ratio or tax evasion as proxy of informality, or variables related to illicit activities (crime variables) but the data on these variables are not available on a monthly frequency in Peru[38].

Other explanatory variables that have been included to explain the demand for cash are: education, sex, in models of cross section analysis and panel data. Macro variables as unemployment rate, inflation and an exchange rate have not been considered in our analysis for statistical problems as autocorrelation and multicollinearity.

4.2 Estimation Results

In this section, we present the estimation results of the demand for money in Peru for two models: a linear and a non linear model, both from January 2002 to June 2013, at an aggregated level and for categories according to denominations. Our analysis of stationarity of the series is showed in Annex 1.

4.2.1 Linear Model

Assuming linearity of the coefficients, we estimate the equations between cash and the explanatory variables above indicated, using Ordinary Least Squares (OLS) with monthly data. The adjustment of the model was low, even though the assumptions of the OLS were fulfilled. We also verified the results obtained using instrumental variables, and we obtained results very similar to OLS.

Table N° 5 presents the estimated model with OLS using the data for aggregated cash (see Annex N° 2). The non stationary variables were run in first differences. We observed that most signs are in line with the economic theory presented in the previous sections of this paper.

Table N° 5

Dependiente: Circulante agregado (CIR)		
	β-MCO	
D_L_PBI(-3)	0.144757	a
TIPMN_SA	-0.005710	b
D_L_OFICINAS(-3)	-0.122411	c
L_COEF_DOL(-1)	-0.053443	a
TEND	-0.000391	a
R^2 ajustado	18%	
D-W	2,29	
Errores	normales	

a: al 99% de confianza.
b: al 95% de confianza.
c: al 90% de confianza.

[38] Fischer, Köhler and Seitz (2004) discuss the use of alternative proxy variables for informality in the Euro zone; and Borzekowski, Kiser and Ahmed (2006) stated different non economic explanations of the use of cash.

Among the determinants of the demand for cash we have: the GDP with a one-quarter lag, interest rate (detrending), the number of banking offices (with a lag of one quarter), technological change (TREND) and the coefficient of dollarization (with a one-month lag). There was not found significance in the variables: credit and debit cards, number of ATM, and informality.

The positive sign of the nominal GDP coefficient is as expected, although with a lag of a quarter, and a value well below 1. The interest rate coefficient is negative, as expected, although with a low value. The dollarization coefficient is negative, as expected; a higher preference for foreign currency brings down the preference for domestic currency. The coefficient of the number of banking offices (OFICINAS) and the financial innovations (TREND) are negative, as expected, indicating that more offices and more innovations reduce the demand for cash[39].

The level of adjustment of the model is low (Adjusted R squared is 0,18). An explanation could be that the determinants of the demand for cash in small and large denomination notes are not the same or are not in the same direction. As a result, the aggregate behavior is an average of the behavior of these two categories of cash.

To separate both determinants of cash, as a transactional and reserve of value motives, we divide the demand of cash in two categories: small denomination notes (*small*) that includes notes of S/. 10, S/. 20 and S/. 50; and large denomination notes (*big*) with notes of S/. 100 and S/. 200.

Table N° 6 shows the results of the estimation of MCO (in the Annex 2 we show the behavior of the errors):

Table N° 6

Dependiente: Circulante por categorías				
	CIR_small		**CIR_big**	
D_L_PBI(-3)	0.290729	a		
TIPMN_SA	-0.008570	b	-0.005092	b
D_L_OFICINAS(-4)	0,203816	c		
L_COEF_DOL(-1)	-0.056026	a	-0.057462	a
TEND	-0.000428	a	-0.000440	a
R^2 ajustado	15%		12%	
D-W	2,29		2,08	
Errores	normales		normales	

a: al 99% de confianza.

b: al 95% de confianza.

c: al 90% de confianza.

The GDP coefficient for lower denominations notes is positive and higher than for the aggregated model. However, this coefficient is not significant for larger denomination notes, reflecting the reduced use of higher denomination notes for transactional motives.

[39] The precautionary demand for cash.

As expected, the interest rate coefficient is higher for large denomination notes, associated to the reserve of value motive. This result is robust to several interest rate specifications.

The sign of the coefficient of dollarization was negative for both categories, small and big. This result gives evidence that the de-dollarization process has increased the demand for domestic currency both for transactional and for reserve of value reasons, in particular for higher denomination notes.

The coefficients of banking offices (OFICINAS) for small and big denominations are not consistent with the aggregate model, the number of offices have a positive sign for the small denominations but this variable is not significant for big denomination notes [40]. One explanation for this result is that, according to the Cash Survey of BCRP of 2012, 43 per cent of persons surveyed get cash from the banking institutions, 20 per cent from ATMs and there is a 30 per cent that do not use the banking system to get cash.

4.2.2 Non Linear Model (Markov Switching Model)

The poor results of the linear model could be explained by the existence of a non linear relation between cash and its determinants. Another possible explanation is that the estimated parameters are not constant during the analyzed period, which is known as switching regimes.

Markov switching models (MSM) calculates a set of parameters for each period (regime) in a time interval.

A time series could show different realization phases of a variable. These phases could be understood as different regimes within the same model; in which the shift from one phase to another could be treated as a change in regime. Due to the uncertainty of the exact moment in which this shift occurs, the regime change is considered a random variable; and, its future occurrence depends on a probability.

