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Falling Use of Cash and Demand for Retail Central Bank Digital Currency

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WORKING PAPER

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Monetary and Capital Markets Department

Falling Use of Cash and Demand for Retail Central Bank Digital Currency**Prepared by Tanai Khiaonarong and David Humphrey***

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ABSTRACT: Cash use in most countries is falling slowly. On the margin, younger adults favor cash substitutes over cash. For older adults it is the reverse. Revealed preference tied to a changing population age structure seems to be the main influence on the demand for cash and why it is falling. Cash use may continue to fall, and card use (the main cash substitute) may fall by more, if CBDC is issued. The extent of this reduction depends on the demand for retail CBDC and the incentives (primarily transaction fees) that can play a determining role in CBDC adoption and use.

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WORKING PAPERS

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Introduction

Cash is demanded for a number of reasons: as a medium of exchange for payments, to hold as a precautionary reserve, and to facilitate illegal activities. Using a standard indicator of cash use, the ratio of all coin and currency in circulation (CIC) to GDP, Ashworth and Goodhart (2020) show that the demand for cash has fallen from its highest level of use in the late 1940s, flattened out during the 1980s, but more recently reversed course and rose steadily after the early 2000s for a selected group of countries: the Euro Area, Japan, the UK and US. When the increase in CIC is analyzed for the UK alone, the rise in household consumption, lower interest rates, and several indicators of tax evasion are all statistically significant. As household consumption includes both the use of coin and low value currency along with cards and perhaps some checks in the UK, the issue of cash/card substitution for payments was not addressed. Knowledge of how and why cards have substituted for cash and other payment instruments provides information on the competitive environment that retail CBDC may face, if issued by central banks. It also suggests what attributes or incentives retail CBDC may provide for users and merchants for them to demand and use CBDC.

Additional information on how currency in circulation to GDP has varied across a broader selection of advanced and emerging market countries is provided by Bech, et al. (2018). They find that this ratio rose for 20 out of the 25 countries they covered. The ratio fell in 5 countries: China, Norway, Russia, South Africa, and Sweden. With the exception of Sweden, these countries were not covered by Ashworth and Goodhart (2020). Both studies showed that the value of cash and cards rose absolutely over earlier and current time periods. Bech, et al., additionally showed that the number of ATM and EFTPOS terminals also expanded, providing greater access to both payment instruments. Based on finding that some 75 percent of the countries covered experienced an increase in their CIC/GDP ratio, they concluded that the overall substitution of cards for cash has been limited. Had the substitution of cards and other payment substitutes for cash been strong enough, more countries would have experienced a falling CIC/GDP ratio.

However, focusing on the use of cash for payments in competition with cards and e-money (stored value money), a different picture emerges. This is because a rise in the ratio of currency in circulation to GDP is really an indicator that the stock of cash rose relative to the value of all types of payments used to produce GDP, such as business to business payments for intermediate inputs, employee payroll payments, international transactions, and purchases of output by the various categories of final demand. The vast majority of these payments use instruments that do not compete with cash, especially where it is normally used (at the point of sale). Although wire transfers and ACH-type payments rarely compete with cash, from the 1950s to the 1970s, checks and giro payments in many countries substituted for cash in payroll, bill payments, and at the point of sale. More recently, debit and credit card payments at the point of sale have eventually become the main cash substitute for purchases, although checks and e-money in some countries may play a minor role.

Assessing how the use of cash is changing in the market for cash requires a different measure. The one we use—a market share measure of cash use—is simply the value of cash withdrawn from ATMs (CASH) as the share of cash in the market for cash or $CASH/(CASH + CARDS + E-MONEY)$. This is a value share measure of the flow of cash to the flow of cash and its substitutes, rather than a stock measure of CIC to the flow of GDP. This measure is not only more focused on the use of cash where it is normally used—which retail CBDC would also be designed to do—but shows which cash substitutes have had the greatest effect on the use of cash for payments over time. One study has used this indicator as a proxy (Taylor, 2006).

Our interest in the cash substitution issue is three-fold. First, we want a direct indicator of the use of cash compared to its substitutes. Such a measure should reflect how competitive cash substitutes are in the current market for cash in a country. Second, since cash use is falling, we want to know what seems to be driving this trend across countries. Third, while retail CBDC may have some effect on the future trend in cash use, it is more likely to have a greater effect on the share of existing cash substitutes (primarily cards) in our cash use measure. This depends on the demand for CBDC and the strength of the incentives that may exist to promote its acceptance and use, if issued.

To this end, in Section II we borrow from competition analysis and adopt the market share measure of cash use defined above. The effect of including over the counter (OTC) cash withdrawals at financial institutions, missing for all but 6 countries of the 25 we cover, is noted in the text and can affect the market share of cash if OTC cash acquisition is very large. Unfortunately, these data include something we don't want and can't be used. Our cash share measure is contrasted with two other measures of cash use: the standard measure of the ratio of CIC to GDP and the ratio of small value CIC to household consumption (HC), the latter being more representative of what cash is used to purchase. Cash use is falling for 8 of our countries using the standard measure, 13 countries using the second measure, and 24 countries using our cash share measure. Countries that have had the most substitution away from cash by 2019, and currently have the lowest share of cash use, generally are not those that have had the greatest absolute increase in this substitution over 2012–2019. Korea, Sweden, and the U.S. have the lowest cash shares in 2019 and experienced a relatively small reduction in their cash share over 2012–2019. China, Spain, and Argentina have higher cash shares and experienced a greater reduction in their shares over the same period. Thus, the downward trend in cash use is not linear but for many countries is falling at a decreasing rate. This suggests that fewer additional individuals are choosing cash substitutes once most have already done so.

In Section III, we attempt to explain why cash shares have fallen across countries. Instead of trying to determine the importance of the many separate influences that can affect the choice of cash versus its substitutes across countries (such as convenience, relative cost, availability of infrastructure, trust in electronic payments, etc.), we use a summary measure reflecting the marginal revealed preference for cash substitutes by younger adults compared to the marginal preference for cash by older adults observed in a set of payment diary studies. This concerns the changing age structure of individuals in a country's population. The end result of using either approach should be the same since the separate influences on payment choice generate the revealed preference we see in payment diary studies. Thus, we use revealed preference, not the multiple influences on payment choice that lead to revealed preference.

In Section IV, we note that some countries already have a rather low level of cash use, indicating that considerable cash substitution has already occurred. If retail CBDC is issued, its adoption and use by users and merchants may have more effect on the share of current cash substitutes than on the future share of cash use in a country. As cards are the main cash substitute in most countries, CBDC adoption would likely be higher, all else equal, if CBDC matched or exceeded the benefits of cards. We take as given that CBDC will be structured to largely match user and merchant benefits associated with card use in terms of convenience, speed of payment, fraud control, and other desirable payment attributes. We then focus on other possible benefits associated with CBDC that may promote its adoption. These incentives are related to transaction fees or costs, such as user fees, merchant interchange fees, and merchant working capital costs. A summary is in Section V and a data appendix notes the sources of our data.

