Covid Cash

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The advent of the Covid-19 pandemic has witnessed a strong uptick in paper currency demand across advanced economies, even as contactless methods surged ahead of cash in payments. This article explores these two contrasting phenomena, which are in fact continuations of much longer-term trends. The use of cash, while still important for small in-person transactions, has been declining as a share of overall consumer payments for decades, thanks to a steady stream of innovations including credit cards, debit cards, electronic transfers, and smartphone payment apps. For example, in the United States, paper currency accounted for 26 percent of the number of consumer payments in 2019 but only 6 percent in value terms, down from 40 percent and 14 percent, respectively, in 2012. Meanwhile, U.S. dollars in circulation have increased from $1.1 trillion in January 2012 to $1.8 trillion in January 2020, exploding to $2.1 trillion in December 2020. The same pattern remains if one excludes foreign holdings (50–60 percent of the total) and is found in most other advanced economies as well. Some argue that soaring currency demand contests the view that the world is headed to a cashless future, or even a "less-cash" society (see Bech et al. 2018; BIS 2020).

Should strong demand for paper currency be considered an unalloyed benefit in the helicopter money era? Many treasuries and

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central banks around the world seem to think so. After all, inflation appears to be dormant; the marginal cost of printing a 100 dollar bill to spend is on the order of 20 cents.

In this article, we reexamine this sanguine view of rapid paper currency growth, assessing it from the perspective of the *consolidated* government balance sheet. Along the lines of other recent studies, we find that the trend decline in interest rates has been a significant factor driving up demand for paper currency (along with high tax rates). Correspondingly, advanced country governments that raise funds by printing currency could do equally well by issuing public debt at extremely low interest rates. Indeed, in Europe and Japan, governments can borrow at negative interest rates, as far out as 30 years in the case of Germany. In such an environment, we argue, the true benefit to issuing paper currency in place of debt is quite small or even negative. This issue has been raised before (e.g., Gross 2016), but there are some subtleties. For example, if converting the entire paper currency supply to 10-year debt were to raise the debt/GDP ratio by, say, 7 percent, what would be the effect on interest rates and the implications for total interest paid on preexisting government debt?

We also consider a way to think about the seigniorage profits to the government from paper currency that considers that a large fraction of cash is held by the underground economy precisely because it is anonymous. Suppose that, instead of buying back the entire stock of paper currency with bond debt, the government creates a central bank digital currency (CBDC) and offers it as an option to anyone tendering paper currency in the buyback. The CBDC can be either a retail version (direct consumer deposits at the central bank) or a two-tier system, where the banking sector continues to intermediate. We conjecture that the demand for non-anonymous CBDC will be considerably less than the preexisting demand for paper currency (perhaps as much as 80 percent less). Given the very low interest rate environment, this option turns out to have only a relatively minor effect on the interest savings from issuing currency. But the government (and society) may gain, at the margin, from reduced tax evasion and crime. By this measure, the seigniorage revenues to the government as a whole on paper currency are likely deeply negative, even when interest rates are positive.

Finally, we examine the rationale that issuing paper currency debt might be a better way for the government to hedge against debt distress or future rises in interest rates since paper currency is

sometimes viewed as a zero-interest perpetual bond. However, this is quite misleading, since holders of paper currency have a "put" option. Crudely, most governments (including the United States) still accept paper currency for payment of taxes. But much more significantly, paper currency holders have the option of depositing their holdings at a bank, which will end up transforming it to bank reserves, with a maturity of close to zero.

Sharply Rising Cash Holdings and Steadily Declining Transactions Demand

We begin by exploring what is known about use of cash, the growing cash in transactions (as opposed to hoarding), and how the total demand for paper currency—including both hoarding and payments—varies across countries. Of course, precisely because cash is anonymous, usage is difficult to track, and direct evidence is thin. Most of what is known comes from central bank surveys that are very limited in scope and number.

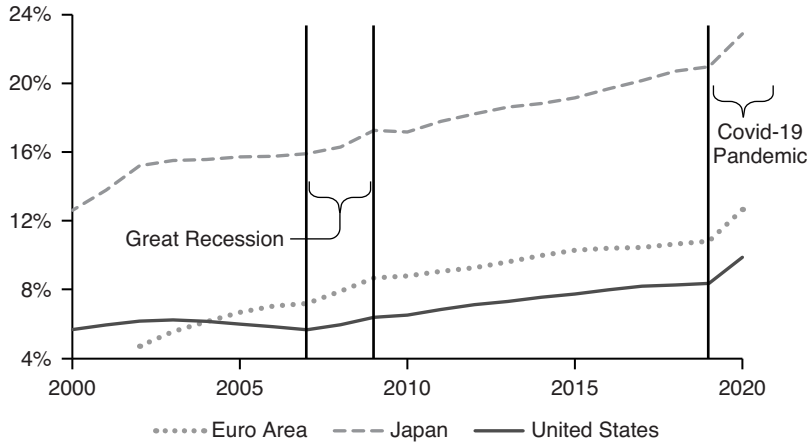
However, although direct data on cash usage in payments is sparse, there is extensive information on other payment media such as bank cards and electronic payments. Across countries, the value of these payment alternatives consistently has been growing significantly faster than consumption. This will allow us to infer with a very high probability that the use of cash in payments is steadily declining, with debit cards encroaching even on small retail payments, the last area (of legal, tax-compliant) transactions where cash remains king.

