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LESS-CASH OR MORE-CASH? DETERMINANTS AND TRENDS OF CURRENCY IN CIRCULATION IN A PANEL OF 17 ECONOMIES

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Less-Cash or More-Cash? Determinants and Trends of Currency in Circulation in a Panel of 17 Economies

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Abstract:
Digital payments are growing rapidly, and the use of cash seems to be declining, at least in advanced economies in Europe and the U.S. However, the literature on payment systems provides an interesting perspective- cash, or currency, when measured as a percentage of the gross domestic product, has not been falling as clearly as might be intuited. Contrarily, many economies face an increase in currency in circulation rates. This paper discusses this topic in literature and explores the determinants of currency in circulation in a panel of 17 countries between 2001-2022 and whether determinants from prior literature are also significant across a group of heterogeneous countries. Interest rates are found to affect the demand for cash significantly and negatively, while tax revenues have a significantly positive impact. Some measures of financial development are also considered but are found to not have any strong explanatory power. Country fixed effects regression analysis suggests that determining what type of economies may have higher or lower currency in circulation is a complex matter requiring more detailed investigation.

JEL: E12, E41, E50, E51
Keywords: Currency in circulation, Monetary demand, Panel data, Fixed-effects regression, Interest rates, tax revenue

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1. Introduction

Boeschoten and Fase (1989) pioneered research into payment systems and behaviour. The choice of payment method is determined by various factors affecting various stakeholders. One motivator for this research has been the extensive financial innovation in payment systems, particularly the digitalization of payment methods, witnessed widely in the move from cash-based transactions to cheques and, most recently, to cards and contactless payments. However, despite the popularity of non-cash payments and various government's push towards less cash societies (LCS), cash has persisted. Arguably, cash has even flourished. According to Esselink and Hernandez (2017), 79% of the total number of payments and 54% of the total value of payments at point-of-service (PoS) terminals across the Euro area were made using cash.

The Global Payments Survey of the Bank of International Settlements showed a clear trend of increasing demand for cash per capita in developed economies like the United States and Japan. A similar trend is observed in less developed but advanced European economies like the Czech Republic, Bulgaria, Poland, and Romania. Meanwhile, digital payments have been increasing even faster in the same economies. The contradiction in these statistics is evident: why does the demand (and supply, as measured by currency in circulation) for cash keep increasing despite the strong growth of digital payments? The two notable exceptions to this rule are Norway and Sweden, both of which have seen falling levels of currency in circulation (CIC) and a simultaneous trend towards digital payments adoption.

One reason for the renewed interest in the cash versus digital payments research has been the recent COVID-19 crisis, which raised questions about infectious transmissions via physical payments, particularly cash (Auer, Cornelli, and Frost, 2020). The ECB (2020) conducted an IMPACT study and found, using microdata, that 40% of surveyed people reduced their cash usage, with 38% claiming that this behavior was motivated by the risk of contamination from handling banknotes and coins. Similar results were uncovered in Canada, Denmark, and the U.S. through central bank surveys (Chen et al., 2020; Jonker et al., 2022 and Kim et al., 2020). Similarly, investigation into the adoption of cashless payment methods, using data from retail payment systems and national payment schemes, found increased penetration of cashless payments even when overall consumption decreased (Kraenzlin et al., 2020 and; Ardizzi et al., 2020).

A shift towards less cash economies would also have implications for financial stability and monetary policy effectiveness. Banks and other financial institutions would see reduced operating expenses since processing paper-based payments is up to two or three times more expensive than digital payments (Humphrey et al., 2013). This is a consequence of the economies of scale enjoyed by banks from establishing infrastructure to process digital payments. It is also easier for banks to establish branches that simply do not process physical money (or to even phase out these services from current branches). Sweden is an example of such an economy, where 60% of bank branches became cashless as early as 2016, which is expected to further reduce cash usage (Chen et al., 2020). However, such steps would suggest a reduction in the catalogue of services historically offered by commercial banks, of which payment services have been a core operation (Rambure and Nacamuli, 2008). While the original revenue model of banks derived from earning interest spreads on deposits and money lent, over time, the model has evolved to include non-interest income, mainly from payment processing and clearing services (Radecki, 1999). This would be threatened in the case of a complete shift to cashless transactions and would need to be replaced by alternative revenue sources for banks. It is not difficult to envision then that the cost of digital payments may increase to account for the lost revenue from processing physical payments.

Overall, the stylized facts arising from the literature assert that demand for cash, whether as a medium of exchange storage of value or a hedge against financial uncertainties, is not likely to

decline despite the rise of alternative payment methods. Further, cash demand is likely to persist for various reasons- from switching costs to shadow economy transactions. It also seems that cash usage is an essential business for commercial banks. The question then becomes about the policy makers' choice to support or disavow the use of cash. The reasons for making this decision may be varied, from the reduction of corruption to a push towards digital payments. Regardless of the motivation, a clearer understanding of the determinants of persistent cash demand and supply is required. This will enable policy makers to take better informed judgement and avoid mishaps like India's relatively unsuccessful push towards increased digitization of payments through demonetisation (Govindaraj and Kavitha, 2018).

The motivation of this paper is to investigate the impact of the most-oft researched regressor (interest rate) on currency in circulation, in a panel of heterogenous countries across the world. The idea being to investigate whether the significant effect on cash demand is universal enough to transverse geographically and economically diverse countries. Further, the less investigated variable of national tax revenues as proposed by Rogoff and Scazzero (2016) as the rationale for its inclusion is considered to be economically robust and worthy of further investigation. Further, the country fixed effects are analysed to conclude whether certain types of countries tend towards higher currency in circulation, or whether there are some high-level categories which can be created to form expectations about currency in circulation trends. The 17 countries were chosen for the diversity in their institutional and economic conditions and their geographical differences. This includes the U.S., some European countries that have not adopted the Euro standard, the Euro region as a single region, and developing countries like Brazil, Russia, India, and China. If the relationship between the independent and dependent variables holds across such varied economies, then we may conclude that they will hold universally.

This paper is divided into four sections. The following section briefly reviews the literature on the movement away from cash and an increasing share of digital payments as a proportion of all payments globally. The caveat of an increasing currency-in-circulation (CIC) rate as a percentage of GDP is also examined. Section (iii) describes the methodology chosen to analyse the determinants of CIC and to further investigate the reasons for increasing CIC in the Czech Republic and the Euro area. An overview of the data gathered, sources used, and summary statistics are also presented in this section. Section (iv) outlines the key results obtained from econometric analysis and a discussion of the implications, particularly for policy decisions. The final section elucidates the key findings and limitations of this paper and how these will inform the next stages of research.