These types of models are a numeric interpretation of the idea that a time series can be represented by an ensemble of stationary processes[41] with different distribution functions. Considering that a y_t variable can come from N likely conditions of nature($s_t = 1, \dots, N$), represented by its own distribution function $y_{t\sim(\theta_{s_t}, \sigma^2_{s_t})}$, it is possible to define a maximum likelihood function as:

$$(1)\quad f\left(y_t \,\middle|\, s_t = j, \Psi_{t-1}; \Gamma\right) = \frac{1}{\sqrt{2.\pi.\sigma^2_{s_t}}} \cdot e^{-\frac{1}{2}\left(\frac{y_t - \theta_{s_t}}{\sigma_{s_t}}\right)^2} \quad \forall_j = 1,2,\dots,N$$

In which: $\Gamma = [\theta_1, \theta_2, \dots, \theta_N, \sigma_1^2, \sigma_2^2, \dots, \sigma_N^2]$

[40] From 2005 big banks like BCP and Interbank have implemented a system of correspondent banking offices (inside retail commerces) that offer some banking services like payments, cash withdrawalls, banking transferences, to places where banking offices are not present.

[41] Stationarity is defined as the process with a stationary covariance matrix.

Considering that the t=1,2,...,T are iid $\forall t$, the function to be optimized can be represented by the natural logarithm of the maximum likelihood function:

$$Max\ £\ (\Gamma)_{\{\Gamma\}} = \sum_{t=1}^{T} lnf\left[y_t \middle| \Psi_{t-1;}\ \Gamma\right]$$

$$(2)\ = \sum_{t=1}^{T} ln\left[\sum_{j=1}^{N} f\left(y_t \middle| s_t = j,\ \Psi_{t-1;}\ \Gamma\right).P\ \left[s_t = j \middle| \varphi_{t-1};\ \Psi_{t-1;}\ \Gamma\right]\right]$$

$$s.a. \sum_{j=1}^{N} \pi_j = 1, \pi_j\ \geq 0, \forall_j = 1,2,\dots,N$$

This problem can be solved using the expectation-maximization algorithm method[42] , which consists in a two-staged iterative procedure. Its stopping rule will be defined by the satisfaction of certain standard or criterion of distance between the vectors of estimated parameters $\hat{\tau}$ through the k = min {k,K} iterations. This methodology allows us to infer the probability that at each point in time the process y_t comes from one of the N alternative states of nature. The probability is obtained using the following equation:

$$p\left[s_t = j \middle| \Psi_{t-1;}\ \hat{\Gamma}\right] = \frac{p(y_t, \left[s_t = j \middle| \Psi_{t-1;}\ \hat{\Gamma}\right])}{f\left[y_t \middle| \Psi_{t-1;}\ \hat{\Gamma}\right]} = \frac{\hat{\pi}_j.f\left(y_t \middle| s_t = j,\ \Psi_{t-1;}\ \Gamma\right)}{\left(y_t \middle|\ \Psi_{t-1;}\ \hat{\Gamma}\right)}$$

The first stage of the method forms the expectation (E), considering a vector of parameters $\hat{\tau}^{(k-1)}$ for the iteration k; while the second stage maximizes (M) the LMLE function considering the parameters of the model; generating $\hat{\tau}^{(k)}$. The iterative process considers the following equation system:

$$(3)\ \hat{\theta}_j = \frac{\sum_{t=1}^{T} y_t.P\left[s_t = j \middle| \Psi_{t-1;}\ \hat{\Gamma}^{(k-1)}\right]}{\sum_{t=1}^{T} P\left[s_t = j \middle| \Psi_{t-1;}\ \hat{\Gamma}^{(k-1)}\right]}, \forall_j = 1,2,\dots,N$$

$$\hat{\sigma}_j^2 = \frac{\sum_{t=1}^{T} (y_{t-}\ \hat{\theta}_j)^2.P\left[s_t = j \middle| \Psi_{t-1;}\ \hat{\Gamma}^{(k-1)}\right]}{\sum_{t=1}^{T} P\left[s_t = j \middle| \Psi_{t-1;}\ \hat{\Gamma}^{(k-1)}\right]}, \forall_j = 1,2,\dots,N$$

$$\hat{\pi}_j = \frac{1}{T}.\sum_{t=1}^{T} P\left[s_t = j \middle| \Psi_{t-1;}\ \hat{\Gamma}^{(k-1)}\right], \forall_j = 1,2,\dots,N$$

To estimate the model we made the test of Davies of non linearity under different specifications of the models of MSM (with intercept, changes in autoregressive, and in the errors variances) and select the model that minimizes the Akaike criterion.

[42] Hamilton 1990 and 1991.

Table N° 7 summarizes the results of the Test of Davis for the three estimated models: a model with aggregated cash, a model with the small denominations, and a model with large denomination notes.

Table N° 7

MODELOS MARKOV-SWITCHING: TEST DE DAVIES DE NO LINEALIDAD

	CIR agregado (CIR_b)		CIR baja denominación (CIR_small)		CIR alta denominación (CIR_big)	
	Criterio Akaike	Test Davies	Criterio Akaike	Test Davies	Criterio Akaike	Test Davies
MSIAH	**-5,7689**	a	-5,0136	a	-5,7184	a
MSI	-5,711	b	-4,9027	lineal	-5,6153	lineal
MSIA	-5,6421	lineal	**-5,0394**	a	-5,5482	lineal
MSIH	-5,7166	b	-5,0168	a	-5,8017	a
MSA	-5,6666	lineal	-5,0142	b	-5,6315	lineal
MSH	-5,7239	b	-5,0296	a	**-5,8128**	a
MSAH	-5,6339	lineal	-5,0151	a	-5,7327	a

a: al 99% de confianza.

b: al 95% de confianza.

c: al 90% de confianza.