Currency Demand during Covid-19

Overall currency demand has soared after the Covid-19 shock in 2020, even more than after the financial crisis. For example, for the United States, currency in circulation rose by 9.5 percent in the 12 months between September 2008 and September 2009. But it rose by 12.5 percent in the 10 months from March 2020 to November 2020. This is all the more remarkable given that during 2008, cash demand was stoked in part by sharply lower interest rates, whereas interest rates were already at very low (or negative) levels at the outset of the Covid-19 shock.

Figure 1 illustrates the rise in currency in circulation as a share of GDP for the major advanced economies from 2000 to the present.

FIGURE 1
Currency in Circulation 2000–2020, United States, Euro Area, and Japan
(Percent of GDP)



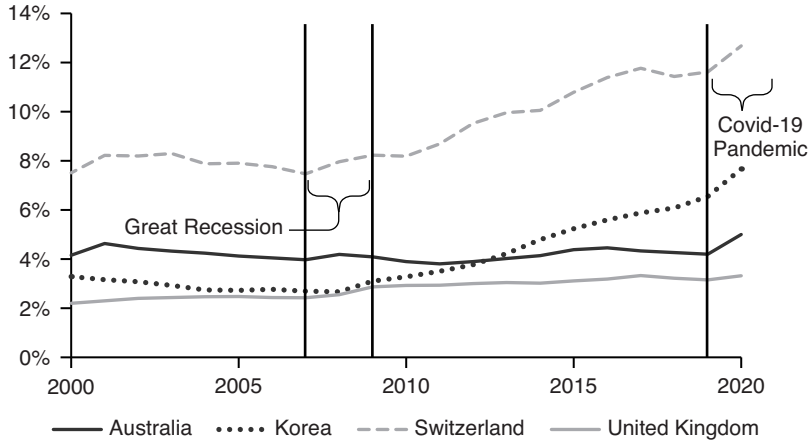
Data Sources: St. Louis Fed (FRED), Bank of Japan, European Central Bank, World Bank, and International Monetary Fund International Financial Statistics.

In the United States, currency in circulation rose by $276 billion (15.4 percent) in 2020, in Europe by €142 billion (11.0 percent), and in Japan by ¥5.69 trillion (4.8 percent). As Figure 2 illustrates, similarly sharp rises in currency demand in 2020 were also seen in smaller advanced economies, as well as the longer-term rise. As Table 1 illustrates for the United States, the Euro Area, Japan, and a set of smaller advanced economies, the bulk of the advanced economy currency supply is in large-denomination notes such as the $100 bill, as has long been the case (see Rogoff 1998, 2016).

Cross-Country Evidence on Determinants of Overall Currency Demand

Was the sharp rise in currency demand during Covid-19 mainly due to lower interest rates or was there a clear structural break in demand? Table 2 presents suggestive simple regressions of currency demand across a range of advanced economies, using

FIGURE 2
Currency in Circulation 2000–2020,
Other Advanced Economies
(Percent of GDP)



Data Sources: Reserve Bank of Australia, Bank of England, UK Office for National Statistics, Swiss National Bank, Bank of Korea, and International Monetary Fund International Financial Statistics.

government bond interest rates. In an appendix (available online), we show that similar results hold for the core regressions using monetary policy rates or deposit rates.[1] Both the interest rate and the tax/GDP ratio enter significantly across the regressions.[2] Interestingly, if we separate out demand between large bills and lower-denomination notes, the interest rate is significant only for the large bills.

Although one should be careful in interpreting these numbers, we note that from Table 2, in the baseline regression with the government bond interest rate and tax/GDP, the roughly 4 percent

[1]The online Regression Appendix is available at https://scholar.harvard.edu/files/rogoff/files/covid_cash_online_appendix.docx.

[2]The volume of debit card transactions (a measure of financial deepening) enters significantly in some of the appendix regressions, but not consistently across different maturity interest rates.

TABLE 1
Breakdown of Share of Largest Notes for Countries in Figures 1 and 2, End of Year 2020

Country	Value of Large Denom. Bills (as a % of total)	Bills
Australia	93.62%	A$100, A$50
Euro Area	91.06%	€50, €100, €200, €500
Japan	95.94%	¥5,000, ¥10,000
Switzerland	96.86%	₣50, ₣100, ₣200, ₣500, ₣1,000
United Kingdom	25.05%	£50
United States	85.82%	$50, $100, $500-$10,000

Note: Threshold for large denomination notes was roughly $50 and above.
Data Sources: Reserve Bank of Australia, European Central Bank, Bank of Japan, Swiss National Bank, Bank of England, Board of Governors of the Federal Reserve System.

