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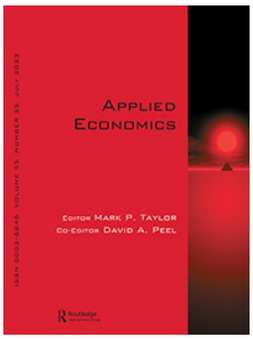

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Are the informal economy and cryptocurrency substitutes or complements?

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ABSTRACT

This research considers a new dimension of the effects of the underground sector by examining the spillovers on cryptocurrency holdings. Cryptocurrencies offer a relatively greater ability to dodge taxes and ensure the anonymity of holders, providing attractive avenues for underground operators to stash their informal-sector earnings. Our results, based on data from more than 50 nations, show that a greater prevalence of the underground economy in a nation is indeed associated with greater cryptocurrency holdings. This result holds across an alternative measure of the shadow economy, and when the bi-directional causality between the shadow economy and cryptocurrency holdings is considered. In other noteworthy findings, greater FDI crowded out cryptocurrency holdings, while greater financial globalization and greater economic uncertainty, ceteris paribus, increased them.

KEYWORDS

Cryptocurrency; informal economy; FDI; economic freedom; central bank independence

JEL CLASSIFICATION

F33; G21; K42; O17

I. Introduction

The influx and global diffusion of electronic money in recent years have begun to challenge the traditional dominance of paper money and undermined the abilities of central banks to control the money supply and, thereby, to effectively combat inflation (or to implement monetary policy more broadly). Given its relative recency, and the evolving technologies and globalization, the full implications of electronic money have not yet been understood (Böhme et al. 2015; Bradbury 2013; Goel and Hsieh 2002; Kim 2017; Schilling and Uhlig 2019). In fact, some researchers have even questioned whether Bitcoin is really a currency (Kunimoto and Kakamu 2022).

Cryptocurrencies have been identified as facilitating illegal activities like drug trafficking, smuggling (Goel 2008), terror funding (Goel 2020), and human trafficking, etc.[1] prompting some international agencies to conduct related training for law enforcement.[2] This has hampered the formulation of effective policies to monitor and/or control such money, especially when some of the related activities are clandestine in the informal sector (Bal 2015; Dniprov et al. 2019; Stolbov and Shchepeleva 2020; Yadav et al. 2022).

This paper examines the spillovers from the shadow or the underground sector onto cryptocurrency holdings using data from a large sample of countries. Are the informal economic activities and cryptocurrency holdings complementary or substitutes? Shadow activities and cryptocurrencies would be complementary when the anonymity and borderless nature of cryptocurrencies provide good avenues to stash underground earnings and avoid taxation/detection.[3] It could be the case that, beyond economic greed, weak institutions might significantly drive individuals' incentives to hold cryptocurrencies and that these incentives might vary across institution types. Institutional capacity varies significantly across nations (see La Porta et al. (1999)). In some developing nations with weak institutions, individuals might prefer

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[1]https://www.gao.gov/blog/virtual-currency-use-human-and-drug-trafficking-increases-so-do-challenges-federal-law-enforcement.

[2]https://www.unodc.org/roseap/en/2022/02/cryptocurrencies-darknet-investigations/story.html.

[3]There is some anecdotal evidence of the positive association between digital currencies and black market activities (https://www.justice.gov/usao-sdny/pr/us-attorney-announces-historic-336-billion-cryptocurrency-seizure-and-conviction). However, formal investigations of the underlying relationship have been missing and the present paper tries to fill this gap.

cryptocurrency holdings to traditional banking.[4] The growth of cryptocurrencies in developing nations has induced some international bodies to suggest restraints on their rapid growth (https://unctad.org/news/unctad-spells-out-actions-curb-cryptocurrencies-developing-countries). The nexus between cryptocurrency holdings and the shadow economy, being formally studied here, potentially compounds the challenges for regulatory bodies, with shadow activities being clandestine and cryptocurrencies being global in nature and largely beyond specific jurisdictions of individual nations, especially (developing) nations with weak institutions.