The model that minimizes the Akaike criterion for the aggregated cash specification is the MSIAH, for the low denominations model is the MSIA (intercept and autoregressive) and for the big denomination model is the MSH (variance of the errors). In all cases, non linearity is accepted at the highest confidence level. All the variables are specified in the same order of integration (first differences).

The model MSIAH (intercept, autoregressive and trend) for the aggregated model during the period 2002-2013 shows two regimes. The probabilities of being in the first regime are near one prior 2003 and between 2008 and 2009. These periods belong to crisis periods in the Peruvian economy: Asian crisis, Russian crisis, and the *sub prime* crisis in the United States. The probabilities of being in the second regime are near one in almost all the sample periods (2003-2008 and 2010–2013) that correspond to a stability period.

Table N° 8 shows the results of the MSIAH for the aggregated model. The variables that are significant to explain cash are different for the two regimes in the period 2002-2013. In the first period (crises period), the aggregated demand for cash is explained by the GDP, interest rate, the number of banking offices and dollarization ratio; while in the second regime, only the GDP and dollarization ratio explain the cash evolution.

The crises periods of the first regime are related to periods of rapid drops in the interest rates, and a higher demand for cash. In the alternative regime, interest rates have not played a role in the demand for cash.

Table N°8

MODELO MSIAH			
Régimen 1			
	Coef	StdError	t-val
Const(Reg.1)	**-0,0034**	**0,0010**	**-3,3036**
D_L_PBI_1	**0,3210**	**0,0437**	**7,3429**
D_L_PBI_2	**1,0085**	**0,0395**	**25,4992**
D_L_TIPMN_1	**-0,1034**	**0,0335**	**-3,0830**
D_L_TIPMN_2	**0,2884**	**0,0234**	**12,3203**
D_L_OFICINAS_1	**0,3042**	**0,0304**	**9,9926**
D_L_OFICINAS_2	**0,1231**	**0,0345**	**3,5680**
D_L_COEF_DOL_1	**-0,5267**	**0,0470**	**-11,2143**
D_L_COEF_DOL_2	**0,2350**	**0,0347**	**6,7647**
Standard error	(Reg.1)	0,0022753	
Régimen 2			
	Coef	StdError	t-val
Const(Reg.2)	**0,0126**	**0,0016**	**7,7887**
D_L_PBI_1	**0,1337**	**0,0739**	**1,8105**
D_L_PBI_2	-0,0365	0,0777	-0,4701
D_L_TIPMN_1	0,0189	0,0391	0,4843
D_L_TIPMN_2	-0,0256	0,0365	-0,7003
D_L_OFICINAS_1	0,0251	0,08	0,3141
D_L_OFICINAS_2	0,0989	0,0804	1,2311
D_L_COEF_DOL_1	0,0218	0,0647	0,3365
D_L_COEF_DOL_2	**-0,1669**	**0,0753**	**-2,2162**
Standard error	(Reg.2)	0,011811	

MSIA model is used to explain the cash for lower denominations. There also are two regimes. One regime in the period 2002-2013; and the second regime in the period 2002 and 2008 related to financial crisis a change in the structure of provision of cash. Thus, in 2006 the central bank increases the quality standard for the notes in circulation following a period of notes replacement, and in 2011 the central bank changes the design in the family of notes incorporating new elements of security (Ramírez, 2011).

Table N° 9 shows the results of the estimation of the MSIA model for the small denomination model. There are also two regimes. In the first regime of the MSIA model, that is valid in normal times, the cash of small denomination notes is explained by the GDP; while in the second regime, the GDP and interest rates are significant.

Table N°9

CIRCULANTE DE BAJA DENOMINACIÓN			
MODELO MSIA			
Régimen 1			
	Coef	StdError	t-val
Const(Reg.1)	**0,0051**	**0,0019**	**2,6731**
D_L_PBI_1	0,0837	0,0919	0,9102
D_L_PBI_2	**0,215**	**0,0889**	**2,4181**
D_L_TIPMN_1	0,027	0,0558	0,4833
D_L_TIPMN_2	-0,0512	0,0554	-0,9243
D_L_OFICINAS_1	0,0866	0,0902	0,9597
D_L_OFICINAS_2	-0,0344	0,0877	-0,3924
D_L_COEF_DOL_1	-0,0529	0,0832	-0,635
D_L_COEF_DOL_2	-0,0334	0,0787	-0,4245
Standard error	0,014417		
Régimen 2			
	Coef	StdError	t-val
Const(Reg.2)	**0,0355**	**0,016**	**2,2137**
D_L_PBI_1	0,5421	0,6397	0,8474
D_L_PBI_2	**-1,86**	**0,5326**	**-3,4924**
D_L_TIPMN_1	**-0,58**	**0,2656**	**-2,1841**
D_L_TIPMN_2	**0,7477**	**0,2291**	**3,2629**
D_L_OFICINAS_1	0,7251	0,6324	1,1465
D_L_OFICINAS_2	-0,5539	0,6056	-0,9147
D_L_COEF_DOL_1	0,0971	0,3106	0,3126
D_L_COEF_DOL_2	0,2296	0,2669	0,8602
Standard error	0,014417		

This result is highly intuitive and confirms the main transaction use of low denomination notes in normal times; while in crisis times or atypical events, the interest rates and the dollarization coefficient are also relevant variables, considering that the costs (opportunity and reposition costs) of cash holding grow.