TABLE 2
Base Regression across Advanced Countries, 2000–2018

Variables	(1) Total Cash to GDP	(2) High Denom. Banknotes to GDP	(3) Low Denom. Banknotes to GDP
Government Bond Interest Rate	−0.646***	−0.656***	0.00932
	(0.167)	(0.177)	(0.0337)
Tax / GDP	0.373***	0.381***	−0.00944
	(0.0789)	(0.0889)	(0.0211)
Constant	3.377***	2.226*	1.176***
	(0.995)	(1.156)	(0.304)
Observations	119	119	119
R-squared	0.516	0.518	0.012
Number of Countries	9	9	9
Country FE	Yes	Yes	Yes

Note: Robust standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

average drop in 10-year Treasury nominal interest rates since 2000 can account for a roughly 2.5 percent increase (4×0.64) increase in currency to GDP ratios.[3]

The Transactions Component to the Demand for Cash

Anonymity is a key feature of paper currency, and, although in principle it would be possible obtain retail transactions data from cash register receipts, no aggregate data source is available.[4] Most of what is known is based on a few rather small-scale surveys sponsored by central banks. In the United States, for example, the 2019 diary of consumer choice gives an estimate of the number and value of payments by instrument, and is used to construct Figure 3.

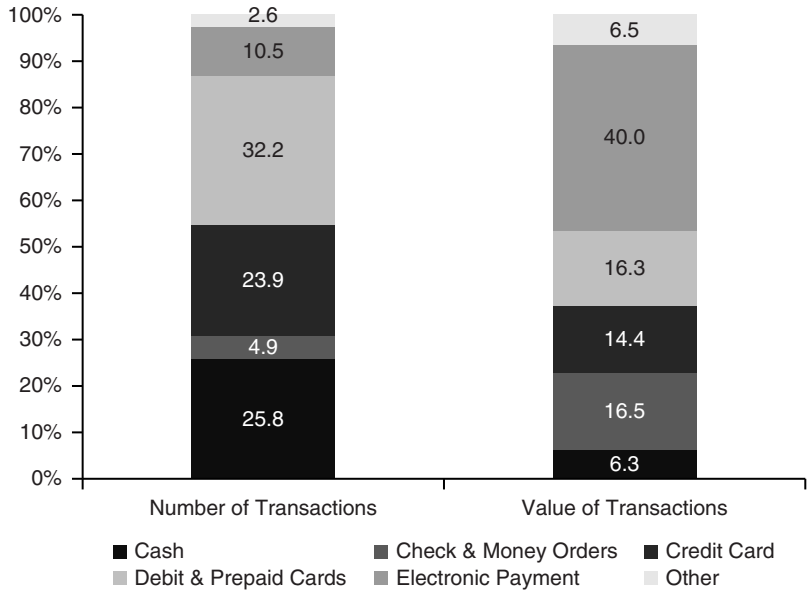
As Figure 3 illustrates, cash accounts for only a 6 percent share of the value of consumer payments, although it is 26 percent of the number of payments. In general, across advanced economies paper currency is mainly (albeit not exclusively) used for small payments, with checks, credit cards, debit cards, and electronic payments (bank account number payments and online banking bill payments) being used for larger payments. The same is true across advanced economies (Bech et al. 2018; Rogoff 2017). As the figure shows, the combined use of other mostly newer payment vehicles, including income deduction, PayPal, account-to-account transfers—using apps such as Zelle and Venmo—and mobile payments, have also far surpassed cash.

As noted in the introduction, both the number of transactions and the value of transactions in cash (at the bottom of Figure 3) are down sharply from just seven years earlier. Nevertheless, the average cash held (on person) in 2018 was roughly $60 (2019 is the

[3] A fixed-effects (FE) regression was carried out across a sample of nine countries (Australia, Canada, the Euro Area, Japan, Korea, Singapore, Switzerland, the United Kingdom, and the United States) from 2000 to 2018. Data were collected from the Bank for International Settlements (BIS) Red Book, IMF International Financial Statistics, Government Finance Statistics, and the World Bank National Accounts. See Stata Manual and Froot (1989) for more information on the methodology.

[4] In a few countries, including Sweden, cash registers incorporate a black box that transmits individual sales data directly to the Treasury. In principle, these data could be used to provide a rich lode of information on cash usage, but at present they are not publicly available (see Rogoff 2016).

FIGURE 3
Percentage Share of Payments by Number and Value, October 2019
(Percent of Total Payments)



Data Sources: Greene and Stavins (2020); Rogoff (2016: Figure 4.1; July 2020 update).

same) compared to $74 in 2012, and including cash held elsewhere $158 (versus $250 in 2012). These survey estimates, which incorporate only adults, are far below the over $5,000 circulating for every man, woman, and child in the United States, of which roughly 40 percent is being held inside the United States (Rogoff 2017).

The numbers for other countries, even "cash-loving countries" such as Germany, tell a broadly similar story, with currency per capita in circulation being an order of magnitude more than in survey data (Rogoff 2016, 2017).[5] We should point out that here we

[5] One outlier paper that gets completely different results than others is a 2017 ECB survey (Esselink and Hernandez 2017), which basically takes a one-time snapshot of small consumer purchases and concludes 80 percent are in cash. The much better data on other forms of payment make this conclusion highly questionable.

are discussing only consumer payments. Cash has long been marginalized in (legal, tax compliant) business-to-business payments (Porter and Judson 1996).