Cash Use: Different Measures for Different Purposes

To gauge the use of cash for all purposes together—small value purchases, precautionary reserve, and illegal activities—it is common to use the ratio of all coin and currency in circulation to GDP. This measure is shown in Table 1 for the countries we cover, with the exception of 6 in the Euro Area. Countries in the Euro Area know the value of Euros they have issued but not how much is used inside their borders. Consequently, only the CIC/GDP ratio for the Euro Area as a whole is reported in their place.¹

The values shown for each country in Column 1 indicate the percent change in the CIC/GDP ratio over 2012–2019. The 8 countries where CIC/GDP is falling are shaded. Countries where this ratio rises or is stable are unshaded. For example, the ratio for Argentina fell 40 percent, from a small base level of 0.090 in 2012 to 0.054 in 2019.² In contrast, the Euro Area's ratio rose by 16 percent, Japan's rose by 15 percent, while India's and Brazil's were stable (as the change was less than or equal to plus or minus 1 percent). To the 5 countries Bech, et al. (2018) found that decreased their overall use of cash (China, Norway, Russia, South Africa, and Sweden), we add Argentina, Indonesia, Turkey, and the UK. Explaining why these country's ratios fell is beyond the scope of the paper, although this is attempted for our cash share measure in Section III.

Another way to measure cash use, shown in detail in Amromin and Chakravorti (2009), is to recognize that most cash is used for lower value purchases. This focuses on coin and lower value currency denominations (small CIC). This separates cash used mostly for purchases from cash held as a precautionary reserve, held overseas, or used to facilitate illegal activities. In the 13 OECD countries they covered, the exchange rate adjusted average dollar value (excluding Switzerland) was \$37. Small CIC was defined as currency denominations lower than the most supplied denomination in a country's ATM network. For the US, the most supplied denomination from ATMs was \$20, so the value of \$10, \$5, and \$1 notes plus the value of all coins defined small CIC. We used \$35 and under to define small CIC for all countries. Multiplying \$35 by the average purchasing power exchange rate (PPP) over 2012–2019 for each country to obtain the average equivalent local currency value, the closest local currency denomination was then the cutoff for small CIC.³

Instead of relating small CIC to GDP, it makes more sense to relate it to that component of GDP where small CIC is most used—household consumption (HC). This gives the ratio small CIC/HC which fell for 13 countries in Column 2. As expected, each of the 8 countries with a falling CIC/GDP ratio, also had a falling small CIC/HC

¹ It is estimated that 30 percent of the value of Euros and 55 percent of dollars are held by other countries (Bank of France, 2020, page 8; ECB, 2017; Judson, 2017). Thus, the values shown in Table 1 and elsewhere for CIC/GDP have already been lowered by 30 percent for the Euro Area and 55 percent for the US. Evidence suggests that the vast majority of this value is in terms of high denomination notes not commonly seen in domestic circulation. This issue should have little effect on the values shown below for the ratio of small CIC to household consumption and none at all for our cash share measure.

² Neither of these initial or ending ratio values for this or other measures are reported below although they are pictured in Figure 1.

³ If this cutoff was closest to the largest currency denomination in a country, the cutoff was reduced to the next lowest denomination. Small CIC in Arango-Arango and Suarez-Ariza (2020) was any denomination less than \$31 in PPP adjusted dollars while Bech, et al. (2018) used a PPP adjusted denomination of \$75 in local currency as their cutoff. They noted that changing this value did not materially affect their analysis.

Table 1. Rising, Stable, or Falling Cash Use: All Countries, 2012–2019 (in percent)

	Jurisdiction	All CIC to GDP	Small CIC to HC	Cash to Cash plus Card & E-money
1	Argentina	-40	-82	-30
2	Australia	8	0	-40
3	Belgium	na	na	-43
4	Brazil	-1	-29	-45
5	Canada	14	0	-2
6	China	-23	-30	-31
	Euro Area	16	15	na
7	France	na	na	-19
8	Germany	na	na	-19
	Hong Kong SAR	25	3	na
9	India	1	16	-28
10	Indonesia	-2	-21	-6
11	Italy	na	na	-13
12	Japan	15	6	-50
13	Korea	74	-26	-35
14	Mexico	33	-6	-14
15	Netherlands	na	na	-40
16	Russia	-14	-51	-58
17	Saudi Arabia	33	-5	-13
18	Singapore	31	1	-20
19	South Africa	-5	-25	-11
20	Spain	na	na	-28
21	Sweden	-51	-30	-53
22	Switzerland	21	12	-2
23	Turkey	-7	-35	0
24	United Kingdom	-5	-12	-40
25	United States	17	-6	-28
	Legend:	Falling	Rising or Stable	

Note: Table 1 is for the purpose of making cross-country analysis. For some jurisdictions, the best indicators of cash usage are from country-level payment diary studies. See Bagnall et al., 2016; Chen et al., 2021.

Source: Author's calculation.

ratio. But there were four reversals: from a rising CIC/GDP to a falling small CIC/HC, one of which applied to the US. And, as shown in Column 3 for our cash share measure, all rising CIC/GDP ratios and rising small CIC/HC measures were reversed to falling shares of cash use using our measure.⁴ The greater the focus on where cash is used—in GDP, household consumption, or in the market for cash, the more countries are found to be reducing their relative use of cash.

More detail is available for some countries. A White Paper from the People's Bank of China (2021) reported a payment survey indicating that the value of cash payments in 2019 was only 16 percent of the total, lower than the value of cards at 23 percent and far lower than mobile payments at 59 percent. Some 46 percent of survey respondents reported using no cash at all during the survey period. This occurred at a time when the value of

⁴ The exception is for the Euro Area and Hong Kong where data was not available to compute the cash share measure.

cash in circulation (M0) rose from RMB 6.83 trillion by year-end 2016 to RMB 8.43 trillion by year-end 2020, an average annual increase of close to 6 percent. This is an example of where a narrow measure of cash use falls even as a broad measure rises.

A. Cash Share Changes Across Countries

As noted above, our cash share measure combines the value of ATM cash withdrawals, debit and credit card payments, and the value of e-money payments that substitute for cash.⁵ It reflects the share of cash in the market for cash: $CASH/(CASH + CARDS + E-MONEY)$.⁶ A clearer picture of how cash use has changed over 2012–2019 is seen in the three parts of Figure 1.