2. Literature Review

The money demand theory explores factors that influence individuals, households, and firms to hold a portion of their total wealth in the form of money, alongside other assets. Historically, there have been two critical economic schools of thought on money demand- Keynesian and classical theories. The Keynesian perspective highlights three critical motives for holding money: the transaction, precaution, and speculative motivations (Bitrus, 2011). The transaction motivation describes the desire (or necessity) to hold money for personal and business transactions in post-barter economies; an individual or business must buy and sell various goods and services, and, therefore settle those transactions using money. Keynes defined money demand as a function of income, emphasizing that the higher the income in an economy, the more money is demanded to conclude transactions, thus increasing the demand for money.

Conversely, the higher the income in an economy, the higher the expectation of money may be required in unexpected economic shocks. Therefore, the exact definition of money demand holds for the precautionary motive for holding money. The speculative motive for money demand and the liquidity preference theory of Keynes (1936) emphasized the importance of interest rates in determining monetary demand- If individuals expect interest rates to rise in the future, they will have a greater demand for money in the present to capitalize on the higher interest rates through investment.

Under Friedman's theory of money, individuals may hold money in the form of bonds, cash, equity, and commodities (Jhinghan, 2004). This follows the assumption that bonds and equity are perfect substitutes with equivalent rates of return. Here, the demand for real money is positively affected by real income and negatively by the nominal interest rate. Therefore, per Friedman, individuals and firms will hold more money as income increases, in agreement with Keynes (1936). Meanwhile, an increase in interest rates would signify an increased opportunity cost of holding money, leading to falling money demand. Inflation negatively impacts money demand, as Friedman suggests that expected inflation, i.e., an increase in general price levels in the future, leads to increased consumption in the present, thus reducing demand for money (since holding money and expenditure on goods are considered substitutes). The demand for digital payments depends on several factors, including the cost of access, income, and tastes (Sukirno, 2009). This is similar to the general demand theory for goods and services in microeconomics. Reducing the money supply (M1) can motivate individuals to switch towards electronic payment methods (Hidayati et al., 2006).

Individuals' payment choices may be based on perceived ease of use, security of transactions, ease of use of particular methods, and cost (Schuh and Stavins, 2016). Unlike choosing between everyday products, the choice of method for monetary decisions may entail privacy and trust related concerns (Png and Tan, 2020), similar to the choice of digital software and bank accounts. The cost of transacting using certain payment systems (Arango-Arango et al, 2018) may outweigh the incentives offered by the payment service providers (PSPs) (Simon, Smith and West, 2010). Finally, businesses may also create steering mechanisms to motivate the use of certain payment methods to maximize their own profits (Arango et al, 2015).

Recently, most of the research into payment methods are conducted by various central banks using the payment diaries method of data collection. De Nederlandsche Bank, since 2010, carries out an annual survey to study consumer payment patterns using a consumer payment diary. The U.S. Fed has been applying similar surveys since 2008 (Foster et al, 2020) and have highlighted that the proportion of total retail transactions conducted using cash decreased from 30% in 2009 to 22% in 2019. The European Central Bank (ECB) conducted a study of payment choices across the Euro area in 2019 (ECB, 2020). They found that cash has been declining as a percentage of total retail payments, from 79% in 2016 to 73% in 2019.

Money demand literature has historically found a positive effect of income on money demand and a negative impact of interest rate on various monetary aggregates, as surmised by Knell and Stix (2006). When investigating cash demand or other narrower forms of money like M1 supply, research has also found interesting explanations for money demand in the form of financial innovations and the shadow economy (Herwartz et al. 2016). Fung et al (2014) reviewed microdata via a payments survey administered to Canadian households in 2009 and found that innovations like contactless payment cards decreased both the volume and value of cash payments as a share of total payments. However, Chen et al (2017) accounted for latent heterogeneity between households and used three years of data to find no significant impact of the introduction of contactless cards on cash usage in Canadian households. This is an

interesting result as financial innovations like contactless payments and ease of access to such innovations would be expected to be a clear driver towards a less cash society (LCS), especially in developed economies.

Perhaps less surprisingly, Fujiki and Tanaka (2009) using data from a survey of Japanese households do not find cash balances to decrease in response to the introduction of electronic money. Attanasio et al. (2002) investigated the impact of financial innovation (proxied using ability to make ATM cash withdrawals) on cash demand using a generalized Baumol-Tobin formulation. They found that households with individuals with access to ATM cards demonstrated higher interest rate elasticity. This finding was supported by Lippi and Secchi (2009) who highlighted that cash holdings decreased as the ability to withdraw cash became more accessible over time, with rising concentrations of ATMs and bank branches.

A whole strand of payment systems literature is dedicated to investigating and predicting the recent move towards cashless retail payments, which are typically defined as a payment made to non-monetary financial institutions (MFIs) (Cronin and McGuinness, 2010). The study of payment choices, whether through cash or non-cash methods, is critical given that the cost of conducting retail payments is up to 1% of the GDP in the Euro area (ECB, 2012). The literature discussed so far assumes substitutability between payment methods, both physical and digital and there is a relative lack of investigation of the level of replaceability between various payments even in the case of easy access to all possible payment methods. Deeper investigation of this substitutability may reveal critical lessons for policy makers and help researchers to better understand the factors that drive the development of certain financial innovations and their adoption.

Let us assume a developed economy with the whole array of payments options available to people who can access them freely. An intuitive explanation of choice of payment method is based on simple choice theory- payers want to choose the lowest cost method for making (accepting) payments. Currently, most bank accounts and digital payments options like plastic cards are more or less free of cost and business owners pay some charges for using payment acceptance services or business accounts. These charges vary- they may be minimal or significant, depending on various factors like the country of operation, the financial service provider, the financial infrastructure of the economy, amongst other things. However, these charges are not seen by thc customer when making the decision about their chosen method of payment. Then it is perplexing to think why the demand for cash has not shrunk to expectation, especially in advanced economies like Switzerland (Assenmacher et al., 2019). This indicates that either there are alternative reasons for holding cash or there is a significant switching cost which may be a one-time financial cost or simply psychological torpor. As stated by Humphrey (2010), dependence on specific payment instruments likely arise from “historical accidents”.

It is critical for central banks and policy makers to uncover the dynamics of payment systems, particularly when many governments globally are actively pushing for digitization of payment systems, particularly in developing economies. Buku and Meredith (2013) and Donovan (2012) suggested that an increase in electronic payment systems engenders efficiency gains in the overall payments systems of economies and improves financial inclusion, particularly in developing countries. Rogoff (2014,2016) argued that policy interventions to reduce the use of cash (or at least large denominations) can reduce shadow economy activities like drug trade, money laundering and tax evasion. This recommendation relies on the historic expectation that the shadow economy is mainly characterized by cash transactions (Gordon, 1990). In agreement with Rogoff (2016), Zhang and Lagos. (2019) found increased cashless payments to be linked to reduce the size of the shadow economy. Similarly, Hondroyiannis and Papoikonomou (2020) highlighted that increased card-based payments led to higher VAT

revenues in the Euro area. This finding also evidenced the shrinking of the shadow economy as a result of growing cashless payments, since the non-taxability of money is a distinguishing factor in shadow economy activities. Immordino and Russo (2018) further supported the notion that cashless payments contributed to cutting tax evasion.