Digital Payments

Although data on cash payments are scarce and sporadic, there are excellent data available on digital payments, which increasingly constitute the vast majority of payments in value terms across advanced countries. Table 3 (illustrated graphically in Figure 4) breaks down the growth of bank cards, debit cards, and check payments over the last 18 years for the United States from the 2019 Federal Reserve Payments Study (Federal Reserve System 2019), both in absolute terms and relative to consumption growth (in current dollars). Table 3 shows that the volume (i.e., total aggregate value of payments) of debit cards has grown considerably faster than the volume of credit cards. The same data can be used to show that the average amount of the transactions has been falling. Indeed, bank cards are increasingly used for smaller and smaller payments. One striking development is that, in value terms, credit card expenditures online have now surpassed credit card expenditures in person. At the same time, consumers are substituting debit cards for cash in increasingly smaller payments.

While Table 3 and Figure 4 present U.S. data, Figure 5 gives a global picture by using the 10-K filings of the major credit card companies, including Mastercard, Visa, and American Express, which form a large fraction of the global market outside of China. Again, the total growth rate of card usage between 2013 and 2019 of 81 percent exceeds that of consumption. As Figure 6 illustrates, using PayPal quarterly reports through 2020, we find the use of electronic payments has actually accelerated during Covid-19, in terms of both total payment volume and total number of transactions.

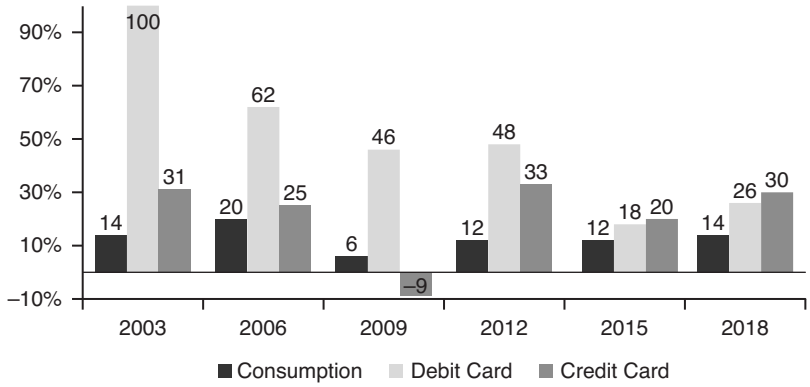
The trends are quite similar across all the major advanced economies, as Figure 7 illustrates. Bank card payments are growing far faster than consumption, even in cash-loving economies such as Germany. Although we do not have comprehensive payments data for other forms of noncash payments, the data we do have point to having other electronic payments forms (e.g., ACH) rising much faster than consumption as well. The only plausible conclusion is that

TABLE 3
U.S. Growth in Personal Consumption vs. Credit/Debit Card Volume, 2000–2018

	2000	2003	2006	2009	2012	2015	2018	Total Period
Consumption ($Billion)	$6,762	$7,723	$9,260	$9,842	$11,007	$12,297	$13,993	
Percent Change		14%	20%	6%	12%	12%	14%	107%
CAGR								4.12%
Total Triennial Growth								12.96%
Debit Card ($Trillion)	$0.30	$0.60	$0.97	$1.42	$2.10	$2.47	$3.10	
Percent Change		100%	62%	46%	48%	18%	26%	933%
CAGR								13.85%
Total Triennial Growth								49.85%
Credit Card ($Trillion)	$1.30	$1.70	$2.12	$1.92	$2.55	$3.05	$3.98	
Percent Change		31%	25%	−9%	33%	20%	30%	206%
CAGR								6.41%
Total Triennial growth								21.49%
Checks ($Trillion)	$39.80	$41.10	$41.60	$31.60	$27.21	$29.18	$25.80	
Percent Change		3%	1%	−24%	−14%	7%	−12%	−35%
CAGR								−2.38%
Total Triennial Growth								−6.30%

Note: CAGR is the compound annual growth rate.
Data Sources: Federal Reserve System (2019); St. Louis Fed (FRED).

FIGURE 4
Cash Growth Lags Consumption, while Bank Card Growth Exceeds It
(Percentage Change)



Data Sources: Federal Reserve System (2019); St. Louis Fed (FRED).

the value of payments made in cash continues to fall, in line with the survey evidence.[6]

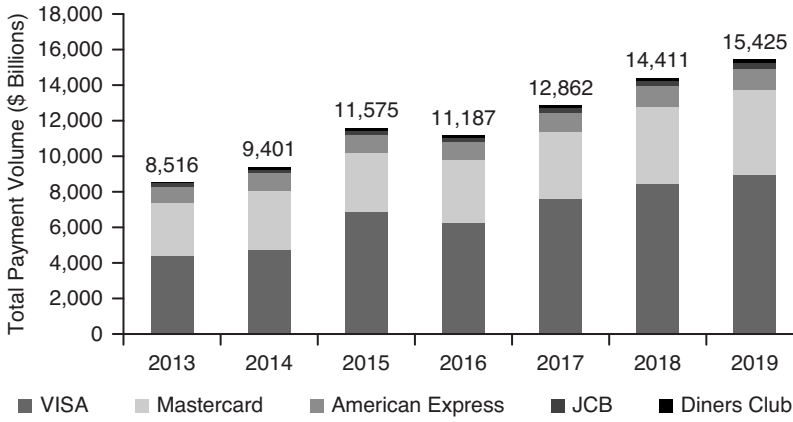
Others using various data sets have reached a similar conclusion on payment trends for the pre-Covid-19 era (e.g., Bech et al. 2018 and Rogoff 2016).[7]

We conclude that most of the rapid growth in demand for cash is for hoarding purposes, as opposed to use in consumer payments. This conclusion is certainly consistent with the well-known fact that the vast bulk of advanced-economy paper currency is held in the form of infrequently used high-denomination notes. (For example, the U.S. 100 dollar bill constitutes 80 percent of all dollar holdings). A wide body of evidence suggests that these notes are not commonly used in consumer payments. This leads

[6] It is true that, in the United States, the value of check payments has fallen slightly, but this decline is overwhelmed by the rise in electronic payments.