The estimation of the model for the large denomination notes, according to Table N° 7, indicates that the MSH model has the best fit. We present the result of the estimation in the Table N° 10, there are two regimes with different intercepts, but in both models the informality and the dollarization ratio explain the evolution of cash of larger denomination. This result shows that the demand for higher denomination notes are related to activities not registered in the formal GDP, and that are not registered in the demand for cash surveyed by the central bank. Also, these results give evidence that the payment for high value transactions made traditionally in US dollars (to buy vehicles and real estate) are made more frequently in local currency (new soles), reflecting a process of dedollarization in this kind of transactions (as can be seen in the section 3.1 of this paper).

Table N°10

MODELO MSH			
Régimen 1			
	Coef	StdError	t-val
Const(Reg.1)	**0,0125**	**0,0013**	**10,0064**
D_L_PBI_1	0,0955	0,062	1,542
D_L_PBI_2	0,0241	0,0637	0,3785
D_L_TIPMN_1	-0,0012	0,0294	-0,0399
D_L_TIPMN_2	-0,0164	0,0283	-0,5788
D_L_OFICINAS_1	0,0576	0,0588	0,978
D_L_OFICINAS_2	0,052	0,0571	0,9118
D_L_INFORM_1	**0,0496**	**0,0212**	**2,3398**
D_L_INFORM_2	**0,0634**	**0,0212**	**2,9881**
D_L_COEF_DOL_1	-0,0507	0,0465	-1,0907
D_L_COEF_DOL_2	**-0,0872**	**0,0498**	**-1,7512**
Standard error	(Reg.1)	0,0090812	
Régimen 2			
	Coef	StdError	t-val
Const(Reg.2)	**0,0224**	**0,0068**	**3,278**
D_L_PBI_1	0,0955	0,062	1,542
D_L_PBI_2	0,0241	0,0637	0,3785
D_L_TIPMN_1	-0,0012	0,0294	-0,0399
D_L_TIPMN_2	-0,0164	0,0283	-0,5788
D_L_OFICINAS_1	0,0576	0,0588	0,978
D_L_OFICINAS_2	0,052	0,0571	0,9118
D_L_INFORM_1	**0,0496**	**0,0212**	**2,3398**
D_L_INFORM_2	**0,0634**	**0,0212**	**2,9881**
D_L_COEF_DOL_1	-0,0507	0,0465	-1,0907
D_L_COEF_DOL_2	**-0,0872**	**0,0498**	**-1,7512**
Standard error	(Reg.2)	0,026167	

5. Conclusions

The main purpose of this paper is to determine the factors that explain the high growth rate of cash in Peru, above the GDP growth rate especially for higher denomination notes. We categorized the cash for the analysis: considering all denominations, considering only low denomination notes (S/. 10, S/. 20 and S/. 50), and considering only high denomination notes (S/. 100 and S/. 200).

In order to study the determinants of cash, we considered variables such as the dollarization of the Peruvian economy and the significance of the informal and illegal sector.

The estimation output allows us to deduce that the demand for cash has different components according to the note's denomination and the analyzed period. First, we use data from 2002 to 2013 in a linear least squares regression. The results show an R-squared value below 20 per cent, for three categories analyzed. For the aggregate model and the low denomination notes model, the GDP, the interest rate, the dollarization level and the technology (approached by a trend variable) are significant. However, neither the informality nor the

number of offices is relevant. The high denomination notes model reports a different result for the variables. While the interest rate, the dollarization level and the technology are significant in the model; the GDP, the number of offices and the informality aren't.

The signs of the coefficients in the estimated linear model are expected, but the low adjustment of the model suggests a non linear relationship. The Markov switching model gives as a result two regimes during the sample period, both for the aggregated model and for the model divided by categories. The existence of those regimes is attributed to periods of financial shocks or periods on which new features were added to the notes (changes in the note's security elements, note's quality, note's design, etc) that can alter the real or perceived opportunity costs of holding money in the economic agents.

The estimated model for the circulation in the period analyzed (2002-2013) reports the existence of two regimes. The first one is in the periods before 2003 and the second one between 2008 and 2009. Those periods are related to the crisis periods in the Peruvian banking system: after the Asian, Russia and Brazilian crisis, and the second one is related to the sub-prime financial crisis. The second regime is during the 2003-2008 and 2010-2013 periods, which are periods with financial stability. In the first regime (crisis period), the circulation is explained by the GDP, the passive interest rate in local currency, the number of bank offices and the dollarization level. However, in the second regime just the GDP and the dollarization level explain the circulation.

It is important to mention that the periods of crisis of the first regime concur with the significant drops in the interest rates that could have lead the agents to demand more cash as a precautionary measure. During the regime of stability, the interest rate does not impact in the demand for cash.