Before delving into the substitutability of different payment methods, literature also finds different relationships between cash demand and its determinants based on the denomination in circulation. Assenmacher et al (2019) found for Swiss Francs, that the demand for large denomination notes responds to changes in interest rates and economic activity/income. However, they found no evidence that digital payment facilities led to a decrease in cash holdings. Bech et al. (2018) highlighted more recently that the data shows an increase in currency demand in developing and developed countries, without investigating the impact of digital payment systems. Amromin and Chakravorti (2009) disaggregated money demand into large and small denominations in a sample of 13 OECD countries. They found that demand for small denominations falls as digital payments become available. Meanwhile, they found no effect of digital payment methods on demand for large denominations.

Rogoff and Scazzero (2016) continue the idea of separating demand effects on large and small denominations in a large panel dataset of 54 developing and developed countries. They consider traditional macroeconomic variables like income and interest rates and expand them to include modern variables for payments digitalization like ATM availability and EFTPOS networks' depth. Their dataset extends from the 1990s to 2014, so it is less able to calculate the impact of the Covid crisis on cash holding decisions. Importantly, theirs is one of the few analyses which includes both developing and developed countries together. They consider two key macroeconomic variables in their study- interest rates and tax/GDP ratio and find both to be key statistically significant in explaining CIC as a percentage of GDP and large denominations as a percentage of GDP. They do not find them to be explain low denominations as a percentage of GDP. They conclude that the transaction motive for cash is decreasing steadily across economies. However, private demand for cash has been increasing, which suggests that the motive is more likely to be hoarding, in line with the precautionary motive. They suggest that in the face of rising interest rates, hoarding demand would be stickier than transaction demand.

3. Data and Methodology

Following the methodology of Rogoff and Scazzero (2016), an initial panel dataset of 20 countries is created for the present research. This dataset includes developed economies like Japan, the United States and various countries from Europe which are not part of the Euro area. The Euro area is included as a separate entity, along with emerging economies like Brazil, India, China, Russia and Mexico. The key motivation is to examine the money demand determinants in a variety of countries as prior studies typically consider only the Euro region and other developed economies and exclude smaller currency areas/countries. It would be interesting to explore whether the typical macroeconomic regressors show the same trends in a panel with heterogenous countries.

The analysis is divided into two key stages. The first simply calculates the currency in circulation (CIC) as a percentage of nominal GDP for the selected countries. The second stage applies the baseline regression following the formulation of Rogoff and Scazzero (2016) who use the tax/GDP ratio as one of the key regressors, which is unusual in the literature. The literature is relatively unclear on the choice of long-term or short-term interest rate as an explanatory variable for cash demand. There is no specific pattern, and the choice of the interest rate variable seems to be ad-hoc. Interest rates have varied significantly in the past

half decade, including large differentials between short term and long-term rates. For instance, the one-month risk-free rate for Czech (1M PRIBOR) was 0.31% and the one-year rate was (1Y PRIBOR) was 0.49%. However, the same rates were 7.11% and 7.28% respectively on at year end 2022. Therefore, two different types of interest rates are used in the present study- the 3-month risk free interest rate, proxied using the 3M interbank borrowing rates and the real interest rate which takes into account the inflation level in the economy. The latter is included to account for central banks' ability to influence money demand through various policy tools which affect both interest rates and inflation levels in the economy. Given that most other interest rates should, at least in theory, be influenced by the policy rate, it should have some effect like the other interest rate variables. Interest rates are expected to have a negative association with cash demand, as people are likely to prefer holding the more liquid cash in a low interest environment. A variable for inflation proxied using the change in CPI rates is also included. Since inflation erodes the value of money, particularly cash (which is earning no interest, to counteract the impact of inflation), it is expected to cause a decrease in the demand for cash due to the opportunity cost effect. Meanwhile, tax revenues are also expected to have a negative effect on cash demand if the demand for cash is indeed linked to shadow economy transactions.

$$Cash_{it} = \beta 0 + \beta 1\ TaxGDP_{it} + \beta 2\ Interest_{it} + \varepsilon_{it} \qquad \text{(i)}$$

where Cash represents the level of cash in circulation in the economy (sum of banknotes and coins) as a percentage of GDP, TaxGDP represents the ratio of tax revenues of the government as a percentage of GDP and Interest is proxied by the different interest variables discussed above, and ε is the error term.

The second stage of the analysis focuses on revealing the determinants of for holding cash motivations for holding cash, particularly a differentiation between the hoarding (precautionary) and transaction motives in Czechia and the Euro area, following a similar investigation into Swiss Francs by Assenmacher et al. (2019). Their equation is modified to the following specification:

$$Cash_{it} = \beta 0 + \beta 1\ Interest_{it} + \beta 2 TaxGDP + \beta 3\ Inflation_{it} + \beta_4 ATM_{it} + \beta_5\ Fin\_Depth_{it} + \varepsilon_{it} \qquad \text{(ii)}$$

where Cash represents the level of cash in circulation in the economy (sum of banknotes and coins) as a percentage of GDP, Interest is the 3 month risk interbank borrowing rate and RIR is the real interest rate. ATM represents the number of ATMs per 100 000 citizens, and Fin_Depth represents the level of financial development through the measure of financial depth. The latter two variables are included to explore whether the demand for cash may simply also be function of financial development. A higher number of ATMs suggests deeper penetration of retail banks in an economy. However, the net impact on the demand for cash is hard to judge. On the one hand, a wider availability of financial services suggests increased financial development and therefore a move towards digitalisation of payment methods. On the other hand, the mere existence of an increasing number of ATMs suggests a higher (or more readily available) supply of cash. Therefore, studying the impact of ATM numbers on the demand for cash may be interesting from an academic perspective.

Financial depth is proxied using the ratio of domestic credit to private sector as a percentage of GDP, as defined in the World Development Indicators (WDI) by the World Bank. This is one of the more popular measures of financial development as it is calculated in most countries and is a transparent and consistent method of measuring financial depth. Similar to the ATM variable, financial depth is included to capture advances in the general financial environment of the economies in the sample.

Initially Austria, Finland and The Netherlands were included in the dataset. However, since they are part of the Euro area, they were excluded and the whole of the Euro was included as a separate variable. The decision to exclude individual Euro area countries in the study is considered reasonable as the primary variables under investigation are related to interest rates, which are likely to be manipulated centrally by the European Central Bank including the assessment of demand for cash and its issuance. Further, there is a free flow of Euros between the Euro area economies, which makes the whole area collectively relevant for a study of the cash in circulation.