The Y-axis of each of the three parts of Figure 1 reflects the cash share level in 2012 while the level in 2019 is reflected above this year on the X-axis. To provide some idea what the cash share might be in 2022 (sans Covid), the trend over the first eight years was extended for an additional three years. The three-year projection was based on estimating an inverse logistic curve for each country using observed data over 2012–2019. The two estimated parameters generated an estimate of cash share values for the extra three years, which were combined with the observed sample. A cubic spline was applied to the total augmented sample for each country which generated all the curves shown in Figure 1.⁷ The projection is only for illustration and using a ruler would have given much the same result. The main takeaway is that the trends in the majority of cash share reductions are the result of something relatively steady and smooth over time, rather than an influence that has significant up/down variation in a country.

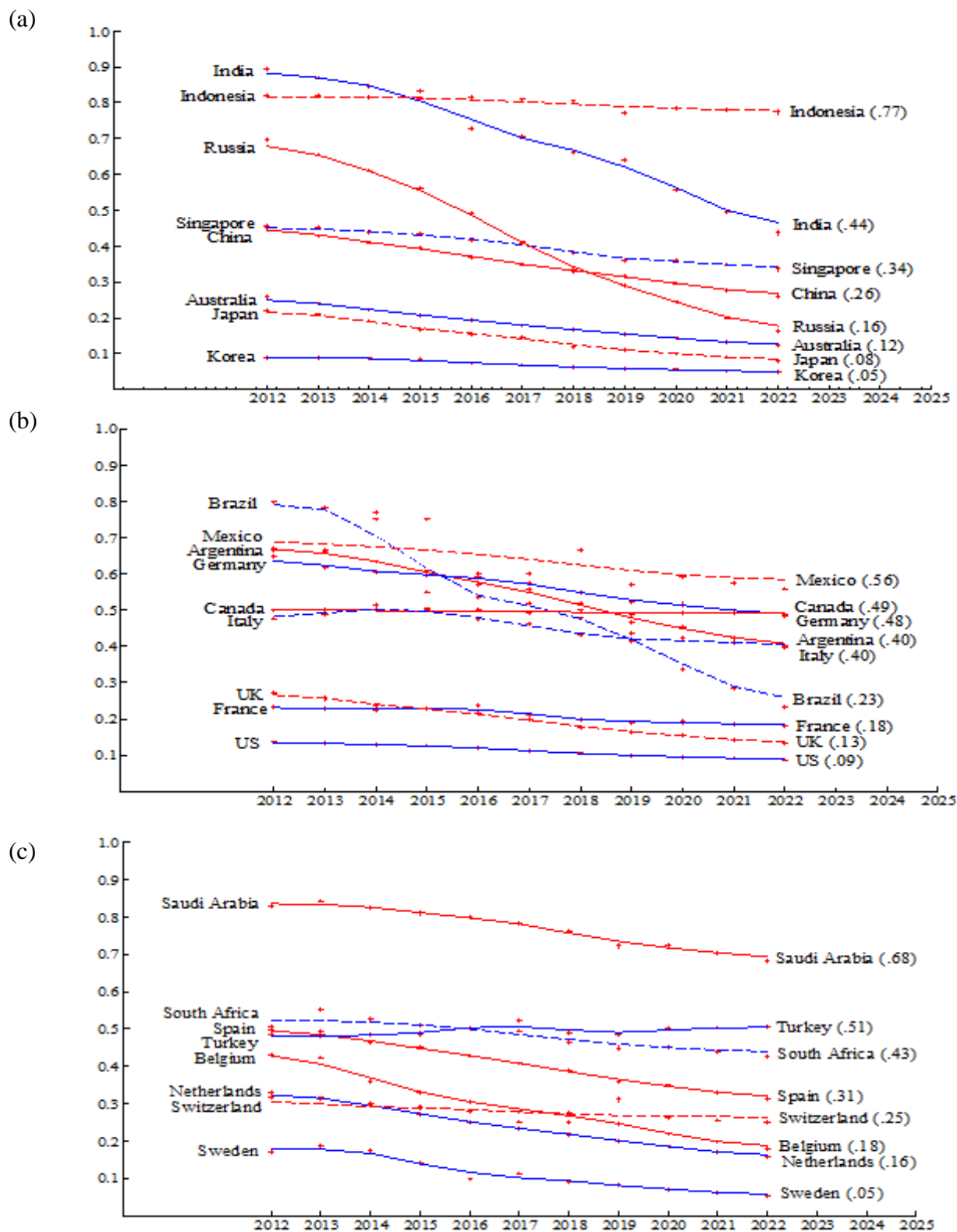
In Figure 1, three countries—Brazil, India, and Russia—had by far the largest absolute reduction in cash shares. Brazil and India both experienced a large one-time drop in their cash shares. In Brazil, the central bank also created its own Fast Payment system (called Pix) to increase competition. There was also an economic crisis that reduced GDP by 3.5 percent in 2015. Most card use in Brazil is buy-now-pay-later, and card expenditures rose by 9 percent while cash use, for those most affected by the crisis, may well have fallen. In that year, the cash share fell by 22 pp, a much larger reduction than the 1.7 pp average annual cash share reduction over 2012–2019 for all countries. In 2016, India demonetized some 86 percent of their currency, slowly issuing new notes in their place. The cash share fell by 17 pp over three years. The surprise demonetization was to drive out "black" money accumulated through corruption and tax evasion (Chodorow-Reich, et al., 2020). Russia was different. To reduce the vulnerability of Russian banks and their domestic payment system to Western economic sanctions, the central bank established and promotes their own card system (Mir). It charges a lower interchange fee and offers users monetary incentives to expand its card use and replace established card systems (The Economist, 2021).

⁵ E-money is defined by the BIS as a stored value arrangement, as where funds are stored on a card or mobile phone (like an electronic wallet). It excludes limited or single-purpose e-money accepted only by the issuer, rather than being widely accepted. The appendix notes the sources of data used in this paper.

⁶ E-money, like cash withdrawn from an ATM, will be spent over a short time period (about 1 to 2 weeks for cash from an ATM). Card values represent actual transactions. We use annual data so the value of e-money and cash from ATMs will represent transactions and only a miniscule amount will represent an unspent balance from the current year, made up for by the unspent amount from the last month of the prior year.

⁷ The estimated inverse Logistic curve was $\ln[(1 - \text{cash share})/\text{cash share}] = a + b \times \text{YEAR1}$, where $\text{YEAR1} = 2012, 2013, \dots, 2019$. The predicted cash share = $1/[\text{EXP}(a' + b' \times \text{YEAR2}) + 1.0]$, where $\text{YEAR2} = 2020, 2021, 2022$. With such a small sample, the result is obviously only approximate.

Figure 1. Cash Share by Country over 2012–2019 and Projection to 2022



Sources: BIS and author's calculations.