Cryptocurrencies may also be tied to shadow banking practices (Claessens and Ratnovski 2013). Coca and Nistor (2022) provide a recent review of the digital shadow economy. Furthermore, cryptocurrency technologies might impact online gambling (Gainsbury and Blaszczynski 2017; Goel 2021), and frequently underground earnings are related to gambling practices, both as a source of gambling funds and of returns from gambling. For now, while the literature on the causes and effects of cryptocurrencies is slowly emerging, the aspect studied in this paper seems novel.

Our results, based on a recent sample of 53 nations over the years 2018–2021,[5] support the main hypothesis that a greater prevalence of the shadow economy is associated with a greater prevalence of cryptocurrency holdings. This result holds across different modelling specifications and when potential bi-directional causality between the shadow economy and crypto holdings is taken into account. Besides being novel, the results have policy value for governments trying to check the shadow economy and grapple with the implications of digital currencies (see Benigno and Robatto (2019)).

The structure of the rest of the paper includes the background and the model in the next section, followed by data and estimation, results, and conclusions.

II. Background and model

Background

The background for this paper can be seen as related to the causes of the spread or prevalence of digital currencies, and to the effects of the underground or shadow markets (in this case on cryptocurrency holdings).

A primary cause of firms and individuals operating in the underground or shadow sectors has been to evade burdensome regulations and/or taxes. While the traditional arguments for tax evasion pre-date the arrival of digital currencies (see, for example, Alm (1988)), the advent of digital currencies, with their international and clandestine nature, might provide individuals a new avenue to avoid taxes. Given its newness and its international prevalence, the governance and taxation of digital or cryptocurrencies are questionable, with nations still trying to formulate effective strategies (Bal 2015; Böhme et al. 2015; Dniprov et al. 2019; Schilling and Uhlig 2019; Stolbov and Shchepeleva 2020; Yadav et al. 2022)). For instance, tracking ownership of cryptocurrencies and then exercising jurisdictional control (via regulation or taxation) is challenging, given the international, borderless, nature of internet-based digital currencies, (see Yadav et al. (2022)). The prevalence of digital currencies, with their global reach and relative independence of the regulatory reach of individual nations, provides individuals and firms with another avenue to stash their earnings (legal or illegal) and avoid taxes (Marmora 2021). The formal analysis in this paper will determine whether shadow activities and cryptocurrency holdings are indeed complementary across nations.

On the flip side, privacy issues associated with internet transactions also relate to digital currencies. This might act as a deterrent to cryptocurrency holdings (Bradbury 2013; Goel 2019; Goel and Nelson 2009),[6] although, with greater internet piracy, some might view cryptocurrency holdings as safer than say electronic banking. This latter effect might explain the prevalence of crypto holdings in some developing nations.[7]

[4] https://guardian.ng/opinion/outlook/bitcoin-adoption-and-its-impacts-on-the-developing-world/; https://www.ft.com/content/1ea829ed-5dde-4f6e-be11-99392bdc0788.

[5] The relatively short span of our data is constrained by the availability of comparable data across nations and the relatively newness of cryptocurrencies (for details, see https://www.statista.com/statistics/1202468/global-cryptocurrency-ownership/).

[6] Kim (2017) deals with the transaction cost of digital currencies.

[7] https://www.ft.com/content/1ea829ed-5dde-4f6e-be11-99392bdc0788.

Different scholars, in the relatively nascent literature on digital currencies, have studied various aspects. While we do not have data on the amount of cryptocurrency holdings by country, Li et al. (2020) note that the performance of cryptocurrencies may be determined by the market size (also see Bianchi and Babiak (2022)). The nexus between cryptocurrencies and the shadow economies, studied in the present paper, would make a correct/accurate determination of the performance of cryptocurrencies problematic. Related to the performance of virtual currencies is the aspect of their value (see Bolt and Van Oordt (2020)), and potential default (Grobys and Sapkota 2020).

The determinants of Bitcoin trading volume have been examined by Bouraoui (2020). The author finds that, in the sample of 21 emerging economies considered, access to the banking system significantly impacts local Bitcoin trading volume.

Another angle studied in the literature is whether liquidity risk is adequately priced or reflected in cryptocurrency markets (Feng, Wang, and Zhang 2018; Han 2022; Zhang et al. 2021). We account for the risk dimension in our analysis by considering macroeconomic uncertainty, exchange rate, central bank autonomy, and the degree of globalization.