Table 1: Variable descriptions and sources

Variable	*Description*	*Source(s)*
Currency in circulation	Calculated by dividing CIC by nominal GDP	IMF and central banks
3M interest rate	The 3-month interbank lending rate	Federal Reserve Economic data (FRED)
Tax revenue as a percentage of GDP	Total revenues collected via tax on income and profits as % of GDP	OECD
ATM	ATMs per 100 000 adults	World Bank
Inflation (CPI)	Changes in inflation year on year	International Monetary Fund
Financial depth	Proxy for financial development using the index: Domestic credit to private sector as % of GDP	World Bank
Real interest rate	Lending interest rate adjusted for inflation as measured by the GDP deflator	World Bank

Data limitations related to the shadow economy were a small but definite compromise which had to be made in this study. As of September 2023, the World Bank's data on Informal Economy indicators has not been updated beyond 2018, with updates typically occurring every two years (the last one being in 2021). Hence, it is prudent to await the 2023 update for more current data.

Descriptive statistics

Table 2 presents a summary of key economic variables across a panel of 17 economies over the period from 2002 to 2022. The countries chosen for this analysis are: Japan, China, India, Brazil, Korea, Poland, Mexico, Russia, Sweden, Norway, Denmark, Finland, Switzerland, Austria, Czechia, Iceland, Netherlands, Hungary, the U.S. and the Euro region.

Table 2: Summary statistics

Variable	*Mean*	*Std. Dev.*	*Min*	*Max*	*Observations*
Currency in circulation	0.0753	0.0461	0.0112	0.2332	349
3M interest rate	0.0338	0.03807	-0.0078	0.2308	354
Tax revenue as a percentage of GDP	0.2856	0.1076	0.0868	0.5029	332
ATMs per 100 000 people	82.0203	58.2132	2.2900	288.5900	288
Inflation (CPI)	0.0327	0.03153	-0.0134	0.1579	357
Financial depth	100.2768	56.7886	12.8694	304.5750	320
Real interest rate	0.0455	0.09007	-0.19362	0.4834	301

The mean values of the variables suggest that the countries in the sample have a relatively well-developed financial system. For example, the average number of ATMs per 100,000 people is 82.02, and the average financial depth is 100.28. However, there is a lot of variation in the data across countries. For example, the standard deviation of financial depth is 56.79. This suggests that some countries have a much more developed financial system than others.

Additionally, the minimum and maximum values for some of the variables are quite spread out. For example, the minimum value for ATMs per 100,000 people is 2.29, while the maximum value is 288.59. This suggests that there is a significant difference in the number of ATMs between countries. As calculated, the mean currency in circulation as a percentage of GDP is around 7.5% for the total sample.

Notably, the minimum CIC is around 1.12%, compared to the maximum of 23.32% from Iceland and Japan respectively. Both of these countries would be considered developed or advanced. Therefore, it is interesting to see the large variation in cash demand between them. There are similarly large differences between the minimum and maximum values of each variable. This is expected given the heterogeneity between the chosen economies.

The dataset is strongly balanced, with over 300 observations per variables (from a possible total of 349 observations per variable). There is some missing data in the ATM variable as the dataset available from the World Bank only begins in 2004. Interestingly, the U.S. does not report the number of ATMs after 2009.

The country-wise average of CIC over the period covered is described below. The highest average CIC rate is observed in Japan at 18.48%, with the lowest in Norway at 1.88%. Considering the popularity of the Nordic countries like Norway and Sweden, it not surprising

to find that they have some of the lowest CIC rates. The median rate is around 7.5% and the emerging economies like India, China and Russia all have CIC rates above the median. This may be an indication of the lower level of development of their financial systems. The minimum number of ATMs per 100 000 people was also reported in India in 2005. Eastern European economies like Hungary and Czechia show relatively high CIC rates at 10.36% and 10.28% respectively. These numbers are quite close to the emerging economies, which is surprising given the much larger difference in financial development between the two types of countries. The Euro area, as a whole, has an average CIC of about 9%. Surprisingly, Brazil and Mexico, which would both be considered emerging economies, have CIC rates below the median.

Table 3: Average CIC between 2002-2022 across the sampled countries.

Country	Average CIC % of GDP
Japan	18.4808%
China	9.6095%
India	12.1016%
Brazil	3.7085%
Korea	4.5306%
Poland	7.7357%
Mexico	5.6912%
Russia	10.5739%
Sweden	2.4415%
Norway	1.8769%
Denmark	3.2145%
Finland	7.2429%
Switzerland	10.1838%
Austria	7.8543%
Czechia	10.2785%
Iceland	2.0151%
Netherlands	6.7482%
Hungary	10.3856%
US	6.9726%
EUR	9.1048%

Table 4 presents the correlation between all the variables:

Table 4: Correlation across variables

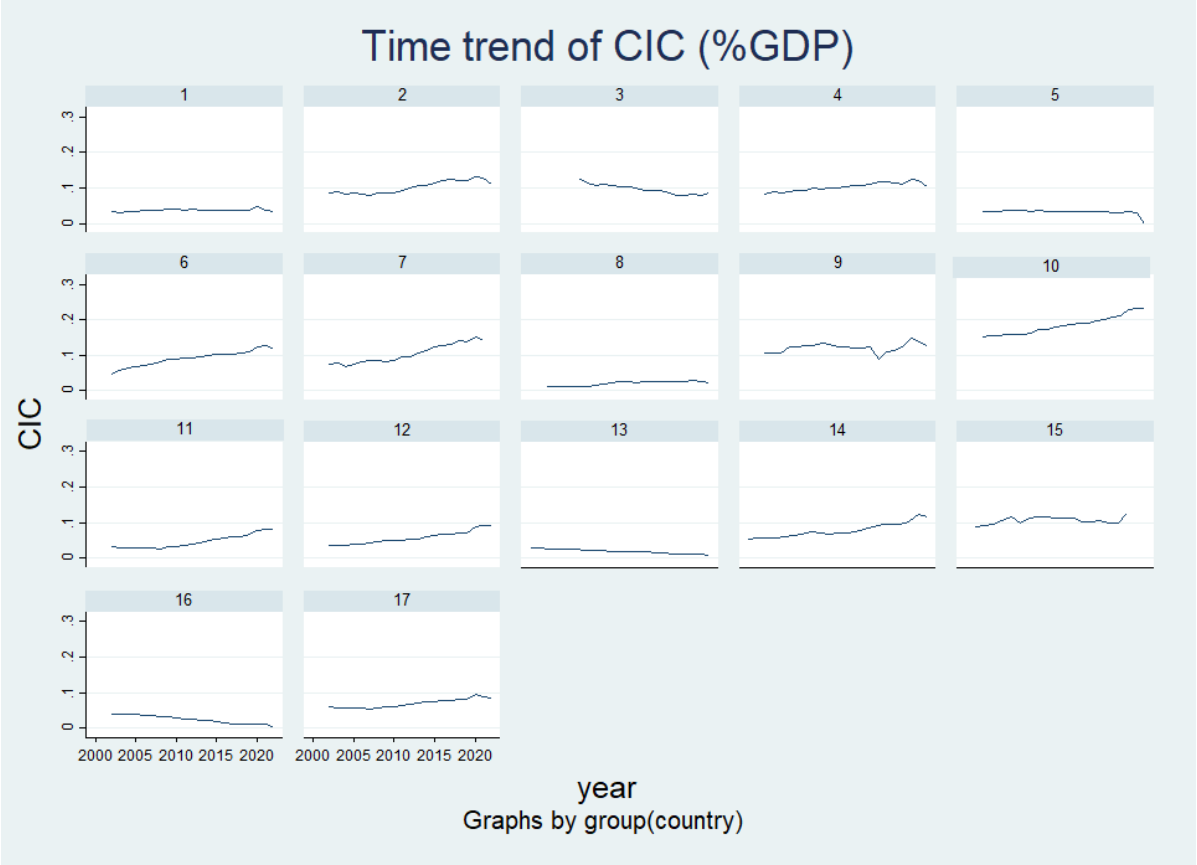
	CIC	*3M rate*	*Tax % GDP*	*ATM*	*Inflation*	*Financial Depth*	*Real Interest rate*
CIC	1						
3M rate	-0.3021	1					
Tax % GDP	-0.3650	-0.1665	1				
ATM	-0.1049	0.0261	-0.0895	1			
Inflation	-0.0579	0.6285	-0.364	-0.1668	1		
Financial depth	-0.1588	-0.3051	0.3322	0.3615	-0.3895	1	
Real interest rate	-0.3024	0.5282	0.1333	0.129	0.1896	-0.1517	1