We also found the existence of two regimes for the small denomination notes model. The first regime is for the period 2002-2013 and the second regime is in 2002, 2007-2008, 2011 and the last periods of 2012. The second regime is related to episodes of financial crisis in 2002 and 2008, as well as to changes in the supply of notes to the public. For instance, in January 2006 the central bank increased the quality standard of the notes in circulation which led to a period dedicated to replace notes. Also, in 2011 a change in the design of the entire note's family was made, incorporating new security elements.

In the estimation of the demand for low denomination notes model during the stability regime, the GDP is the main determinant of the demand for cash and to a less extend the interest rate, both with expected signs of the coefficients. On the contrary, these variables have no relevance in the large denomination notes model.

The coefficient for the dollarization level variable in the demand for small denomination notes model has an expected sign, though it has a small value which could suggest that some components of the small denomination notes group play a store of value role. This is corroborated by the cash usage surveys taken by the Central Bank, since there are agents that save money in cash form.

The high correlation between the small denomination notes and the GDP and the nonexistent correlation between this variable and the large denomination notes allow us to deduce that the demand for cash for transactional purposes

in Peru represents 56 per cent of the total demand for cash. This result assumes that the notes of /. 10, S/. 20 y S/. 50 are the only ones that are used in the day to day transactions. Nonetheless, we mention before that this is not completely accurate because the interest rate is a relevant variable in this group of notes. So, we could read this percentage (56 per cent) as a maximum percentage.

Once the high denomination notes model is corrected by regime, the interest rate no longer is significant in the model, but the dollarization level and the degree of informality variables did result significant. In recent years, the dollar was replaced by the local currency (Nuevo sol) in large scale transactions such as the purchase of real estate or vehicles. It is important to state that the informal sector manages large sums of cash in large denominations in order to avoid taxes or to pursue illegal activities. Cash facilitates those actions because of the anonymity that provides and the transportation advantages that gives. This result is interesting because it contrast with the model in which the variable of informality wasn't relevant.

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Annex 1: Unit Root Test

Series en Niveles

	Intercepto							
	ADF	DF-GLS	PP*	ERS	NG P			
					MZa	MZt	MSB	MPT
cirb_sa	1,98	1,13	5,74	759,54	1,97	1,48	0,75	50,42
small_sa	0,19	0,62	1,07	194,39	1,06	0,73	0,69	37,39
big_sa	2,65	1,53	7,13	1299,88	2,68	3,02	1,12	115,97
pbi_sa	1,50	0,74	1,37	1370,12	1,41	1,21	0,86	57,59
tipmn_sa	-2,11	-1,10	-2,97 b	21,56	-2,46	-0,97	0,39	9,25
oficinas	-0,07	0,42	1,14	74,86	0,74	0,44	0,59	27,61
atm	4,19	1,22	6,97	801,84	0,60	0,26	0,43	17,63
inform_sa	-1,98	-0,57	-5,71 a	20,37	-1,27	-0,67	0,53	15,63
coef_dol_sa	-1,61	0,72	-1,57	243,18	0,86	0,90	1,05	73,64
	Intercepto y tendencia							
cirb_sa	-0,55	-0,65	-0,29	342,49	-6,52	-1,59	0,24	14,08
small_sa	-1,97 c	-1,05	-2,10 c	31,56	-3,62	-1,29	0,36	24,29
big_sa	0,14	-0,39	0,79	222,83	-1,98	-0,66	0,34	28,50
pbi_sa	-1,82	-0,84	-2,24	48,25	-1,91	-0,85	0,45	39,66
tipmn_sa	-2,50	-2,31	-2,92	15,46	-7,07	-1,86	0,26	12,92
oficinas	-2,17	-1,55	-2,17	74,02	-8,77	-2,05	0,23	10,55
atm	1,23	-0,90	0,78	254,32	-22,29 b	-3,18 b	0,14 b	5,07 b
inform_sa	-2,62	-2,35	-8,85 a	11,65	-8,05	-1,93	0,24	11,54
coef_dol_sa	-1,83	-1,45	-1,89	19,91	-4,95	-1,49	0,30	17,99

a. Rechazo al 1%, b rechazo al 5%, c: rechazo al 10%

Series en Primera diferencia

	Intercepto							
	ADF	DF-GLS	PP*	ERS	NG P			
					MZa	MZt	MSB	MPT
cirb_sa	-1,50 c	-0,98	-10,91 a	10,98	-2,09	-1,02	0,49	11,69
small_sa	-2,30	-1,90 b	-12,26 c	7,52	-3,40	-1,30	0,38	7,20
big_sa	-1,87	-1,43	-9,30 a	5,59	-4,29	-1,45	0,34	5,74
pbi_sa	-3,10 b	-1,25	-15,61 a	5,00	-1,19	-0,77	0,64	20,29
tipmn_sa	-4,28 a	-0,69		22,24	-1,25	-0,68	0,54	16,28
oficinas	-1,97	-1,62	-12,12 a	11,02	-1,94	-0,97	0,50	12,47
atm	0,16	0,95	-9,39 a	65,18	-0,34	-0,37	1,10	60,64
inform_sa	-19,93 a	-0,28		2,29 b	0,03	0,04	1,47	113,42
coef_dol_sa	-4,24 a	-4,23 a	-9,02 a	0,98 a	-29,28 a	-3,78 a	0,13 a	0,98 a
	Intercepto y tendencia							
cirb_sa	-2,93	-2,45	-12,43 a	15,51	-4,35	-1,42	0,33	20,46
small_sa			-12,37 a	23,43	-3,64	-1,31	0,36	24,48
big_sa	-3,54 b	-3,09 b	-11,46 a	5,34 b	-12,91	-2,52	0,20	7,19
pbi_sa	-3,29 b	-2,82 c	-15,87 a	10,16	-5,01	-1,57	0,31	18,13
tipmn_sa	-4,20 a	-1,59	-5,99 a	21,94	-5,26	-1,57	0,30	17,15
oficinas	-2,01	-2,04	-12,32 a	33,79	-2,66	-1,15	0,43	34,15
atm	-1,60	-1,29	-10,90 a	52,19				
inform_sa	-19,86 a		-24,27 a	3,43 a	-0,35	-0,33	0,93	164,12
coef_dol_sa	-4,31 a	-4,30 a	-9,08 a	3,03 a	-29,88 a	-3,85 a	0,13 a	3,17 a