Shadow economies are prevalent worldwide, although the extent of their prevalence in individual nations varies (Buehn and Schneider 2012; Schneider 2022). The broad term of shadow or underground activity includes illegal activities and otherwise legal activities that are not reported to the authorities to escape regulations and/or taxes. Thus, precisely measuring the extent of the shadow economy remains a challenge (Dybka et al. 2019; Frey and Weck-Hannemann 1984; Schneider 2012; Schneider and Buehn 2013). Despite the measurement shortcomings, some estimates of the shadow economy that are comparable across nations have emerged (Buehn and Schneider 2012). Based on these international estimates, a number of empirical studies of the causes and effects of the shadow economy have been conducted over time (see Berdiev, Goel, and Saunoris (2022), Goel and Nelson (2016), Goel and Saunoris (2022), Marmora and Mason (2021),Schneider and Enste (2000)). However, the aspect studied in the present research, namely, the nexus between the shadow economy and cryptocurrencies, seems unique. Our empirical model is discussed next.

Model

Based on the above discussion, we formulate the main hypothesis, which we will test by applying the data discussed in the data section to the model outlined below:

Hypothesis **H1**: Greater prevalence of the shadow or the informal sector is associated with greater cryptocurrency holdings, ceteris paribus.

The underlying logic is that the earnings from the underground activity are unrecorded, and cryptocurrencies, being mostly outside the regulatory and taxation nets, provide an easy way for individuals and firms to stash their earnings from the black markets. Some underground operators might choose to receive their payments in cryptocurrencies directly. By operating in the shadow sector, many firms and individuals are breaking the law, and thus their cost of breaking an additional law (e.g. by not voluntarily disclosing their digital currency holdings) might be relatively low.

The general format of the empirical model that we estimate is the following (with individual observations in the underlying data at the country (i) and year (t) level – see Section 3.1 for details):

CRYPTO = f(informal economy (Informal1 or Informal2), Economic prosperity (GDPpc), Economic freedom (EconFREE), Exchange rate (EXCHrate), Foreign Direct Investment (FDI), Central Bank independence (CBindependence), Economic uncertainty (ECONuncertain), Financial globalization (FINglobal), Island nation (ISLAND)) ... (1)

The dependent variable (CRYPTO) is cryptocurrency holdings in a nation and the main variable of interest on the right-hand side is the prevalence of the shadow economy. A positive and statistically significant coefficient on Informal1 (or Informal2), across alternative specifications would signify that Hypothesis H1 is valid. Table 1 provides complete details on all the variables.

Our baseline specification includes, in addition to the informal sector size, the GDP per capita (GDPpc) of a country, and the level of economic freedom (EconFREE – measured via an index (see Table 1)). The former is included as a proxy for the average living standard which may have a bearing on the preference for new modes of financial transactions. Arguably, people with higher incomes

Table 1. Variables definitions and sources.

Variable	Definition (observation; mean, std. dev.)	Source
CRYPTO	Percentage of the country's population using or owning cryptocurrencies, (155; 11.32, 5.99)	Statista Global Consumer Surveys [1]
Informal1	Prevalence of the informal economy, measured via Multiple Indicators Multiple Causes (MIMIC) model-based estimates (as a percentage of official GDP), (155; 24.29, 11.27)	Elgin et al. (2021)
Informal2	Prevalence of the informal sector, measured via Dynamic General Equilibrium (DGE) model-based estimates (as a percentage of official GDP), (155; 21.92, 9.70)	Elgin et al. (2021)
EconFREE	Economic freedom, index values range from 0 to 10; higher values indicate greater economic freedom, (155; 7.36, 0.72)	Fraser Institute [2]
FINglobal	Financial globalization. A subcomponent of KOF globalization index with values ranging from 0 to 100. Higher values indicate greater financial openness, (155; 70.68, 17.55)	Gygli et al. (2019)
GDPpc	GDP per capita (in logs of constant 2015 international $), (155; 9.68, 1.11)	World Development Indicators [3]
FDI	Foreign direct investment, net inflows (% of GDP), (155; 0.62, 2.98)	World Development Indicators [3]
ECONuncertain	Economic uncertainty, measured as the standard deviation of inflation during the last three years, (155; 1.67, 2.23)	Authors' calculations
EXCHrate	Official exchange rate, local currency units per US dollar. The values represent yearly averages, (155; 861.3, 3739.80)	World Development Indicators [3]
CBindependence	Central bank independence. A subcomponent of the central bank transparency index. The values range from 0 to 1, with higher values suggesting greater bank independence, (143; 0.86, 0.23)	Dincer, Eichengreen, and Geraats (2022)
ISLAND	Dummy variable identifying an island nation, (155; 0.15, 0.36)	Wikipedia [4]
CORRUPTION	Corruption Perceptions Index. The original index was rescaled so that higher values imply greater corruption, (155; 44.17, 19.56)	Transparency International [5]
COLONY	Dummy variable identifying a former British colony, (0.28; 0.45)	Treisman (2007)
REGION	Discrete variable varying from 1 to 7 according to the regional location of a country. Higher values represent countries in the Southern or Eastern hemispheres, (3.03; 1.50).	World Bank [6]