Currency in circulation has a relatively high and negative correlation with both measures of interest rate (-0.30 for 3M rate and the real interest rate). This is expected given that the interest rate represents the opportunity cost of holding cash instead of investing it or simply putting the money in a savings account, at minimal risk. Similarly, the stronger correlation between the 3M rate and the real interest rate is expected, as they are both different measures of interest rates.

Interestingly, there is a negative correlation between CIC and the ATM variable, which suggests that having a larger number of ATMs may in fact be a better measure of financial development than of cash demand in the economy. This is further reflected in the positive correlation between ATM and financial depth (0.36). The negative correlation between financial depth and inflation suggests that more developed countries should have lower levels of inflation. This is intuitive and reflected clearly in the real world, where more advanced economies in Europe typically have significantly lower inflation rates than in developing countries in Asia and Africa. The same is reflected in the negative correlation between financial depth and the two interest rate variables. Contrastingly, the ATM variable has a small but positive correlation with the interest rate variables.

Figure 1 shows the time trend of CIC across the sample of countries. There is no clear universal trend which can be observed in these graphs. Some countries like Czechia and Japan have seen a clear increase in the CIC over time, while others like China, Norway and Sweden have seen a decline. Appendix B contains the time trend graphs of each variable across different countries.

Figure 1 CIC over time across countries



(Countries are numbered as: 1. Brazil, 2. Switzerland, 3. China, 4. Czechia, 5. Denmark, 6. Euro area, 7. Hungary, 8. Iceland, 9. India, 10. Japan, 11. Korea, 12. Mexico, 13. Norway, 14. Poland, 15. Russia, 16. Sweden and 17. USA)

4. Results and Discussion

All variables are tested for unit roots, or the existence of non-stationarity using the Im Pesaran and Shin (IPS) test (2003). It is an extension of the augmented Dickey-Fuller test (ADF) test but allows for heterogeneity in panel data. The test is applied to each unit in each panel and the t-statistics from individual ADF tests are averaged to produce panel t-statistics, which are then compared to critical values derived for the IPS test. The null hypothesis in this case is that all units in the panel have a unit root, with the alternative being that at least one unit in the panel does not have a unit root. The null hypothesis was rejected for each variable and all variables were found to be stationary at the level. Therefore, there is no need to transform the data before the analysis. For the ease of interpretation, all data was converted to decimals before the regression analysis. The results for the various regression specifications are provided in table 5:

Table 5 Regression results (** shows significance at the 5% level)

	CIC (i)	CIC (ii)	CIC (iii)	CIC (iv)	CIC (v)
3-month risk free interest rate	-0.2078**	-0.1630**	-0.1584**	-0.2048**	-0.1763**
Tax/GDP	0.2549**	0.1550**	0.1546**	0.1654**	0.1442**
Real interest rate		-0.0582**	-0.0218**	-0.0754**	-0.0791**
Inflation (CPI)			-0.0131	0.0226	
ATM				0.0002**	0.0001**
Fin_depth				0.0000	
Constant	0.0078	0.0423**	0.0427**	0.0297**	0.0354**
R-squared	0.2226	0.2079	0.2082	0.3269	0.2563
Prob>F	0	0	0	0	0
Fixed effect present?	Yes	Yes	Yes	Yes	Yes
Country Fixed effects:					
1.Brazil	-0.0285	-0.0162	-0.0158	-0.0162	-0.0156
2.Switzerland	0.0265	0.0264	0.0262	0.0150	0.0226
3.China	0.0500	0.0324	0.0322	0.0378	0.0327
4.Czechia	0.0119	0.0125	0.0125	0.0165	0.01864
5.Denmark	0.0891	-0.0771	-0.0772	-0.0762	-0.0737
6.Euro region	0.0353	0.0124	0.0123	0.0156	0.0138
7.Hungary	0.0109	0.0132	0.0132	0.0148	0.0194
8.Iceland	-0.0660	-0.0635	-0.0634	-0.0631	-0.0626
9.India	0.0902	0.0675	0.0679	0.0817	0.0785
10.Japan	0.1007	0.0902	0.0899	0.0843	0.0840
11.Korea	-0.0198	-0.0296	-0.0297	-0.0575	-0.0572
12.Mexico	0.0250	0.0025	0.0024	0.0083	0.0067
13.Norway	-0.0882	-0.0868	-0.0868	-0.0806	-0.0809
14.Poland	-0.0102	-0.0200	-0.0201	-0.0130	-0.0124
15.Russia	0.0814	0.0567	0.0571	0.0537	0.0509
16.Sweden	-0.0923	-0.0688	-0.0689	-0.0666	-0.0636
17.USA	-0.0012	-0.0093	-0.0094	-0.0318	-0.0325

Currency in circulation as a percentage of GDP is the dependent variable in all specifications and country fixed effects are present in all specifications.

Specification (i) incorporates only the 3-month interest rate and Tax/GDP variable as the regressors, in line with Rogoff and Scazzero (2016). Here, the interest rate has a significant negative impact on the CIC, which is in line with expectations- a higher opportunity cost, in the form of interest on investment/savings, leads to a lower incentive to hold cash. The impact of tax revenues is significantly positive on CIC. This suggests that when the government collects revenues through higher taxes, people are incentivised to hold cash. This implies that people prefer to conduct cash transactions when they believe that they will have to pay more taxes indirectly through tax on consumption or through direct income tax. This also suggests that black market or shadow economic cash-based transactions may be occurring as a consequence

of higher taxation by the government. The r-squared value of the model is about 22% which shows that 22% of the variation in the dependent variable i.e CIC is explained by these two independent variables in specification (i). The remaining 78% of variation is not explained in this model and may occur due to other factors or omitted variables.