[7] These results, of course, apply only to the legal economy; hardly any data are available for the shadow economy, which is estimated to be on the order of magnitude of 8–25 percent of GDP in advanced economies, with countries such as Italy and Greece being on the high end, the United States and Switzerland on the low end, and Germany and France intermediate (see Rogoff 2016).

FIGURE 5
Growth in Credit and Debit Usage, 2013–2019



Data Sources: Nilsen Report and VISA 10-K filings.

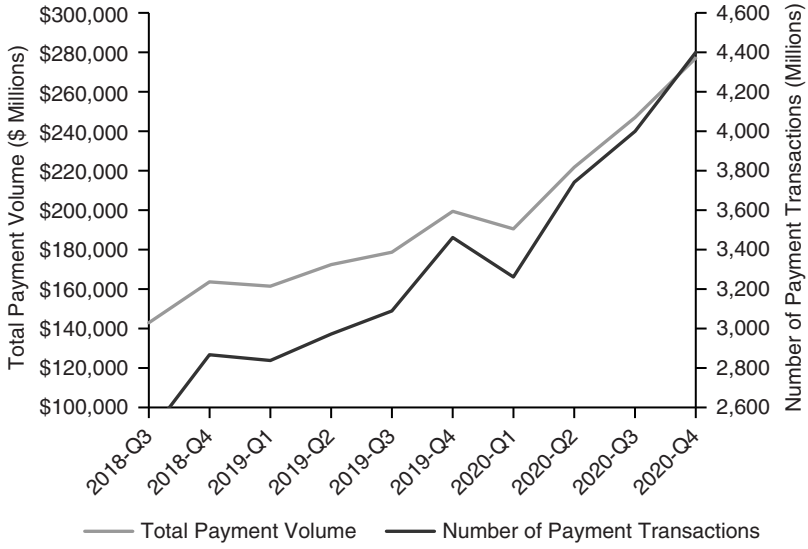
us also to consider the possibility that most paper currency in the underground economy is held by agents who would prefer not to hold standard government debt, because they could not do so anonymously.

Costs and Benefits of the Cash Explosion

There are two traditional ways of calculating seigniorage, that is, the government's profits from monopoly issuance of paper currency (see, e.g., Buiter 2007). The first measure of seigniorage is simply the net increase in the currency supply, $M_t - M_{t-1}$. For example, during 2020 the U.S. paper currency supply increased by a quarter of trillion dollars just in the first 10 months alone. Table 4 shows average seigniorage for 19 countries using this definition, taken as a ratio to GDP, or $(M_t - M_{t-1})/ P_tY_t$, where P_tY_t is the nominal income. This is the concept most often used in media coverage and is frequently highlighted in policy discussions. Not surprisingly, 2020 saw a sharp rise in this first measure of seigniorage, given that sharply falling interest rates raised currency demand while output temporarily collapsed.

But there is a second metric for seigniorage, arguably more suited to advanced economies in an era when the elasticity of the

FIGURE 6
Acceleration in Electronic Payment Usage throughout Covid-19

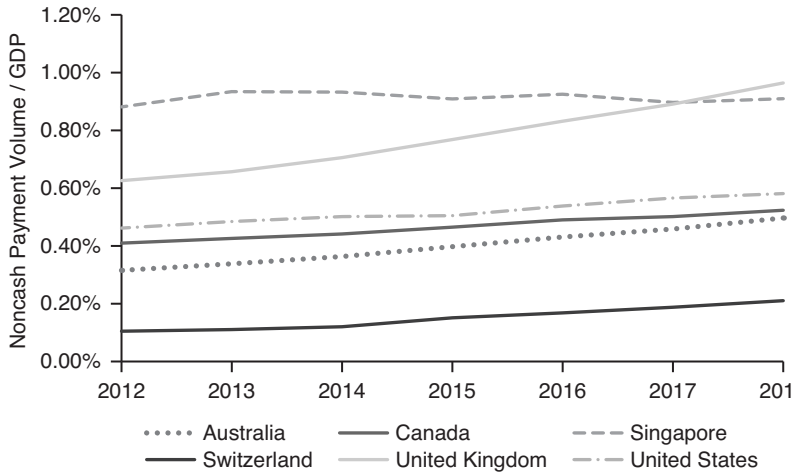


Data Source: PayPal Quarterly Reports.

interest rate with respect to rises in the level of debt appears to be very low: Suppose the government were to retire the outstanding money stock and replace it with interest-bearing government debt. What would be the added cost? This measure, as a ratio to nominal GDP, is given by $i_{t-1}M_{t-1}/P_tY_t$, where $i_{t-1}M_{t-1}$ is the interest that would have to be paid if the initial money stock was converted to debt. Of course, this second measure requires an assumption about the maturity of the debt that will be used to retire the currency. Although both definitions are referred to as "seigniorage" in much of the literature, for clarity we will follow Flandreau (2006) in terming this second definition "central bank revenue." This is only for labelling purposes since we are mainly concerned here with the consolidated government balance sheet, not the central bank balance sheet in isolation.[8]

[8] For a developing economy with little capacity to issue debt, and where the interest rate would rise rapidly with quantity in the face of significant new issuance, the central bank revenue concept of seigniorage has little relevance.