All observations are annual at the country level for the years 2018 to 2021.
[1] https://www.statista.com/statistics/1202468/global-cryptocurrency-ownership/. Accessed 22 September 2022. Information on cryptocurrency users is from 2019 to 2021. For the other variables, the information lags one time period (and, where data is not available, more than one time period).
[2] https://www.fraserinstitute.org/studies/economic-freedom. Accessed 23 September 2022.
[3] https://databank.worldbank.org/source/world-development-indicators. Accessed 22 September 2022.
[4] https://en.wikipedia.org/wiki/List_of_island_countries.
[5] https://www.transparency.org/en/cpi/2021. Accessed 23 September 2022.
[6] https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups. Accessed 19 September 2022.

have a greater appetite for the risk associated with owning digital assets. While the room for unrestricted economic decisions available to the public is captured through economic freedom.

Various extensions to the baseline specification are checked to account for the influence of factors like exchange rate volatility (EXCHrate), foreign direct investment (FDI – net inflows, as a percent of GDP), economic uncertainty (ECONuncertain – measured as the standard deviation of inflation over last three years), the effect of spatial location e.g. whether a country is an island (ISLAND), financial globalization (FINglobal – an index), and policy institutions (CBindependence – an index). These factors cover not only the domestic macroeconomic environment but also account for geographical features and the level of international integration of a country.[8] For example, economic freedom and financial globalization capture transaction costs, while economic prosperity is related to affordability, education, and institutional strength in a country. Furthermore, economic uncertainty, central bank independence, and the exchange rate would proxy for potential returns from digital investments.

In subsequent analysis, we employ instrumental variables for the informal economy to overcome its possible endogeneity. Our instruments include country characteristics capturing its colonial past, the regional location, and the corruption perceptions (CORRUPTION).[9] Corruption has been shown to be related to shadow activities (Dreher and Schneider 2010), while a nation's colonial past and location can be seen as impacting the prevalence of underground activities. The next section outlines the data used and the estimation procedures employed to estimate equation (1).

We can also argue that the instruments are independent from the outcome variable: (a) The geographical location of a country (REGION) cannot

[8]Shadow economies might be impacted by banking crises (Colombo, Onnis, and Tirelli 2016).
[9]Dimant and Tosato (2018) review the empirical literature on the causes and effects of corruption and Goel and Mehrotra (2012) how different financial payment instruments (not including cryptocurrencies) might impact corruption.

be the cause for the acceptability of alternative means of payment. Thus, we look at the regional distribution of our sample, the countries where cryptocurrencies are in use are dispersed all over the globe and across different income categories (Table A1). Therefore, the location is unlikely to have any direct effect on the potential to use cryptocurrency.

The same is the case with COLONY. There is no reason to suggest that particular colonial origins make a country more likely to use crypto. For instance, if we check the simple Pearson's correlation between crypto use and COLONY, it comes out to 0.009 and is insignificant with a p-value of 0.905.

Finally, corruption perceptions can affect crypto use. But we can argue that their effect goes through the shadow economy rather than operating directly (see Goel, Mazhar, and Saunoris (2020) for a related angle). Thus, if we regress crypto use on instrumental variables, the CORRUPTION coefficient comes out significant. But it becomes largely insignificant (at a 10% level) once we control for the shadow economy.[10] In addition, the probability value of the joint significance of the three instruments is 0.117. This suggests that our instruments are independent of the outcome variable.

III. Data and estimation

This section discusses the data and estimation techniques.