The second measure of interest rate- real interest rate is integrated into specification (ii). The result is in line with expectations- the coefficient on real interest rate is negative and statistically significant. The value of the coefficient is lower than on the 3M interest rate (-0.06 versus -0.16), which is an intuitive result. The 3M interest rate is a simpler variable and more "short-term" than the real interest rate. The latter is a more complicated variable which incorporates different types of interest rates in the economy and also the inflation rate. Therefore, people are more likely to "see" the 3M rate and respond to it, compared to the real interest rate in the economy. Therefore, the demand for cash is more elastic in response to the 3M or short-term interest rate. The significance and direction of the coefficient for Tax/GDP remained unchanged with a value of 0.1550.

The r-squared value decreases to 20.79% in specification (ii). This is likely due to the similarity in the two types of interest rate variables and the relatively high correlation between them, as observed in table 3. However, since the coefficients on both interest rate variables are significant, and their correlation is not considered too high to eliminate one or the other variable, neither variable is dropped from the specification process.

The inflation variable is added to specification (iii) and is found to have no statistically significant impact on the dependent variable, with a very small coefficient. This is likely due to the impact of inflation already being incorporated in the real interest rate variable. The direction and significance of the coefficients on the 3M interest rate and Tax/GDP were maintained as for specifications (i) and (ii).

ATM and financial depth, the variables to capture advances in financial development are added to specification (iv). The ATM variable has a negligible but statistically significant coefficient, while financial depth has an insignificant, almost zero coefficient. This implies that the financial depth variable is not relevant in determining the currency in circulation in an economy. This may be because this particular variable only calculates the domestic credit to the private sector, which may not directly impact the demand for cash in the economy. The coefficient on the ATM variable shows that there is a statistically detectable impact on CIC but the effect may not be economically or practically significant. However, the r-squared of specification (iv) is higher at 0.33, which means that this specification explains 33% of the variation CIC. Therefore, there is a better model fit in specification (iv) relative to the prior specifications. The inflation variable continues to have a non-significant coefficient, as with model (iii).

The insignificant variables of inflation and financial depth are dropped in specification (v). The coefficients for the 3M interest rate, Tax/GDP, real interest rate and ATM are all statistically significant at the 5% confidence level. This specification has the second highest explanatory power, with an r-squared value of 0.26.

To ensure the robustness of results, the models were re-estimated using robust errors and no significant deviations from the above were noted. Bootstrapping with 100 replications was performed to obtain robust estimated of standard errors, and to assess the stability of the specification under resampling, with no notable differences in results obtained.

Two key findings arise from the various specifications above: (i) interest rates have a significantly negative impact on currency in circulation and (ii) Tax revenue as a percentage of GDP has a significantly positive impact on currency in circulation. Both of these findings are

in line with the conclusions of Rogoff and Scazzero (2021) from their sample of developed countries. They too apply country fixed effects. However, they do not delve into the details of the fixed effects. This is possibly due to their sample of developed countries which may, arguably, be considered to be homogenous.

However, it was noted in the summary statistics section, that the CIC rates did not seem to be consistent with expectations across advanced economies. The individual countries' fixed effect coefficients are listed below the regression results in table 4. These coefficients represent the country-specific effect on the dependent variable which are not explained by the variables included in the model specification.

Brazil, Iceland, Korea, Norway, Poland, Sweden and the United States have a negative fixed effect (F.E.) for each of the specifications, with Sweden having the largest negative F.E. coefficient. This suggests that all else being equal, Norway has the largest downward effect on currency in circulation, at least in specification (v). Conversely, the largest positive F.E. is from Japan. Other positive coefficients are in Switzerland, China, Czechia, the Euro area, Hungary, India, Mexico and Russia. This is an interesting result as the countries with the positive coefficients all had a higher than median average CIC rate, with the exception of Mexico. Therefore, there are country-specific factors which push the CIC rate upwards or downwards, which are not easily identifiable based on geographic factors or the level of financial development at least. Hungary and Czechia are Eastern-European countries with a positive F.E. coefficient on CIC, but simultaneously Poland which is also an Eastern-European country, has a negative F.E. coefficient. Similarly, emerging economies like India, China, Russia and Mexico have a positive F.E. coefficient, but Brazil has a negative coefficient.

5. Limitations, avenues for future work and conclusions

The results from the analysis in this paper concur with the current findings in literature. Particularly, the relatively new and unexplored combination of interest rate and tax revenue as a percentage of GDP variables and their impact on currency in circulation is examined in detailed. The regression results here match the expectation based on the sample of advanced economies which were investigated by Rogoff and Scarezzo (2021). The number of ATMs per 100 000 people and a measure of financial depth were used as proxies for developments in the financial systems. However, both were found to be insignificant in determining the level of currency in circulation. These two are relatively underused variables in literature. The statistical significance of the ATM variable begs further investigation. As discussed in the initial sections, the importance of the number of ATMs on the demand for cash can be twofold and contradictory. Does having access to more ATMs increase the demand for cash, or does it signify financial development such that the demand for cash becomes less and instead ATMs just serve as a signalling mechanism for increased digitalisation of financial transactions? This raises further questions in the field of financial development and which indicators best reflect financial development.

Perhaps the inclusion of EFTPOS terminals, as is the norm in the payment systems literature, would be a better indicator of the type of financial development which reduces the demand for cash. This was initially considered but not used here, as it is difficult to find a reliable and consistent source of data for EFTPOS terminals in such a wide variety of countries as was explored in this paper.

Beyond the issue of data availability about shadow economies, motivation and scope of this paper was not wide enough to incorporate the shadow economy. In the first stage, the intention was check whether the typical regressors in the currency in circulation literature are also

significant in a heterogenous panel- as the literature typically looks at similar sets of economies: OECD, advanced economies or individual countries. Since a clear category of economies which tend towards higher or lower currency in circulation could not be highlighted, subsequent papers should employ country specific control variables like shadow economy, financial access, banking penetration and others. This will help to understand the country-specific institutional variables which may impact currency in circulation. Furthermore, the shadow economy variable is complex, especially as there is literature which suggests that shadow economy conditions may be persistent (Chowdhury, 2004; Lio et al, 2011). Therefore, dynamic panel model analysis would be required, which begs a separate empirical investigation. Further, various papers like Assenmacher et al. (2019), Seitz et al. (2018) present a strong case for breaking down the currency in circulation into small and large denominations to investigate their demand for shadow economy, hoarding or other purposes. Therefore, an investigation into shadow economy would significantly change the original motivation of the paper and may be better incorporated into a follow-up paper.

As discussed, simply defining sub-groups as developing and advanced economies would not be enough to understand the country specific fixed effects which impact the currency in circulation rates across countries. Countries with ostensibly similar characteristics were found to have opposite fixed effects on the CIC variable in this research. A more in-depth investigation of the institutional factors which may be affecting the demand for cash is required. An even larger dataset, with more countries, may help understand the currency's determinants in circulation better. Notably, a larger dataset may reveal more interesting groups of economies that show a higher or lower demand for cash and which economies are actually moving towards being “less-cash” societies (and why?)