FIGURE 7
Cross-Country Evidence on Payments



Data Source: BIS Red Book Statistics.

Table 5 calculates the savings to the consolidated U.S. government balance sheet each year from 2010 to 2020 that would have accrued had the zero-interest currency supply been replaced by, alternatively, three-month debt or 10-year debt, calculated at the average interest rate for the year. The final two columns give the ratio of seigniorage (calculated this way) to GDP. The alternative measure of seigniorage implemented in Table 5 averages under two-tenths of a percent of GDP over the decade, less than half what the oft-used seigniorage measure presented in Table 4 gives.

Note in Table 5 that central bank seigniorage from currency has not been rising despite the steady rise in currency, and even dropped dramatically during the pandemic. The reason, of course, is that interest rates have been trending down sharply since the 2008–2009 financial crisis.

Table 6 calculates the central bank measure of seigniorage for a range of advanced economies for 2010–2020. For the United Kingdom, Canada, and Australia (for example), the seigniorage benefits from currency issuance are similarly small as for the United States. For the Euro Area, the calculation is much more complex, since until very recently there has been no significant European

TABLE 4
SEIGNIORAGE ACROSS COUNTRIES USING CHANGE IN THE MONEY SUPPLY
(PERCENT OF GDP)

	AUS	CAN	CHL	COL	EUR	HKG	ISR	JPN	MEX	NZL	NGA	NOR	SGP	ZAF	SWE	CHE	TUR	GBR	USA
2006	0.19	0.18	0.43	1.26	0.72	0.53	0.16	0.11	0.66	0.02	0.48	0.13	0.52	0.51	0.04	0.33	0.91	0.09	0.17
2007	0.53	0.11	0.54	0.70	0.53	0.47	0.47	0.28	0.39	0.07	0.54	0.04	0.45	0.22	0.06	0.18	0.07	0.10	0.06
2008	0.55	0.19	0.39	0.65	0.91	0.73	0.69	0.04	0.67	0.14	0.51	−0.02	1.18	0.19	−0.06	0.79	0.43	0.20	0.39
2009	−0.01	0.11	0.52	0.35	0.48	1.44	0.87	−0.11	0.45	0.11	0.06	−0.04	0.43	0.20	−0.05	0.13	0.66	0.25	0.28
2010	0.11	0.14	0.50	0.81	0.36	1.38	0.38	0.27	0.46	0.02	0.35	−0.01	0.76	0.18	−0.15	0.24	0.91	0.16	0.36
2011	0.19	0.18	0.42	0.72	0.51	1.52	0.44	0.34	0.48	0.14	0.29	0.03	0.69	0.62	−0.14	0.66	0.44	0.11	0.58
2012	0.21	0.15	0.72	0.40	0.25	1.65	0.58	0.54	0.52	0.07	0.09	−0.03	1.11	0.33	−0.10	0.94	0.34	0.15	0.56
2013	0.26	0.15	0.52	0.73	0.45	1.50	0.26	0.70	0.45	0.18	0.18	0.01	0.40	0.19	−0.28	0.60	0.78	0.16	0.42
2014	0.24	0.17	0.44	0.96	0.60	0.72	0.51	0.57	0.83	0.12	0.02	−0.03	0.66	0.32	−0.06	0.27	0.50	0.11	0.57
2015	0.31	0.27	0.53	1.29	0.65	0.80	0.88	1.00	0.95	0.15	0.06	0.00	0.77	0.16	−0.23	0.78	0.76	0.18	0.47
2016	0.23	0.25	0.14	0.29	0.40	1.65	0.21	0.75	0.90	0.07	0.31	−0.09	1.28	0.26	−0.25	0.76	0.76	0.20	0.44
2017	0.13	0.25	0.18	0.53	0.41	1.82	0.49	0.78	0.56	0.14	−0.02	−0.06	0.15	0.15	−0.10	0.51	0.27	0.25	0.54
2018	0.16	0.19	0.26	0.67	0.54	0.98	0.28	0.67	0.56	0.16	0.13	−0.10	0.63	0.21	0.09	0.08	0.02	0.00	0.48
2019	0.14	0.13	0.65	1.04	0.52	1.07	0.09	0.44	0.28	0.12	0.08	−0.09	0.65	−0.02	0.03	0.30	0.49	0.04	0.40
2020	0.74	0.63	2.02	1.97	1.26	1.61	NA	1.05	1.63	0.31	0.30	−0.02	1.06	0.24	−0.01	0.65	0.69	0.02	1.36
Avg.	0.26	0.21	0.55	0.82	0.57	1.19	0.45	0.49	0.65	0.12	0.23	−0.02	0.72	0.25	−0.08	0.48	0.54	0.13	0.47

DATA SOURCES: International Monetary Fund World Economic Outlook Database, International Monetary Fund International Financial Statistics, Hong Kong Monetary Authority, Statistics of Singapore, Swiss National Bank, Bank of England, European Central Bank.