Data

The main outcome of interest is the global prevalence of cryptocurrencies. This information comes from a survey that asks respondents whether they own or use cryptocurrencies.[11] The information is available for three years from 2019 to 2021. The use of cryptocurrencies has increased over the years: from 10.26 in 2019 to 13.5 in 2021. In terms of its spatial or geographic distribution, it is most prevalent in Nigeria, where 42% of those surveyed claimed to have owned or used digital currencies. At the other extreme, we have Japan where only 4% of those surveyed claimed to own or use digital currencies.[12] Table A1 presents the countries in our sample along with their regional and income classifications.

The main variable of interest, as mentioned above, is the size of the informal sector. For this information, we use the Elgin et al. (2021) estimates. The main advantage of these estimates is their availability in two different forms: the Dynamic General Equilibrium (DGE) model-based estimates (Informal2) and those derived using the Multiple Indicators Multiple Causes (MIMIC) approach (Informal1). Our baseline results use MIMIC estimates because of their greater relevance with the empirical underpinnings of this analysis. The other variant is employed to check the consistency of our estimates. The correlation between Informal1 and Informal2 is 0.99 in our sample (Table A2 in the Appendix).

The latest year for which the estimates of the informal sector are available is 2018. Therefore, the variable informal sector is coming with a lag of three years with respect to the outcome variable and is contemporaneously exogenous in our analysis. Given the high persistence in the informal sector size, we can claim that this time structure has no adverse side effect on our inference. The average size of the informal sector in our sample is 22% in the year 2016 and 21.6 (as percent of GDP) in the year 2018 with a standard deviation that is 11.3 in both years.

Details about the variables used, including definitions, summary statistics, and data sources, are provided in Table 1. Table A1 in the Appendix includes a list of countries included in the analysis. The sample size is constrained by the availability of cryptocurrency data.

Estimation

For estimating the effect of the informal sector on the prevalence of crypto use we develop a simple

[10]The results of this regression are not reported to save space.
[11]The precise question is phrased as follows: 'Which of these financial products and investments do you currently use/own? (multi-pick)'. The information in this analysis concerns respondents who selected the option 'Cryptocurrency (e.g. Bitcoin)'. For sources, see Table 1.
[12]Source: https://www.statista.com/statistics/1202468/global-cryptocurrency-ownership/ (Table 1).

panel least squares model. The model permits control of panel-level serial correlation and adjusts standard errors for the possible heteroskedasticity in the error term due to cross-country linkages (Beck and Katz 1995).

The panel fixed-effects regression model is not appropriate for our purposes because of the high persistence in the size of the informal sector, the main explanatory variable of interest. However, to account for the possible secular changes shaping the outcome of our interest we use time dummies. The use of time dummies somewhat enables us to capture the effects of the recent coronavirus pandemic (see Naeem et al. (2022)). The country-level fixed effects are considered through regional dummies.[13] Finally, the issue of potential reverse causality is separately treated through the use of the instrumental variable regression.

IV. Results

Baseline models

The baseline results, reported in Table 2, support the main hypothesis – the shadow economy and cryptocurrency holdings are complementary and the positive spillovers from the shadow economy are present in all the models estimated. In terms of magnitude, a ten percent increase in the shadow economy (Informal1) would increase cryptocurrency holdings by about 6% (based on the corresponding elasticity evaluated at the respective means).

Greater economic freedom (EconFREE) and greater economic prosperity lower crypto holdings, with relatively greater statistical support for the former. These results can be seen as capturing dimensions of the opportunity costs of crypto holdings. In economically free nations, for instance, the economic systems work smoothly and there are less intrusive regulations. Thus, there would be fewer incentives for individuals to seek alternate (digital) financial assets.

Interestingly, greater FDI tends to crowd out crypto holdings. FDI inflows in a nation are a reflection of the promising economic climate there, which would likely also attract domestic investments, diverting funds away from digital currencies. The corresponding impact is modest,

Table 2. Spillovers from the underground economy to cryptocurrency: baseline models.