a. Rechazo al 1%, b rechazo al 5%, c: rechazo al 10%

Annex 2: OLS Estimations

Dependent Variable: D_L_CIRB
Method: Least Squares
Sample (adjusted): 2002M05 2013M06
Included observations: 134 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D_L_PBI(-3)	0.144757	0.065722	2.202568	0.0294
TIPMN_SA	-0.005710	0.001658	-3.444010	0.0008
D_L_OFICINAS(-3)	-0.122411	0.068314	-1.791882	0.0755
L_COEF_DOL(-1)	-0.053443	0.009289	-5.753626	0.0000
TEND	-0.000391	8.20E-05	-4.769842	0.0000

R-squared	0.201098	Mean dependent var	0.014637
Adjusted R-squared	0.176326	S.D. dependent var	0.013079
S.E. of regression	0.011870	Akaike info criterion	-5.993000
Sum squared resid	0.018176	Schwarz criterion	-5.884872
Log likelihood	406.5310	Hannan-Quinn criter.	-5.949060
Durbin-Watson stat	2.288583		

Dependent Variable: D_L_SMALL
Method: Least Squares
Sample (adjusted): 2002M06 2013M06
Included observations: 133 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D_L_PBI(-3)	0.290729	0.098932	2.938668	0.0039
TIPMN_SA	-0.008570	0.002514	-3.409057	0.0009
D_L_OFICINAS(-4)	0.203816	0.103346	1.972168	0.0507
L_COEF_DOL(-1)	-0.056026	0.014069	-3.982277	0.0001
TEND	-0.000428	0.000124	-3.437428	0.0008

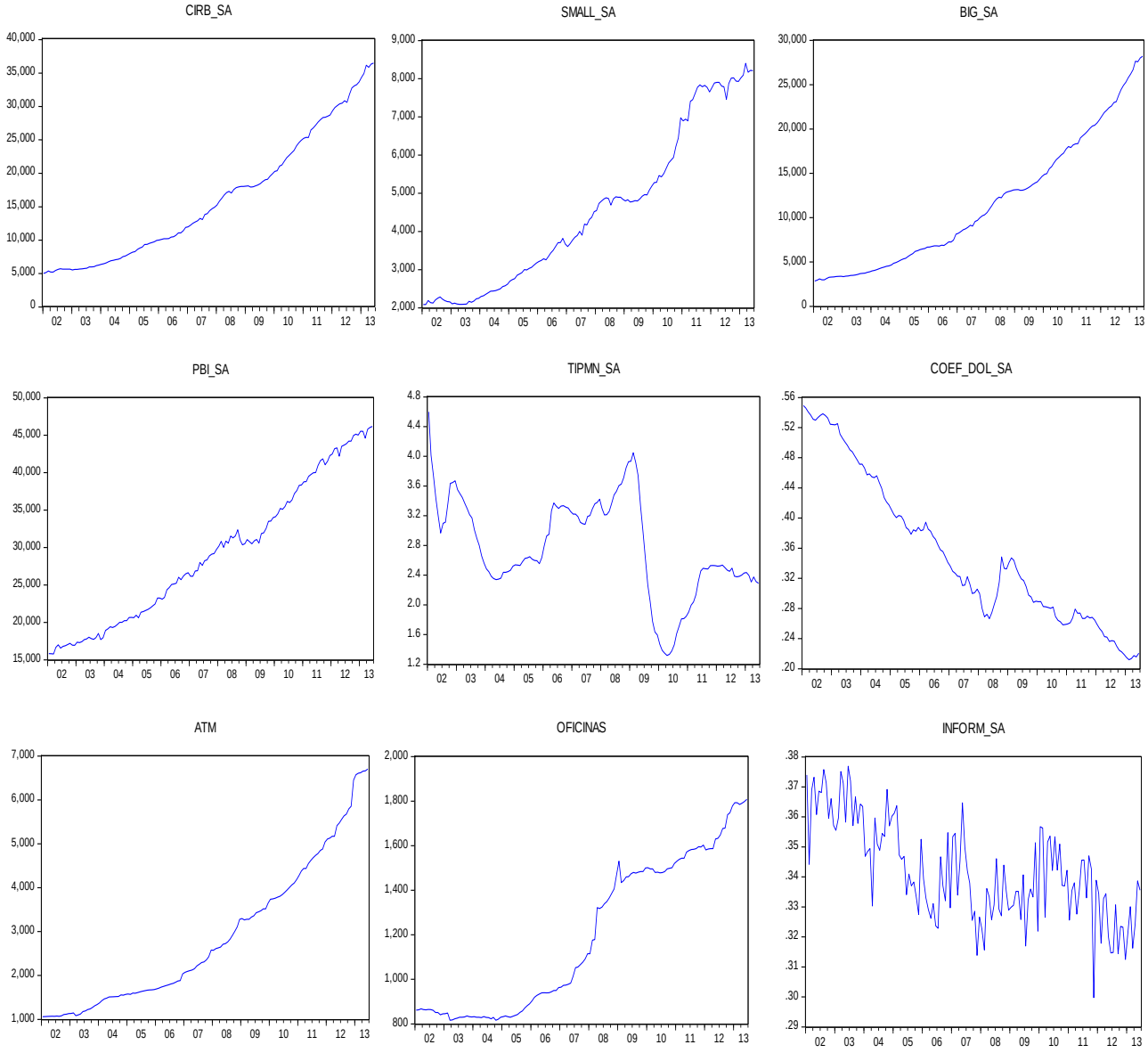
R-squared	0.172441	Mean dependent var	0.010161
Adjusted R-squared	0.146580	S.D. dependent var	0.019505
S.E. of regression	0.018019	Akaike info criterion	-5.157936
Sum squared resid	0.041559	Schwarz criterion	-5.049276
Log likelihood	348.0027	Hannan-Quinn criter.	-5.113781
Durbin-Watson stat	2.173392		