Only Russia is in the group of three that also experienced the greatest percentage reduction in their cash share in Column 3 of Table 1: Russia, -58 percent; Sweden, -53 percent, Japan, -50 percent. Both Sweden and Japan have already experienced a substantial reduction in their cash share and by 2019 had a relatively low cash share base ("inflating" their -50 percent reductions). Other than Brazil, India, and Russia, most other countries experienced a rather mild annual average absolute reduction in cash use over the period. In particular, Canada, France, Indonesia, Italy, Korea, South Africa, Switzerland, Turkey, and the US experienced less than a 1 pp average annual reduction in cash use.⁸

Our cash share measure is similar to a single firm market share measure in competition analysis. We believe it to be close to reflecting a one-to-one substitution of cards and e-money for cash where cash transactions are most used. However, it is not perfect. Some consumers may withdraw cash over the counter (OTC) at their bank rather than use an ATM and businesses may provide "cash-back" at the point of sale. Few countries collect this information and thus it is not included in our analysis. However, some limited information is available for 6 European countries (ECB, 2020). Based on the survey questions being asked, the available OTC data appear to be the sum of two things: OTC cash withdrawals by businesses at their financial institutions to make change plus OTC withdrawals by a bank's consumer depositors rather than using an ATM. Unfortunately, only the latter represents information we would want to use. Business use of cash to make change does not show up in the value of a transaction and thus is not comparable to the value of card transactions in our cash share measure.

If we neglect the fact that the available OTC cash data are larger than what we want (it includes business cash withdrawals OTC for making change), including it in the numerator and denominator of the cash share measure for 6 European countries results in a smaller reduction in the cash share measures than we report in Table 1 and Figure 1. For Germany and Spain, our reported reduction would be too low by, respectively, 7 and 6 pp—two countries where banking offices are quite numerous relative to the population. For Italy and France, the reduction would be too low by 2 and 1 pp, while for Belgium and Netherlands it would be too low by less than 1 pp. In sum, the reported reduction only importantly affects 2 of the 6 countries.⁹ One final data issue is that in some countries, a portion of check, giro, or credit transfer payments may actually be replacing what could otherwise be a cash transaction. However, only total values of these payment instruments are available—not the value of each instrument that may, in some countries, be classified as a possible cash substitute. Only very well-informed persons in a country would have the experience needed to make this determination as well as have the contacts needed to collect information on OTC cash withdrawals by consumers alone and cash-back at firms.

In Table 2, eight countries have a cash share ranging from 6 percent to 20 percent in 2019. They are Korea, Sweden, US, Japan, Australia, UK, France, and Netherlands. Their average reduction in cash share level is 1.2

⁸ From Table 2, Column 2.

⁹ Payments.com has published different country and regional editions of their *Global Cash Index* which approximates the value of OTC cash withdrawals in many countries, all based on limited time-series information on OTC withdrawals for a few European countries from ECB (2020) and (apparently) just one published observation for the US. We do not feel comfortable using these approximations (which were used in an earlier and less detailed analysis by Khiaonrong and Humphrey, 2019). They also seem to include business cash use for making change, which we do not want. Individual countries may develop the missing cash information.

pp a year. At this rate, it may take 5 to 17 years for the cash share measure to be close to zero.¹⁰ The more important point is that for these countries, cash substitutes have a market share of from 80 percent to 94 percent. Going forward, the share of cash substitutes will likely only rise, even as habit formation of individuals that continue to use cash may be stronger. Next, we investigate why the cash shares in Figure 1 have fallen.

Table 2. Countries Ranked by Cash Share Level in 2019, Showing Annual Percentage Point and Percent Reductions Over 2012–2019

Jurisdiction	Cash Share Level 2019 (%)	Annual Absolute Reduction (pp)	Annual Percent Reduction (%)
Korea	6	-0.5	-5.0
Sweden	8	-1.3	-7.5
United States	10	-0.5	-4.0
Japan	11	-1.6	-7.2
Australia	16	-1.5	-5.7
United Kingdom	16	-1.6	-5.8
France	19	-0.6	-2.7
Netherlands	20	-1.9	-5.7
Belgium	25	-2.7	-6.1
Russia	29	-5.8	-8.3
Switzerland	31	-0.1	-0.3
China	32	-2.0	-4.4
Singapore	36	-1.3	-2.8
Spain	36	-2.0	-3.9
Italy	41	-0.9	-1.9
Brazil	44	-5.2	-6.5
South Africa	45	-0.8	-1.6
Argentina	47	-2.9	-4.3
Turkey	49	0.0	0.0
Canada	49	-0.2	-0.3
Germany	52	-1.8	-2.8
Mexico	57	-1.4	-2.0
India	64	-3.6	-4.0
Saudi Arabia	72	-1.6	-1.9
Indonesia	77	-0.7	-0.9
Euro Area	na	na	na

Source: Author's calculations

¹⁰ The overall average percentage point reduction in our cash use measure in Table 2 is 1.7 pp a year, from (2012 cash share level minus 2019 level)/7.

Source of the Demand for Cash Versus Its Substitutes

Following earlier money demand studies, we attempt to identify the major sources of the demand for cash relative to the value of cash substitutes across countries. Specifically, what is driving the reduction in cash shares and why is the rate of change for all but a few countries relatively slow? An answer here will tell us why the cash shares in Figure 1 have fallen and how these shares may continue to change in the future if retail CBDC is not issued.

Money demand studies usually find that higher interest rates tend to reduce the demand for cash (e.g., Ashworth and Goodhart, 2020). Countries with relatively high interest rates may experience a lower demand for cash, lowering its share of cash relative to cards and e-money. These studies also include an indicator of economic activity in a country. While greater economic growth logically leads to more payments being made, by itself it is unclear why this would favor cash substitutes over cash—unless there already is a preference for one over the other and greater economic activity just reveals this a priori preference. Here economic expansion is not the driving force: it would be the a priori preference.

Such a preference would be a function of relative user prices, rewards for use, convenience in making payments, acceptance by retailers, availability of ATM and POS terminals, marketing programs, and so on—all the things that can be difficult to measure well in a regression equation. Consequently, this is not the approach taken. Instead, we specify a composite indicator of user preference for cash substitutes versus cash that is inferred from payment diary studies presented for the US and seven other countries. Payment diary studies suggest a weaker preference for cash by younger adults than for older age groups in a population, due to all those things that are difficult to measure in a single equation and to habit formation as adults age.