	Dependent variable: CRYPTO					
Model →	(2.1)	(2.2)	(2.3)	(2.4)	(2.5)	(2.6)
Informal1	0.259***	0.189***	0.233***	0.252***	0.190***	0.366***
	(0.093)	(0.040)	(0.066)	(0.059)	(0.026)	(0.083)
GDPpc	0.843	−0.051	0.166	−0.082	−1.526***	−0.985***
	(0.715)	(0.453)	(0.545)	(0.361)	(0.552)	(0.355)
EconFREE	−2.378	−2.659***	−2.196***	−2.216***	−3.137***	1.156
	(0.590)	(0.620)	(0.770)	(0.775)	(0.414)	(1.343)
EXCHrate	0.440**					
	(0.170)					
FDI		−0.255***				
		(0.066)				
ECONuncertain			0.270**			
			(0.125)			
ISLAND				−0.387		
				(0.951)		
FINglobal					0.148***	
					(0.033)	
CBindependence						1.455
						(1.811)
Observations	155	155	155	155	155	143
R-squared	0.889	0.892	0.861	0.899	0.935	0.886
F-test (p-value)	0.000	0.000	0.000	0.000	0.000	0.000
Number of countries	53	53	53	53	53	49

Table 1 for variable details. The estimates are based on panel least squares estimation. All the specifications include, but are not reported, a constant, regional, and year dummies. Standard errors, reported in parentheses, are robust against panel-specific heteroskedasticity and autocorrelation. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

[13] https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups. Accessed 19 September 2022.

however. A ten percent increase in FDI inflows would decrease cryptocurrency holdings by about one percent (Model 2.2).

Furthermore, EXCHrate, FINglobal, and ECONuncertain increase crypto holdings, ceteris paribus. So, while own economic freedom lowers CRYPTO, greater financial globalization has the opposite effect. Financial globalization captures external financial opportunities and cryptocurrencies might provide a lower transaction cost means to access external financial markets. Additionally, economic uncertainty and exchange rate can be viewed as capturing hedging opportunities that cryptocurrencies might provide. Finally, island nations and nations with greater central bank independence were no different from others. The island nation result makes sense when one thinks about the fact that the internet-based borderless nature of digital currencies mitigates any disadvantages that island nations might otherwise have.

Considering simultaneity issues

It is possible that the relationship between the shadow economy and cryptocurrency holdings is bi-directional, with cryptocurrency holdings being affected by and possibly affecting the underground sector.

To account for this, Table 3 presents results with Informal1 considered as an endogenous variable. The instruments used are COLONY, REGION, and CORRUPTION.[14] Corruption and shadow economies have been found to be related (Dreher and

Table 3. Spillovers from the underground economy to cryptocurrency: accounting for possible reverse causality.

	Dependent variable: CRYPTO					
Model →	(3.1)	(3.2)	(3.3)	(3.4)	(3.5)	(3.6)
Informal1	0.248***	0.217**	0.242**	0.235***	0.296***	0.317***
	[0.055–0.441]	[0.023–0.411]	[0.046–0.437]	[0057–0.413]	[0.111–0.482]	[0.125–0.509]
	(0.098)	(0.099)	(0.100)	(0.091)	(0.095)	(0.098)
GDPpc	−0.116	−1.082	−1.145	−0.925	−1.742*	−0.466
	(0.839)	(0.790)	(0.779)	(0.797)	(1.019)	(0.736)
EconFREE	−0.009	−0.002	0.398	−0.396	−0.611	0.449
	(0.717)	(0.685)	(0.760)	(0.739)	(0.756)	(0.805)
EXCHrate	0.605***					
	(0.211)					
FDI		−0.308***				
		(0.074)				
ECONuncertain			0.176			
			(0.166)			
ISLAND				1.179		
				(0.903)		
FINglobal					0.106**	
					(0.049)	
CBindependence						0.309
						(1.763)
Observations	155	155	155	155	155	143
R-squared	0.411	0.399	0.375	0.378	0.382	0.443
Number of countries	53	53	53	53	53	49
First stage F-stat	14.45	13.94	12.97	13.55	15.05	12.12
Underidentification test[a]	0.000	0.000	0.000	0.000	0.000	0.000
Overidentification test[b]	0.584	0.614	0.654	0.877	0.299	0.766
Anderson-Rubin Wald test[c]	0.060	0.103	0.069	0.067	0.003	0.005

Table 1 for variable details. Each specification uses instrumental variables to predict the values of Informal1. The instruments used are COLONY, REGION, and CORRUPTION.