Dependent Variable: D_L_BIG
Method: Least Squares
Sample (adjusted): 2002M02 2013M06
Included observations: 137 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
TIPMN_SA	-0.005092	0.001781	-2.859168	0.0049
L_COEF_DOL(-1)	-0.057462	0.009963	-5.767213	0.0000
TEND	-0.000440	8.83E-05	-4.984886	0.0000

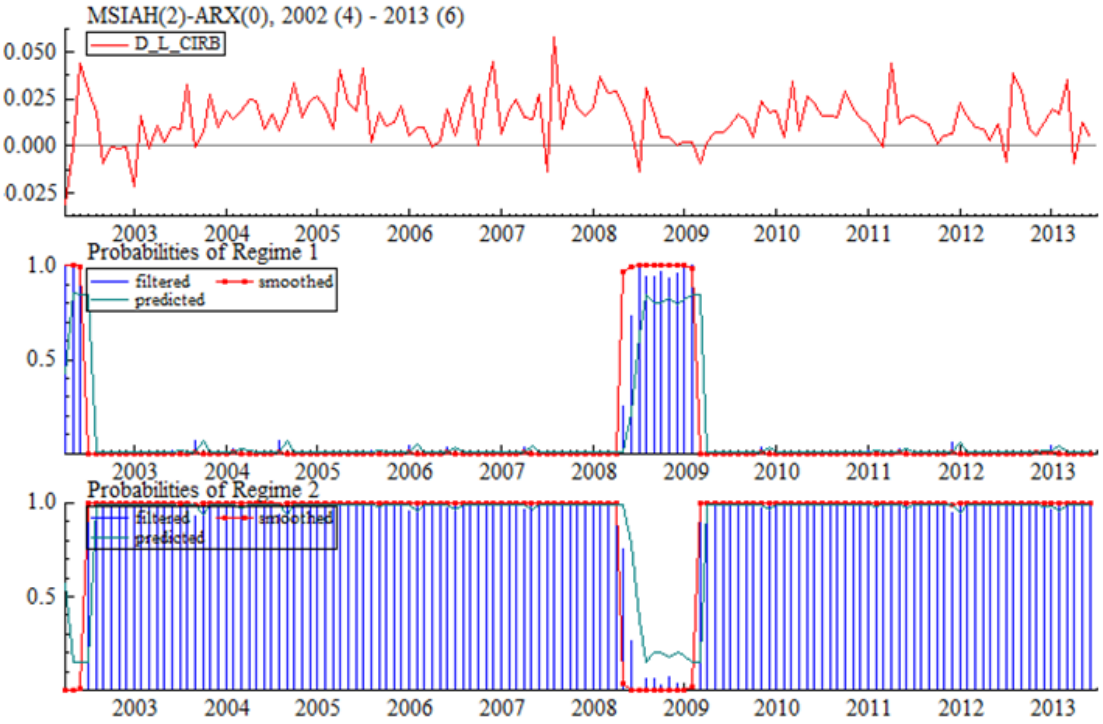
R-squared	0.117461	Mean dependent var	0.016698
Adjusted R-squared	0.104288	S.D. dependent var	0.013969
S.E. of regression	0.013221	Akaike info criterion	-5.792431
Sum squared resid	0.023421	Schwarz criterion	-5.728490
Log likelihood	399.7815	Hannan-Quinn criter.	-5.766447
Durbin-Watson stat	2.077850		

Annex 3: Graphs of the series (in levels)