Two studies show a lower share of cash transactions by younger adult age groups (Yoshizawa et al., 2021; Kim, et al., 2020). Another shows that the value share of cash used by younger adults is lower than that for older adults across six additional countries (Bagnall, et. al., 2016). A third study shows fewer cash transactions and a lower value of cash spent per transaction for younger adults (Swiss National Bank, 2020).¹¹ Transaction shares or value shares by age are not levels of use. The important measure for our purpose is the actual number of cash transactions or the total value of cash spent by age group. This is the denominator of the transaction or value shares but is not reported in published payment diary studies.¹²

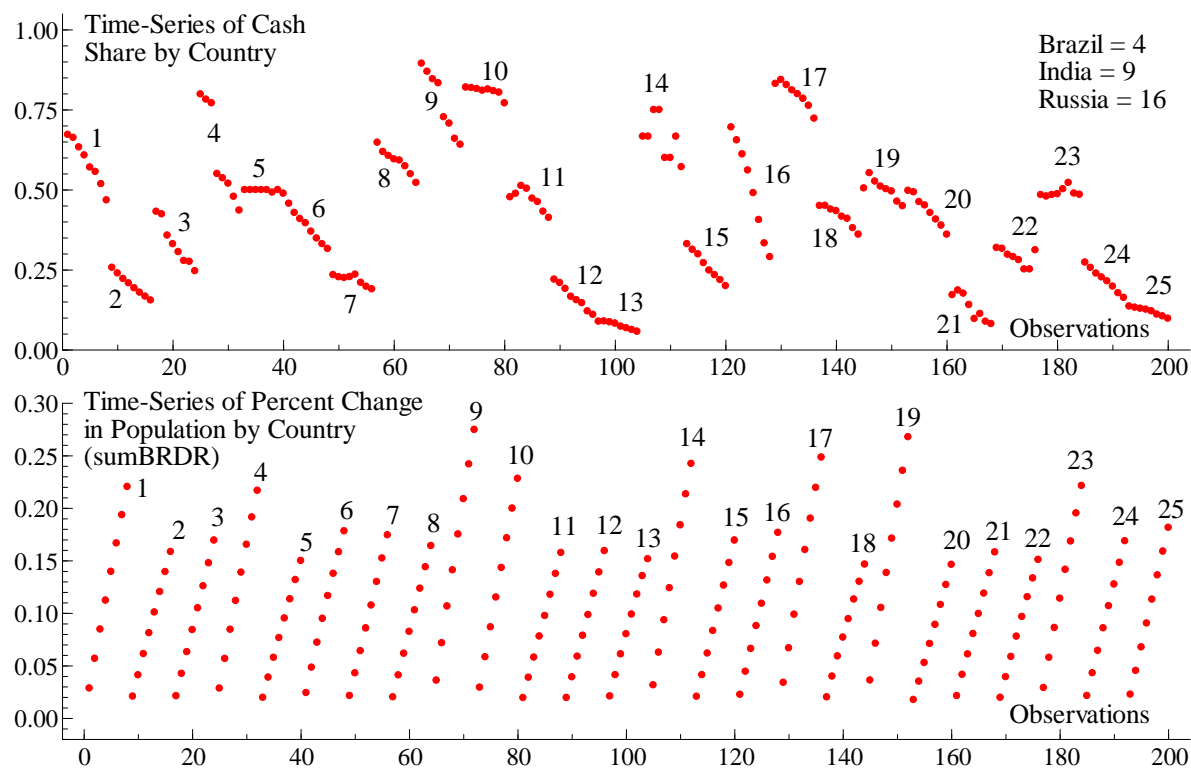
A more detailed analysis of three US payment diary studies over 2017–2019 illustrates the difference in cash use by age more clearly. Looking only at two age groups—younger adults aged 18 to 44 and older adults aged 45 and older, the total number of cash transactions for the younger group is 3,119 compared to 6,684 for the

¹¹ The eight countries covered in the three studies included Australia, Austria, Canada, France, Germany, Netherlands, Switzerland, and the US. Earlier studies by Stavins (2002) and Hayashi and Klee (2003) point in the same direction.

¹² For example, Kim, et al. (2020) report that US 18–24 year-old young adults have the highest share of cash transactions (at 33 percent) than any of the other five age groups. However, their income, from which transactions are made, is likely to be among the lowest. As the total number of cash transactions for the age group is the denominator for the cash share calculation, it is possible that a low denominator leads to a high cash share being computed. A high share of cash transactions need not roll over into a high number of cash transactions being made. The same would hold for the share of the value of cash transactions.

older group. The total value spent using cash was \$94,541 for the younger group but \$153,988 for the older group (63 percent higher). In part, this reflects the fact that the older group represents 41 percent of the US population while the younger group represents 33 percent.¹³ This suggests that one reason for the general fall in cash use observed for individual countries in Figure 1 is associated with inter-generational differences in the revealed preference for cash relative to its substitutes.¹⁴

Figure 2. Cash Share Values and Change in Population Age Structure by Country



Note: The numbers in Figure 2 represent the alphabetical order of the numbered countries in Table 1.

Sources: BIS and author's calculations.

Due to a lack of detailed data on the preference for cash across multiple age groups for our 25 countries, we form a simple indicator of this preference: the sum of a country's birth rate plus its death rate, which approximates the expected annual change in the intergenerational structure of the population and thus its preference for cash or a cash substitute. The birth rate of new younger adults born in 1995 and turning 18 in 2012 approximates the addition of new, younger adults in 2012 with a general marginal revealed preference for cash substitutes. The current death rate in 2012 approximates those for older adults aged 44 and above leaving the population who have a higher preference for cash. Those in between our indicators of annual entry

¹³ The data used to generate these figures (Federal Reserve Bank of Atlanta, 2020) were age-adjusted to the same portion of the US population.

¹⁴ Some portion of ATM cash withdrawals is surely used for illegal activities. If so, we may expect the share of cash in the market for cash to rise, but it is falling instead. Even so, rising illegal activity may mitigate the observed reduction in cash use for some countries in Figure 1.

and exit move up the line and contribute to the change in the revealed preference for cash substitutes over cash in a population.

As individuals in each age category are changing each year, the (earlier) birth rate + the (current) death rate in year 1 (BRDR1) is the change in the age structure in year 1. By year 2, the cumulative change in age structure is the sum of the change from year 1 (BRDR1) plus the change in year 2 (BRDR2), and so on for eight years of time-series observations across 25 countries in our pooled sample of 200. This variable (sumBRDR) represents the cumulative sum of the individual annual changes in the age structure of the population. As the cash share level falls for each country over time, it is consistent with a correspondingly higher proportion of younger adults in the population—both from adding new younger adults and having fewer older adults. Here the expected relationship would be negative for each country separately over time.