TABLE 5
U.S. Central Bank Seigniorage from Currency ($i_{t-1}M_{t-1}/P_tY_t$), 2010–2020
(Percent of GDP)

	CiC ($ Billions)	3-Month Treasury Rate	10-Year Treasury Rate	Seigniorage (3-Month Rate)	Seigniorage (10-Year Rate)
2010	$945.64	0.14%	3.22%	0.01	0.20
2011	$1,023.45	0.05%	2.78%	0.00	0.18
2012	$1,112.80	0.09%	1.80%	0.01	0.12
2013	$1,193.20	0.06%	2.35%	0.00	0.17
2014	$1,279.13	0.03%	2.54%	0.00	0.19
2015	$1,371.52	0.05%	2.14%	0.00	0.16
2016	$1,457.53	0.32%	1.84%	0.02	0.14
2017	$1,555.44	0.95%	2.33%	0.08	0.19
2018	$1,661.46	1.97%	2.91%	0.16	0.23
2019	$1,745.10	2.11%	2.14%	0.17	0.17
2020	$1,947.41	0.36%	0.89%	0.03	0.08

Note: CiC is currency in circulation; both interest rates and CiC are average annual statistics.
Data Source: St. Louis Fed (FRED).

Union (EU) debt to use for an interest rate, and the ECB in fact disproportionately holds the debt of the weaker southern countries.[9] We note, however, that the 10-year bond yield on the new pandemic relief EU debt is actually negative (Bloomberg 2020). Of course, ECB liabilities play a very different role in the multicountry Euro Area than in a single country with its own central bank. In essence, ECB reserves constitute a de facto Eurobond.

As already noted, an important assumption embedded in Tables 5 and 6 is that issuing debt to replace currency will not raise interest rates. Relaxing this assumption is complex since government debt typically has a rich maturity structure. However, just to get an order of magnitude, if in the long run the average interest rate on U.S. debt

[9] Table 6 for the euro employs ECB weighted average measure of yields on Euro Area central government bonds. Capital shares in the ECB can be found at www.ecb.europa.eu/ecb/orga/capital/html/index.en.html.

TABLE 6
CENTRAL BANK SEIGNIORAGE FROM CURRENCY ($i_{t-1}M_{t-1}/P_tY_t$) IN ADVANCED COUNTRIES, 2010–2020
(PERCENT OF GDP)

	United States		Canada		Euro Area		Japan		Switzerland		Australia		United Kingdom	
	3-mos	*10-year*	*3-mos*	*10-year*	*3-mos*	*10-year*	*3-mos*	*10-year*	*3-mos*	*10-year*	*3-mos*	*10-year*	*3-mos*	*10-year*
2010	0.01	0.20	0.02	0.11	0.03	0.32	0.02	0.19	0.01	0.12	0.17	0.20	0.01	0.11
2011	0.00	0.18	0.03	0.10	0.05	0.37	0.02	0.19	0.01	0.11	0.17	0.17	0.01	0.09
2012	0.01	0.12	0.03	0.07	0.00	0.27	0.02	0.14	−0.01	0.06	0.13	0.12	0.01	0.06
2013	0.00	0.17	0.03	0.08	0.00	0.28	0.01	0.12	−0.01	0.09	0.10	0.14	0.01	0.07
2014	0.00	0.19	0.03	0.08	0.00	0.22	0.01	0.09	−0.01	0.06	0.10	0.14	0.01	0.08
2015	0.00	0.16	0.02	0.06	−0.03	0.13	0.00	0.06	−0.10	−0.01	0.09	0.11	0.01	0.06
2016	0.02	0.14	0.02	0.05	−0.06	0.09	−0.04	−0.01	−0.09	−0.04	0.08	0.10	0.01	0.04
2017	0.08	0.19	0.03	0.07	−0.08	0.12	−0.03	0.01	−0.10	−0.01	0.07	0.11	0.01	0.04
2018	0.16	0.23	0.06	0.09	−0.07	0.13	−0.03	0.01	−0.09	0.00	0.08	0.11	0.02	0.05
2019	0.17	0.17	0.07	0.06	−0.07	0.06	−0.04	−0.02	−0.10	−0.05	0.05	0.06	0.02	0.03
2020	0.03	0.08	0.02	0.04	−0.08	0.03	−0.03	0.00	−0.11	−0.06	0.01	0.04	0.00	0.01

DATA SOURCES: St, Louis Fed (FRED), IMF International Financial Statistics, European Central Bank, Bank of Japan, Swiss National Bank, Reserve Bank of Australia, Bank of England, and Bank of Canada.

went up by 0.1 percent, this would add an extra $23 billion per year to the carrying cost of today's debt levels. The interest elasticity with respect to debt would presumably be much higher if all advanced economies were to retire their paper currency supplies at once, though it should be noted that the United States accounts for almost half of all advanced economy public debt trading in private markets (Ilzetski, Reinhart, and Rogoff 2020).