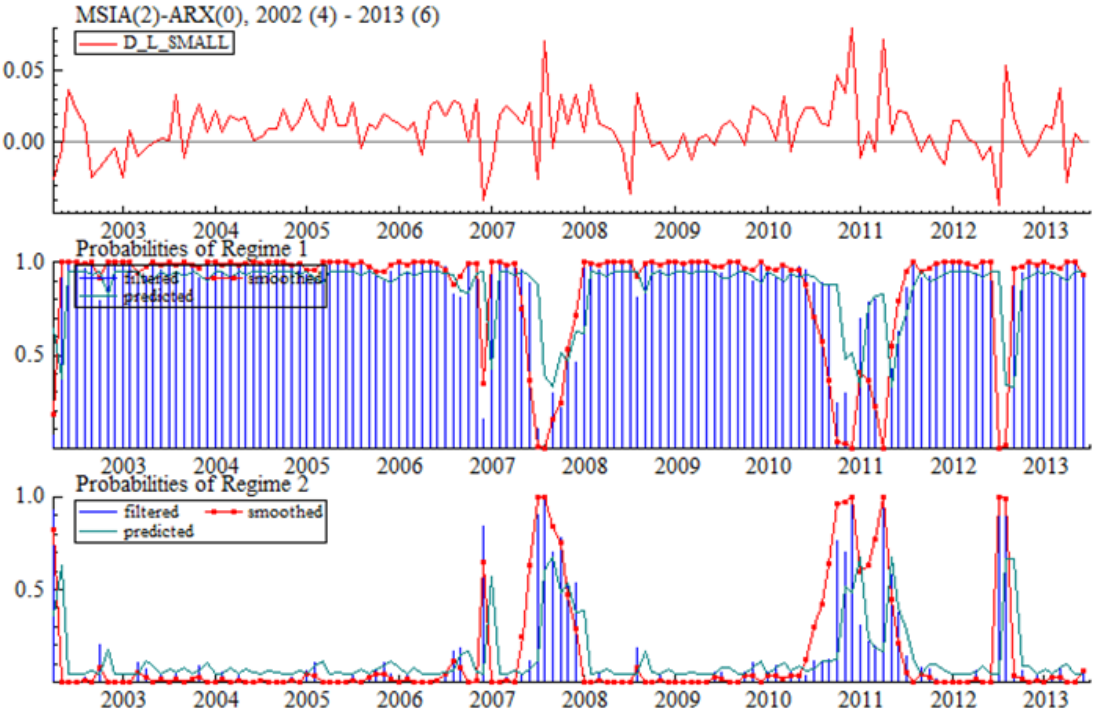


Annex 4: Probabilities of the Regimes in the Markov Switching Model

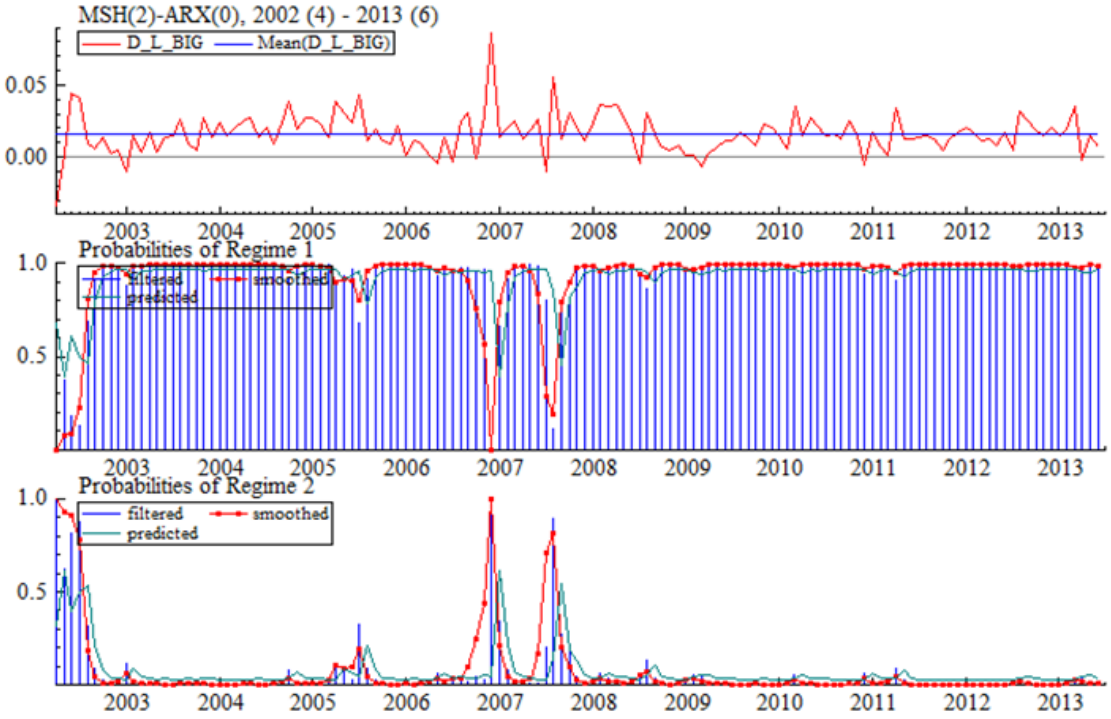
MSIAH Model



MSIA Model



MSH Model


MSH(2)-ARX(0), 2002 (4) - 2013 (6)
D_L_BIG
Mean(D_L_BIG)
0.05
0.00
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Probabilities of Regime 1
filtered
smoothed
predicted
1.0
0.5
Probabilities of Regime 2
filtered
smoothed
predicted
1.0
0.5