The bottom half of Figure 2 illustrates how this changing age structure (sumBRDR), and its associated preference for cash substitutes, has varied over time in the pooled sample of 25 countries over 2012–2019. The numbers in the figure represent the alphabetical order of the numbered countries in Table 1. As the population becomes increasingly less cash centric, we see that the share of cash—our cash share measure in the top of Figure 2—typically falls, in some countries at a faster rate than others. The large reductions in the cash shares of Brazil (number 4), India (9), and Russia (16) shown in Figure 1 are seen here as well. The time-series component of our pooled countries shows a generally negative relationship separately for each country, as expected.¹⁵ More information is obtained from the following money demand equation using pooled data displayed in Figure 2:

$$\text{CASHSHARE}_j = \beta_0 + \beta_1 \text{sumBRDR}_j + \beta_2 \text{HC}_j + \beta_3 \text{iRATE}_j + V_j \quad (1)$$

where:

- CASHSHARE = the cash share values for each of 25 countries observed over 2012-2019 (N = 200) shown in Figure 1 and the top of Figure 2;
- sumBRDR = the cumulative sum of the birth rate plus the death rate for each country over 8 years, clearly an exogeneous influence on the dependent variable;¹⁶
- HC = the local currency PPP adjusted US dollar value of household consumption in each country to reflect economic activity; and
- iRATE = the monetary policy related percent interest rate, some of which are zero or negative during this period (so logging variables in the estimating equation to obtain elasticities is not feasible).

Equation (1) is estimated using a Fixed Effects model where a dummy variable is used to control for cross-country "intercept" shifts in the panel data so that time-series effects across countries may be better locally identified. In Table 3, the Within results show that the intergenerational change in population age structure (sumBRDR) is negatively and significantly related to the variation in each country's cash share and explains a good deal of the variation of that measure. This just reflects the country-by-country times-series relationship

¹⁵ We would see the same relationship if the simple passage of time ($t = 1, 2, 3, \dots, 8$) replaced the cumulative sum of annual changes in the age structure of the population. The latter, however, has a hypothesis behind it with support from payment diary studies (although only for eight countries, not all 25).

¹⁶ The variable $\text{sumBRDR} = \text{BRDR in year 1, BRDR in year 1} + \text{BRDR in year 2, BRDR in year 1} + \text{BRDR in year 2} + \text{BRDR in year 3, and so on for 8 years for each country separately and then pooled across the 25 countries.}$

across countries illustrated in Figure 2. The effect of time-series changes in household consumption (HC) and the interest rate (iRATE) are both statistically insignificant.¹⁷ The Between result is also shown in Table 3 and the sumBRDR variable experiences statistically significant shifts between countries.¹⁸

Table 3. Pooled Regression Results, 2012–2019

Variable:	Fixed Effects (Within)		OLS on Means (Between)	
	Parameter	t-Statistic	Parameter	t-Statistic
Intercept			-.225	-1.38
Sum of Birth Rate + Death Rate	-.773	-11.94	6.28	3.92
Household Consumption	.305E-14	.34	-.155E-13	-1.26
Interest Rate	.259E-03	.33	.234E-02	.41
Adjusted R ²	.97		.46	

Source: Author's calculations

The interpretation is as follows: cash shares are falling (Figure 1; Table 1, Column 3) at a slow pace (Table 2, Column 2) and countries with the lowest cash shares generally have the smallest reductions (Table 2, Columns 1 and 2). The cumulative sum of intergenerational change in the age structure of a population (a higher value of sumBRDR) is negatively associated with a lower cash share (Figure 2 and Table 3). As noted in the Introduction discussing Section III, we do not try to determine the importance of the many separate influences that can affect the choice of cash versus its substitutes across countries. That involves ranking subjective answers to surveys of what payment instruments people use and why (c.f., Koulayev, et al, 2016; Stavins, 2002 and 2017, and others). Instead we use a summary measure reflected in payment diary studies indicating a marginal revealed preference of younger adults for cash substitutes compared to the marginal preference for cash by older adults. The end result should be the same since the unspecified separate influences on payment choice generate the revealed preference seen in payment diary studies.

Cost Incentives to Adopt Retail CBDC

From the above analysis, it appears that further reductions in cash use across countries are likely to be slow and relatively predictable. This could change with the introduction of CBDC.¹⁹ While CBDC is expected to have attributes that are quite similar to cash as well as cards, for most countries (20 out of 25, Table 2, Column 1) the share of cards dominates that for cash and thus is likely to be more affected by CBDC. In addition, countries where cash use is already very low should find that the introduction of CBDC would likely also have a greater effect on cards than cash. We see this already in Table 2 and it was noted in the Introduction. Countries with a very low cash share in 2019 also had a relatively small percentage point reduction in their cash share

¹⁷ Some would add the number of ATM and POS terminals to the equation. However, the number of terminals is often used as a proxy for likely "use" or "demand" for cash or cards (raising a contemporaneous correlation issue). For illustration only, both were added to (1) and both were statistically significant (not shown). The added explanatory power was 1 pp and the value of the sumBRDR coefficient fell slightly (to -.691), likely due to collinearity with the added terminal data. This suggests that ATM terminals reflect ATM cash withdrawals and the same for POS terminals for card use. Consequently, they are not an exogenous influence on the dependent variable.

¹⁸ The Hausman test did not support the random effects model.

¹⁹ This is an assumption as CBDC designs are evolving and still emergent. The design choices and features of CBDC (including, for example, the extent of remuneration, application of limits and/or level of anonymity) may influence its attractiveness and demand.

over 2012–2019. Many countries with a higher cash share had a relatively larger reduction in their shares over the same period. That is, the substitution process away from cash generally slows down as the cash share itself becomes lower and lower.²⁰

CBDC adoption would likely grow relative to cash or cards going forward if CBDC improved on the attributes of these two established instruments, and/or offered other appealing attributes. We focus on the former. Being similar to a fast debit card with P2P functionality, may not be enough. In this regard, central banks have identified many reasons for and benefits from possibly issuing retail CBDC. This would include providing countervailing market power to current card schemes, possibly lowering payment costs, making payments faster, expanding financial inclusion, providing a way to make payments when other systems may be disrupted, and limiting systemic risk to financial markets and the economy from non-bank privately-issued money. These considerations and others drive decisions on why and how central banks may decide to supply retail CBDC.

This addresses the supply side of the retail CBDC issue and are nicely outlined in Bank for International Settlements (2021). The list is comprehensive and would largely duplicate the benefits from card use except for three transaction cost/fee considerations that can importantly affect the benefits obtained from CBDC compared to cards. These include user fees, merchant interchange fees, and merchant working capital costs. In our view, these will be the main determining incentives for individuals and merchants to adopt and use CBDC and thus the main influence on the future course of the cash share measures in Figure 1.