It was also noted in the summary statistics that the independent variables had some level of correlation with each other. This is understandable given that most of them are country-level variables which will inevitably be affected by each other. Therefore, the interactions between such variables and the consequent impact on currency in circulation would make for an interesting investigation. Specification (iv) had the highest explanatory power out of all the models specified in this paper, despite only having two extra variables which were both statistically insignificant independently. The joint, interaction effect of such variables (with each other and on other independent variables) requires further exploration. There may be variables which are insignificant individually but have strong interaction effect on currency in circulation, which was not considered here.

Some recent literature like Assenmacher et al. (2019) have begun delving deeper into individual country’s CIC determinants. Considering the relatively high CIC rates in advanced economies in Europe, it may be interesting to consider the hoarding and shadow economic motivations for cash demand. This can be explored further with the breakdown of CIC into large and small denominations and which of these are demanded more in the economies. Since many central banks readily provide a breakdown of the currency in circulation, this topic begs investigation. A method to utilize panel data methods into such an investigation would significantly contribute to the payment systems and payment behaviour literature. Further, an investigation into the supply side- why central banks continue to issue currency, seigniorage and non-economic decision making could also provide a different perspective on the currency in circulation debate.

Overall, there is no doubt that digital finance is on the rise. People increasingly use their mobile phones and plastic money to pay for their transactions, both in brick-and-mortar shops and online on e-commerce websites. Intuitively, the expectation is that cash usage ought to be on the decline. However, looking at the literature on currency in circulation, makes it clear that the decline of cash is not so evident. In fact, currency in circulation may be rising or remaining

steady in many countries, despite the increased prevalence of digital payments. This paper extended the stream of literature on currency in circulation by taking a dataset of 17 countries around the world, including both emerging and advanced economies, between the periods of 2002-2022.

The conclusions here match the literature- that there is no clear decline in currency in circulation. In fact, it is rising in many places. It was found that interest rates have a negative impact on cash demand, while government tax revenues have a positive demand on cash. The reasons for the former are in line with the literature on interest rates and risk premia. However, it is also found that there is no easy or obvious categorisation possible for countries which demand more or less cash. Financial depth and access to ATMs is found to have little impact on the demand for cash- therefore, it cannot just be said that less developed economies should have more demand for cash or that advanced economies must have a falling currency in circulation statistic. This paper extended the research conducted in prior literature, and provided a basis for various further questions which need to be investigated in the field of payment systems and the motivators of less (and more)- cash economies.

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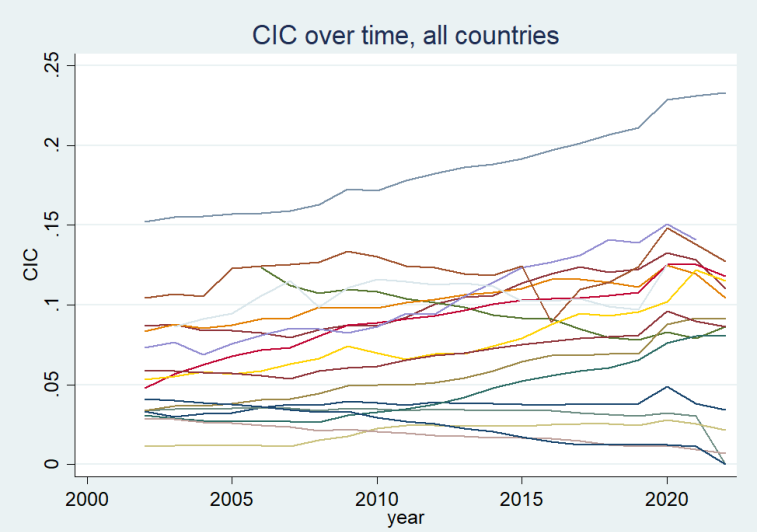
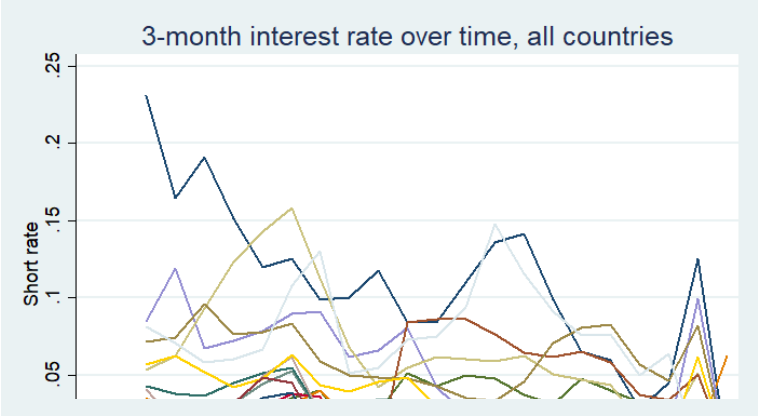
Appendix A

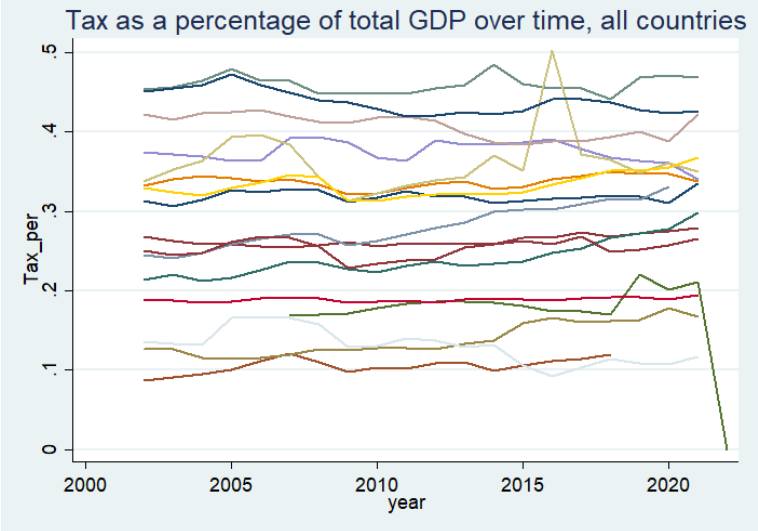
Variable		Mean	Std. Dev.	Min	Max	Observations
CIC	overall	0.075257	0.04606	0	0.23316	N = 349
	between		0.044287	0.018769	0.184809	n = 17
	within		0.015583	0.032017	0.123608	
3M rate	overall	0.033848	0.03807	-0.00784	0.230833	N = 354
	between		0.029335	0.001806	0.108591	n = 17
	within		0.025163	-0.07474	0.15609	
Tax revenue (% GDP)	overall	0.285573	0.107564	0	0.50286	N = 332
	between		0.109595	0.105277	0.459786	n = 17
	within		0.019961	0.113002	0.426376	
ATMs per 100 000 people	overall	82.02031	58.2132	2.29	288.59	N = 288
	between		58.83597	13.16824	257.4718	n = 17
	within		19.0488	-16.1238	153.0562	
Inflation (CPI)	overall	0.032781	0.031533	-0.01342	0.157887	N = 357
	between		0.022087	0.002766	0.083851	n = 17
	within		0.023107	-0.05107	0.155971	
Financial depth	overall	100.2768	56.78861	12.8694	304.575	N = 320
	between		54.8569	25.66934	185.9358	n = 17
	within		19.7848	42.78085	263.1668	