Standard errors, reported in parentheses, are robust against clustering effects at the income per capita level of a country and panel-specific heteroskedasticity. Squared brackets contain 95% confidence interval. All the specifications include a constant and year dummies, but are not reported. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

a.The numbers are the p-values of the Kleibergen-Paap rk LM statistics. The null hypothesis is that the first-stage equation is underidentified.

b.The numbers are the Hansen J statistics. The null hypothesis is the joint test that all instruments are valid.

c.Anderson-Rubin Wald test. It tests the null hypothesis that the coefficients of the endogenous regressors in the structural equation are jointly equal to zero and overidentifying restrictions are valid.

[14]Given the modest number of observations in our analysis, it is necessary to avoid using too many instrumental variables e.g. Hansen, Hausman, and Newey (2008). Therefore, COLONY represents a former British colony with respect to all other colonies and non-colonies; while REGION is regional location of a country, varying from 1 to 7, with higher numbers representing countries in the Southern or Eastern regions of the globe.

Table 4. Spillovers from the underground economy to cryptocurrency: robustness check with an alternate measure of the underground economy.

	Dependent variable: CRYPTO					
Model →	(4.1)	(4.2)	(4.3)	(4.4)	(4.5)	(4.6)
Informal2	0.314***	0.217***	0.261***	0.271***	0.218***	0.373***
	(0.064)	(0.047)	(0.070)	(0.055)	(0.027)	(0.078)
GDPpc	0.734	−0.115	−0.149	0.014	−1.593***	−0.809**
	(0.700)	(0.484)	(0.560)	(0.365)	(0.612)	(0.361)
EconFREE	−1.940***	−2.354***	−1.859***	−2.457***	−3.001***	0.425
	(0.642)	(0.629)	(0.653)	(0.672)	(0.402)	(1.096)
EXCHrate	0.378**					
	(0.168)					
FDI		−0.250***				
		(0.065)				
ECONuncertain			0.314***			
			(0.118)			
ISLAND				−0.189		
				(1.127)		
FINglobal					0.149***	
					(0.036)	
CBindependence						1.197
						(1.612)
Observations	155	155	155	155	155	143
R-squared	0.892	0.883	0.896	0.908	0.933	0.878
F-test (p-value)	0.000	0.000	0.000	0.000	0.000	0.000
Number of countries	53	53	53	53	53	49

See Table 2.

Schneider 2010; Goel and Saunoris 2017, 2019), and shadow activities might have colonial legacies (Goel and Nelson 2016).

The different diagnostic tests support the instrument choice and the results generally (reported towards the bottom of Table 3) support what was reported in Table 2. Our main hypothesis of complementarity between the shadow economy and cryptocurrency holdings stands the test of potential endogeneity consideration.

Other considerations: considering an alternate measure of the shadow economy

Given the issues with adequately measuring the underground sector (Frey and Weck-Hannemann 1984), it seems useful to test the validity of the findings with an alternative measure of the shadow economy.

Accordingly, Table 4 tests the robustness of the results in Table 2 by employing Informal2 as the main independent variable. Although, the correlation between Informal1 and Informal2 is high (Table A2), this exercise adds some validity tests. The results quite closely support what is reported in Table 2. Importantly, the main hypothesis of positive spillovers from the shadow economy on cryptocurrency holdings is supported. Thus, tying to the title of the paper, shadow economy and cryptocurrency are complements. The concluding section follows.

V. Conclusions

The recent influx of digital currencies, with their global trading reach and relative anonymity, has provided new avenues for the public to trade and store/conceal earnings and this has challenged policymakers to effectively manage/monitor financial transactions. The rapid, mostly unregulated, growth of digital currencies in certain nations has induced some United Nations bodies to advise caution or restrain in their use (https://news.un.org/en/story/2022/08/1124362).

This paper examines the spillovers from the shadow or the underground sector onto cryptocurrency holdings, using data from a large sample of countries. Whereas different aspects of digital currencies have been studied in recent years (e.g. Bal (2015), Bradbury (2013), Coca and Nistor (2022), Schilling and Uhlig (2019)), the nexus between cryptocurrencies and the shadow economy studied

in this paper appears to be unique. It seems plausible that the relatively secretive nature of both underground activities and digital currencies would induce some complementarity in their prevalence. Besides adding to the literature, the results have implications for the effective management of digital currencies and the channels that might affect them.