A. Incentives for the Payment User

User Fees/Convenience. Cash is inconvenient to obtain but is typically free, often being covered in a bank's monthly account maintenance fee or minimum balance requirement whether or not cash is withdrawn. There can be a charge if cash is withdrawn using another bank's ATM or if use of a depositor's own bank ATMs exceeds some monthly limit. Cards do not typically have a user fee but FinTech firms (such as PayPal, Square, Stripe) have innovated on existing card infrastructures to improve convenience for card users, facilitate some aspect of e-commerce and charge a fee for the extra service. By not charging a user fee, card firms turn a fundamental tenet of efficient resource allocation on its head. Usually, the efficient allocation of resources requires a user to value the benefits with the costs. With cards, this does not occur. The retailer, not the user, pays the price—an interchange fee.²¹

²⁰ This just reflects an inverse logistic curve or a reverse Gompertz S-curve. A Gompertz S-curve for new innovations (or for the growth of cash substitutes) would likely follow a growth path that is at first increasing at an increasing rate, reaches an inflection point, and thereafter increases at a decreasing rate. Turning that around, the level of cash use reflected in our cash share measure would tend to initially fall at an increasing rate, reach an inflection point, and continue to fall but at a decreasing rate until cash use is zero or reaches a stable minimum level of use. This does not apply to all of our countries but generally is the case.

²¹ It is not all one way. By accepting credit cards, a retailer may increase sales as users receive a product immediately while paying for it later. It differs from the stronger budgetary control of paying by cash, debit card, check, giro, or mobile phone. And, historically, cards did solve a serious payment problem in countries that relied on checks (a debit instrument) for payment. Accepting a check was, and still is, a risk to the receiver. The check may be drawn on an account with insufficient funds or may be forged. A receiver then faces the task of finding the check writer and collect the funds a second time or writing it off as a loss. While fraudulent use of a card does exist as well, card firms spend a lot of effort minimizing this problem for both the receiver and the user.

Retail CBDC may have an explicit user fee, no fee at all, or (perhaps less likely) may even pay interest. This may differ across countries. While cash does not have an explicit fee, the opportunity cost of holding cash is the interest paid on deposits. The ability to charge an interchange fee to retailers or billers, rather than the user of cards, would be viewed as an incentive for users to favor a card for payments if CBDC contains a user fee. This incentive goes away if CBDC, like cash, has no explicit user fee.

Possible Loss/Fraud. All types of payments have one of these problems. Cash and stored value e-money payment instruments face the possibility of loss while fraud (via cyber means or otherwise) can affect users of cash, cards, e-money, or CBDC. Fraud largely relies on users to make a mistake, even though suppliers of all payment services go to great lengths to prevent this through currency design for cash and tokenization, pin numbers, plus artificial intelligence for cards. The latter would likely also be applied to e-money and CBDC.

Universal Acceptance/Privacy/Anonymity. At present, all current cash and cash substitute payment instruments basically have near universal acceptance, and one would expect the same for CBDC. Anonymity applies to cash. While purchase information from card use seems to be anonymous, it clearly is not as it is heavily used in targeted advertising. In any case, some CBDC transactions could be made anonymous by simply placing a restriction on the value of CBDC funds stored on a card or mobile phone for a sub-group of users.

B. Incentives for the Payment Receiver

Cost of Accepting Payments. Substantial costs are incurred by retailers and billers to accept cash (internal handling/monitoring, vault expense, insurance, armored couriers) as well as cards and e-money (interchange fees, terminal and communication link expense). The benefits and costs for CBDC would likely be similar to that for cards, but possibly without interchange fees. Past studies of these expenses usually show that credit card costs exceed the costs of accepting cash but have been mixed for debit cards (c.f., Food Marketing Institute, 1998; Brits and Winder, 2005; Hayashi, 2021).

In some countries it is possible for a receiver of a card payment to charge the user a "convenience fee" or a surcharge which offsets the interchange fee paid by the receiver (or even to provide a discount for paying in cash). Even so, when these alternatives are available only a few receivers may apply them, likely due to a fear of lost sales if only they, and not others, apply them as well. Organized action by a group of payment receivers to apply these alternatives all at the same time would usually be restricted by antitrust laws.²² Overall, the cost to merchants of interchange fees would make them amenable to accepting a payment instrument that does not have such fees, which may be the situation for CBDC.²³

²² There have been exceptions. In Norway, banks pointed out to authorities the potential for socially beneficial reductions in payment costs if checks were priced, inducing users to switch to cheaper electronic payments. A date was set whereby banks that wanted to price checks could voluntarily do so. Not all did so at the time. But seeing that pricing did not affect deposit market shares, others subsequently adopted pricing as well (Humphrey, Kim, and Vale, 2001).

²³ Interchange fees have been lowered in Europe and elsewhere. Before 2018, European firms could surcharge card users. Although no longer possible in Europe, surcharging is now possible in some US states as well as in Australia. Hayashi and Maniff (2021) have some information on card interchange fees and surcharging across countries.

Quick Access to Funds Received. Immediate access to funds is not currently available for receivers of cash, cards, or e-money payments. With CBDC, funds received today would be final funds immediately deposited in the receiving firm's deposit account and available for immediate reuse.²⁴ Many firms have revolving bank credit lines to cover working capital needs. Immediate access to funds received, one or two days sooner, can reduce working capital costs.²⁵

In contrast, reuse of daily cash receipts is possible with a one or two-day lag as it has to be deposited in a financial institution account before it can be reused for payments. In practice, cash is one-day or two-day money. For cards, the time lag after receipt to reuse can be from one to three days. The same would hold for e-money backed by a card. Quick access to funds received may favor Fast Payments or retail CBDC over cash, cards, and e-money, especially when there is an opportunity to reduce card use and save receivers from paying interchange fees.

To illustrate the possible incentive to adopt CBDC, assume that all US retail sales in 2018 (\$5.27 trillion) was paid for by cards with an average interchange fee (and other expenses) of 1.5 percent of the value of a transaction. Receivers would have paid \$79 billion in fees but would still have to wait one to three days to use the sales revenues. If all retail sales were replaced by retail CBDC (or Fast Payments) receivers may save the card fees and, in addition, save one to three days waiting to have access to and use of their sales revenues. With immediate availability of sales revenues, receiver working capital costs could be reduced by \$505 million if one day is saved.²⁶

A user fee for retail CBDC (or Fast Payments) may be charged in the US (due to the Monetary Control Act of 1980) and may be charged in other countries as well to recover costs. Even so, there would seem to be ample incentive for receivers to find a way of enticing retail customers to purchase items using retail CBDC. The full advantage of saving the card interchange fee, however, may be weaker for countries that already allow payment receivers to surcharge for card use.²⁷

The incentive may be stronger if CBDC, like cash, is not priced at all. This may be the situation for a digital Euro (Bindseil, 2020) and perhaps in other countries as well. One possible reason for this would be that providing CBDC incurs much the same expense as providing cash in terms of the costs of printing, transporting, storing, and replacing currency. If so, payment receivers may respond, if legally permitted to do so, by offering cash-back or a price discount to users of CBDC to reduce their card interchange fees. As a

²⁴ Immediate availability of payments for reuse can also occur for same-day ACH, certain giro payments, wire transfers, as well as 24/7 Fast Payment schemes in Europe, the UK, and the planned FedNow payment initiative in the US. Fast Payment service providers also exist in other countries (c.f., Bech and Hancock, 2020).