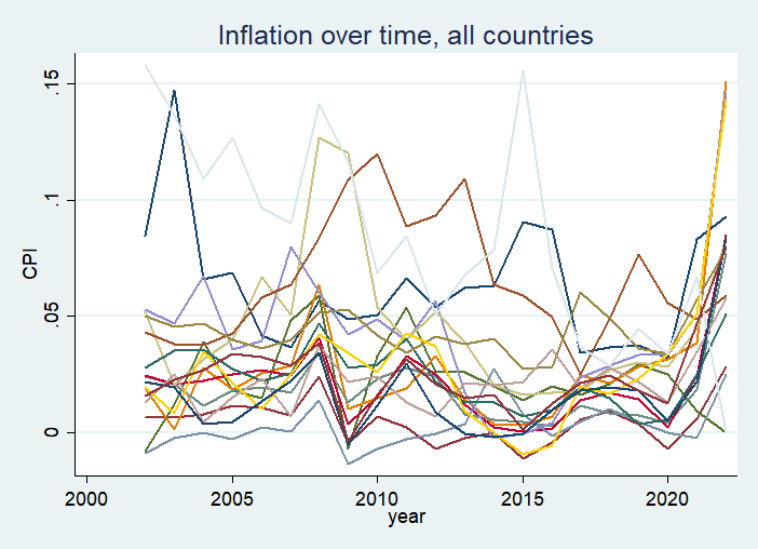
Real interest rate	overall	0.045483	0.090071	-0.19362	0.483404	N =	301
	between		0.07765	-0.01055	0.336652	n =	17
	within		0.038739	-0.13758	0.192235		

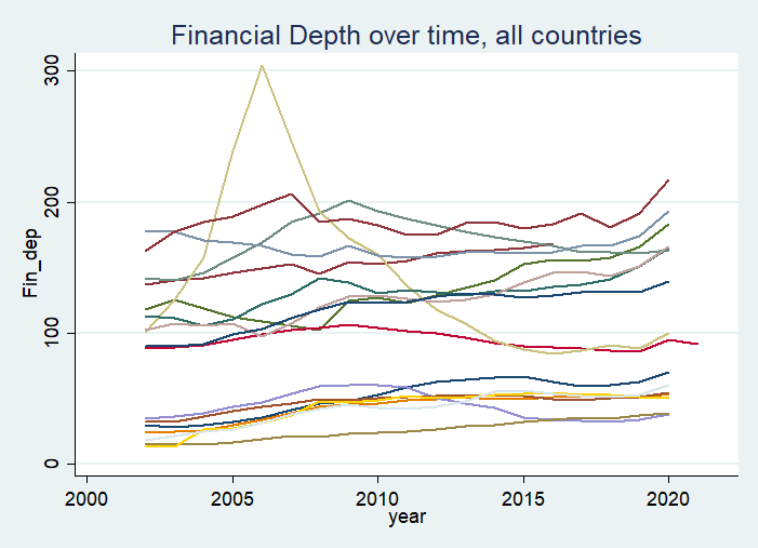
Appendix B

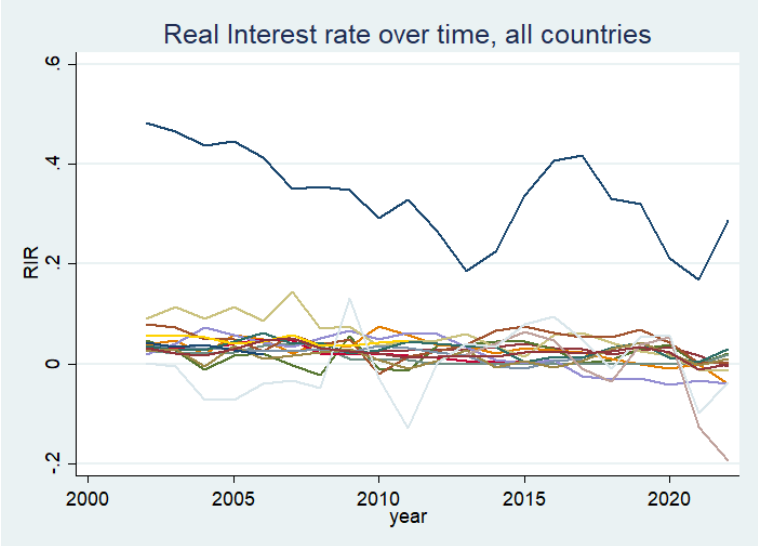


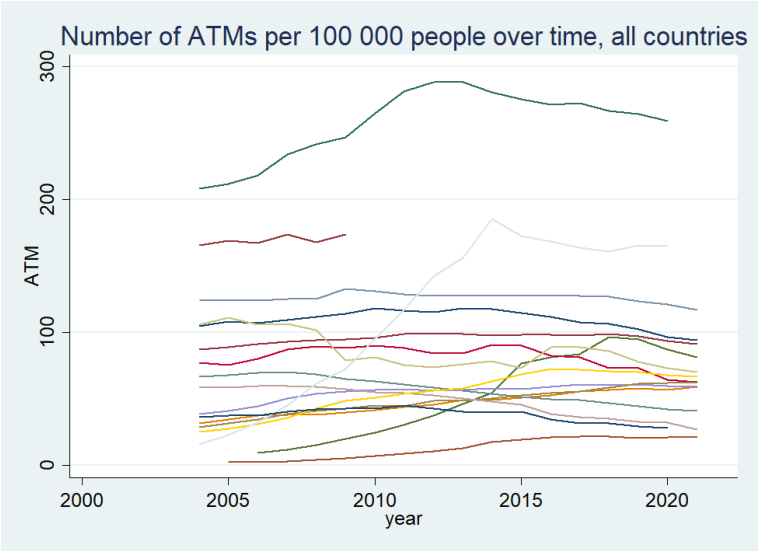





Inflation over time, all countries
CPI
0
.05
.1
.15
2000
2005
2010
2015
2020
year


Financial Depth over time, all countries
Fin_dep
0
100
200
300
2000
2005
2010
2015
2020
year


Real Interest rate over time, all countries
RIR
-.2
0
.2
.4
.6
2000
2005
2010
2015
2020
year


Number of ATMs per 100 000 people over time, all countries
ATM
0
100
200
300
2000
2005
2010
2015
2020
year

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