Our empirical results show positive spillovers from the shadow sector on cryptocurrency holdings, and this finding is robust to considerations of potential endogeneity and the measurement of the shadow economy. The complementarity between the underground economy and cryptocurrency holdings is a new insight into the literature on the effects of the shadow economy (Schneider and Enste 2000). An implication of this is that as nations are able to control shadow economies, such efforts might have payoffs in terms of their abilities to manage digital currencies.

On the other hand, periods of greater economic uncertainty would be associated with the flight of some capital to digital currencies. Thus, monetary policies to lower economic uncertainty would result in likely unforeseen spillovers on digital currency holdings. This finding can be seen as complementary to studies that have examined the effects of uncertainty on other investments (e.g. Dixit and Pindyck (1994), Goel and Ram (1999)).

Furthermore, the effects of economic prosperity (denoted via GDPpc), negative in all cases and statistically significant in about a third, are consistent with the favour that digital currencies are finding in developing nations. Finally, we find that nations with greater net FDI inflows have lower cryptocurrency holdings, ceteris paribus. The tradeoff between FDI inflows and cryptocurrency holdings does not seem to be generally recognized. On the other hand, a nation's greater financial globalization increases cryptocurrency holdings (due to greater information and lower transaction costs).

As corresponding data on more nations and years become available, additional aspects of the emerging diffusion of digital currencies can be studied. An interesting avenue for future research, for example, would be to see to what extent cryptocurrencies are able to impact traditional banking. Another aspect that requires greater formal research relates to a formal determination of the limitations of crypto markets.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendix

Table A1. Income classifications and regional distribution of sample countries.

Country	Income class	Region	Country	Income class	Region
Argentina	UME	LAC	Pakistan	LME	South Asia
Australia	HIE	EAP	Peru	UME	LAC
Austria	HIE	W. Europe	Philippines	LME	EAP
Belgium	HIE	W. Europe	Poland	HIE	W. Europe
Brazil	UME	LAC	Portugal	HIE	W. Europe
Canada	HIE	N. America	Romania	UME	EECA
Chile	HIE	LAC	Russia	UME	EECA
China	UME	EAP	Saudi Arabia	HIE	MENA
Colombia	UME	LAC	Singapore	HIE	EAP
Czechia	HIE	W. Europe	South Africa	UME	ESA
Denmark	HIE	W. Europe	South Korea	HIE	EAP
Dominican Republic	UME	LAC	Spain	HIE	W. Europe
Egypt	LME	MENA	Sweden	HIE	W. Europe
Finland	HIE	W. Europe	Switzerland	HIE	W. Europe
France	HIE	W. Europe	Thailand	UME	EAP
Germany	HIE	W. Europe	Turkey	UME	EECA
Greece	HIE	W. Europe	UAE	HIE	MENA
Hungary	HIE	W. Europe	UK	HIE	W. Europe
India	LME	South Asia	USA	HIE	N. America
Indonesia	LME	EAP	Vietnam	LME	EAP
Ireland	HIE	W. Europe			
Israel	HIE	MENA			
Italy	HIE	W. Europe			
Japan	HIE	EAP			
Kenya	LME	ESA			
Lithuania	HIE	W. Europe			
Malaysia	UME	EAP			
Mexico	UME	LAC			
Morocco	LME	MENA			
Netherlands	HIE	W. Europe			
New Zealand	HIE	EAP			
Nigeria	LME	WCA			
Norway	HIE	W. Europe			

$N = 53$. The number of countries in specific models varies due to missing data.
This table uses information from *United Nations World Economic Situation and Prospects* 2022 annexure.
UME = upper-middle income economy; HIE = high income economy; LME = lower middle income economy; LIE = low income economy.
LAC = Latin America and the Caribbean; EAP = East Asia and Pacific; MENA = Middle East and North Africa; ESA = Eastern and Southern Africa; WCA = West and Central Africa; W. Europe = Western Europe; and EECA = Eastern Europe and Central Asia.

Table A2. Correlation matrix of key variables.

	CRYPTO	Informal1	Informal2
CRYPTO	1.00		
Informal1	0.60	1.00	
Informal2	0.57	0.99	1.00

See Table 1 for variable details.
$N = 143$.