²⁵ Legislation allowing checks in the US to be collected electronically, rather than physically, led firms to collect \$14 trillion in remittance checks at least one day faster, saving \$1.37 billion in business working capital interest costs a year in 2010 but less in following years as check use is declining about 5 percent a year (Humphrey and Hunt, 2013).

²⁶ This is from $\$5.27 \text{ trillion} \times 1/365 \times .0350$, where the last term represents a short-term bank borrowing rate.

²⁷ Two of the three incentives noted here are also briefly noted in Bank for International Settlements (2021), page 6. For example, "Consumers' utility is affected mostly by the transaction cost of the payment instrument ... there should be little or no (explicit) cost to the CBDC end user" and "Merchants are interested in new payment instruments that ... reduces their costs of transacting relative to payment methods currently accepted." We add that merchants may also reduce their working capital costs.

possible response, card firms may attempt to lower their interchange fees, raising prices on other banking services to make up for lost revenues.

This occurred in the U.S. when legislation required that debit card interchange fees be reduced by close to 50 percent. Card firms could also seek to provide immediate availability of funds to receivers by contributing funds to a jointly-owned special purpose deposit account that could settle transactions immediately or with a slight delay inside/outside of the central bank.²⁸ Either response would reduce card firms' net revenues and may or may not occur. Perhaps large card firms and other payment suppliers will instead focus on expanding their current Fast Payment services which, for certain payment applications, appear to have many of the same attributes or incentives for user and merchant use as just discussed for retail CBDC.²⁹

Summary

We document the falling use of cash for payments across 25 countries over 2012–2019, showing its total decline over this period as well as its annual average percentage point and percent reduction. Our measure concerns the share of the value of cash used (cash withdrawn from ATMs) relative to the market for cash, consisting of the value of cash, cards, and e-money (a stored value alternative). Data limitations prevent the inclusion of possible additional cash substitutes in the analysis. Our measure is compared to a standard measure of cash use (the ratio of all currency and coin in domestic circulation to the level of GDP) and a more focused measure of small value currency and coin as a ratio to household consumption.

Using our indicator of cash use, all but one of 25 countries covered (Turkey) experienced a decline in relative cash use, with some reductions being quite large due to special circumstances (for Brazil, India, and Russia). Reduced use of cash in a country indicates that cash substitutes are favored over cash and this may have implications for the demand for retail CBDC (if issued). Specifically, there are countries with an already low level of cash use. In eight countries, cash substitutes make up 80 to 94 percent of the payment market where cash is primarily used, and habit formation may hinder a shift to a new payment arrangement.

In trying to explain why the share of cash is generally falling across countries, a money demand equation is estimated. Instead of looking at the demand for cash or cash substitutes separately, we attempt to determine why cash as a share of cash plus cash substitutes is falling. Revealed preference for one instrument over the other, implied in payment diary studies for eight countries, and in a reworking of US payment diary information for three years, is tied to changes in the age structure of individuals in a country's population. It could also work through differences in economic activity across countries, but this turned out to be insignificant, as did interest rates across countries. The apparent revealed preference of younger adults for cash substitutes combined with the apparent preference of older adults for cash appears to be an important determinant of cash share variation across our pooled sample of 25 countries. This is consistent with the recent generally slow and relatively predictable annual average reduction of 1.7 pp in the share of cash use across countries.

²⁸ This occurs with the settlement arrangement adopted by The Clearing House to settle interbank transactions for their Real Time Payments service for paying business invoices.

²⁹ Payment suppliers and card firms currently own and supply Fast Payment services in different countries (Bank for International Settlements, 2017).

The observed slow reduction in cash use across countries may speed up somewhat if retail CBDC is offered by central banks. However, the main effect is likely to be on the share of current cash substitutes (primarily cards) as the share of these substitutes dominates the share of cash in our measure for 20 of our 25 countries. As well, for countries that already have a low level of cash use, further reductions tend to be less than where cash use is still high, indicating a slower substitution process. While central banks have largely focused on reasons for supplying retail CBDC and how this may be achieved, our interest concerns the demand side of this issue and the incentives for the adoption of CBDC. We expect that central banks will likely design their CBDC services to provide most or all the benefits currently provided by the main cash substitutes, and potentially additional benefits. In our view, some additional incentives dealing with transactions cost will importantly influence the adoption and use CBDC and largely determine of the future use of cash and card use across countries.

Treating CBDC like cash, without a user fee, would be one incentive as this would mirror the current situation for cards. The possibility for merchants to save card fees by accepting CBDC would be another incentive. And, as CBDC would be final payment and available in a receiver's deposit account for immediate reuse through a bank, one or multiple days of working capital cost could be saved. In a more dynamic setting, card schemes may seek to mitigate these CBDC incentives by modifying their interchange fees and providing immediate access to merchant revenues from card sales and make up the revenue loss elsewhere. Alternatively, those card firms that already own and supply Fast Payment services may choose instead to rely on these newer payment services going forward. In some countries this can involve P2P mobile payments at zero cost, as well as P2B POS transactions and B2B invoice payments, both for a fee paid for by the receiver.

We take as given that CBDC will be structured to largely match user and merchant benefits associated with card use in terms of convenience, speed of payment, fraud control, and other desirable payment attributes. We then focus on other possible benefits associated with CBDC that may promote its adoption. These incentives are related to transaction fees or costs, such as user fees, merchant interchange fees, and merchant working capital costs.

Appendix: Data Sources

The data used in the study were collected from public sources, including from the Bank for International Settlements, European Central Bank, International Monetary Fund, and World Bank. During the data collection work, publicly available statistics were available from 2012 to 2019. For payment statistics, the methodology of the statistics on payments and financial market infrastructures in the CPMI countries (Red Book statistics) are used as guidance.

Data	Sources
ATM cash withdrawal	Bank for International Settlements European Central Bank
Bank notes in circulation	Bank for International Settlements
Birth rate and death rate	World Bank, World Development Indicators
Card payments	Bank for International Settlements European Central Bank
Currency in circulation	International Monetary Fund, International Financial Statistics
Electronic money	Bank for International Settlements European Central Bank
Gross domestic product	International Monetary Fund, International Financial Statistics
Household consumption	International Monetary Fund, International Financial Statistics
Interest rates	International Monetary Fund, International Financial Statistics

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