One might ask why the interest rate would need to go up at all if holders of currency were simply swapping one type of debt for another. Aren't the two forms of debt close enough substitutes that very little price movement would be required? Not necessarily. As noted earlier, it is quite possible that the demand for currency derives mainly from a very segmented part of the market (the underground economy) that might have a very strong preference for anonymous debt. Even if the loss of this "clientele" did not have a big impact in the near term, it could matter much more at a later date.

One way to underscore the importance of the underground economy in paper currency demand is to consider a third measure of seigniorage in addition to the traditional two measures we have already considered. Our third measure asks the question, suppose the central bank creates a central bank digital currency, and that it pays zero interest like currency (this is how China's prototype central bank digital currency is currently designed). However, unlike cash, CBDC is no more anonymous than other traded debt.[10] Instead of trading only interest-bearing debt for paper currency, the central bank offers all paper currency holders the option of trading their paper currency for CBDC. Otherwise, they can launder their holdings back into the real economy, and then over time the central bank will soak up the excess cash with open market sales of debt. Given the earlier estimates we presented of reported cash holdings, and even considering other legal cash holdings (mainly in bank ATM machines), it seems quite likely that the long-run demand for non-anonymous CBDC would be considerably less than present-day demand for paper currency. Assuming a positive interest rate on government debt, the direct gains to this exercise, which we

[10]The ECB, however, has explored ways to issue small value payment cards that allow complete anonymity (see ECB 2019).

shall term "consolidated government revenue from anonymous currency," would be proportionately smaller by the amount held in non-anonymous CBDC. Thus, the direct gain from anonymous currency revenue is $\mu(i_{t-1}M_{t-1}/P_tY_t)$, where $0 < \mu < 1$ represents the share of currency demand that would evaporate if currency were not anonymous. Put differently, the CBDC allows those who are willing to hold zero interest government debt the ability to do so in digital form, and, when interest rates are positive, the government manages to keep some of its seigniorage revenues this way. But the demand for CBDC would likely be far lower than it currently is for anonymous paper currency.

To the extent that the demand for CBDC is much less than for paper central bank currency, central bank seigniorage revenues will be lower by any measure. But the rest of the government may gain much more than the central bank loses if paper currency can still be used to facilitate tax evasion and crime. (Large-denomination notes in particular, which constitute the bulk of paper currency holdings for most countries, are heavily used in the underground economy because they are relatively easy to transport and hide.) Let us label the revenue cost to the government due to how currency facilitates tax evasion/crime as α (a percent of GDP). Rogoff (1998, 2016) presents evidence that these tax evasion and crime costs are at least on the order of classic seigniorage revenue estimates and likely much larger, and this is not even considering the other social costs of criminal activity. Federal tax evasion alone is estimated at $500 billion in the United States, and is likely much higher as a share of GDP in most European countries where taxes are higher (a variable that, as we saw earlier, is consistent with cross-country differentials.) The annual costs of crime and crime fighting certainly run into the hundreds of billions of dollars. If on the margin, the use of cash (especially large-denomination notes) raises either or both by even a few percent, the costs far outweigh the gains from seigniorage.

Indeed, considering the indirect costs, and recognizing that in advanced economies the central bank revenue measure of seigniorage is likely closer to the relevant one, we see that consolidated government revenue from anonymous currency, $\mu(i_{t-1}M_{t-1}/P_tY_t) - \alpha$, is likely significantly negative, and has been for decades. That is, the consolidated government has long been losing income, not making a profit, by issuing paper currency.

Currency Issuance as a Public Finance Hedge

Finally, we turn to the question of how much of a hedge cash issuance provides in the event that global interest rates rise, either because there is upward pressure on real rates or if inflation makes a reappearance. A rise in real interest rates or in expected inflation would force governments to pay higher nominal interest rates on ordinary nominal debt. All else equal, this would raise the value of central bank seigniorage. However, cash demand would fall, and potentially quite significantly. From our point estimate for the United States in Table 2, the long-term demand for cash balances, relative to nominal GDP, would fall by 0.65 percent with a 1 percent rise in the steady state Treasury bill rate. This estimate is in line with other estimates, for example, Bech et al. (2018).

If the demand for paper currency drops in the aggregate, the central bank will either have to allow inflation or convert the currency to ordinary interest-bearing debt through open market operations. Indeed, in the first instance as consumers shed currency, it will end up being converted to bank reserves, which effectively have a maturity of one day. Thus, cash offers very limited optionality for a government facing fiscal distress, and in fact gives the government much less insurance against, say, rising real interest rates than do long-term bonds.

In sum, if rising rates and greater economic stability led to falling currency demand, headline seigniorage calculations could turn sharply negative for many countries—even if central bank revenue by our preferred "opportunity cost" calculation stayed positive.

Conclusion

Both the direct and indirect evidence strongly suggest that the use of paper currency in transactions is steadily declining. However, the overall private demand for currency is rising, particularly reflecting demand for large-denomination notes. In this article, we argue that the actual direct seigniorage benefits to most advanced economies are extremely small, despite the large headline numbers. Considering the collateral damage that large bills cause in undermining tax systems and facilitating crime, the costs to the consolidated government are negative. Finally, if hoarding rather than transaction demand has become the main motive, it is extremely misguided to view currency demand as "perpetual debt" that never needs to be

redeemed. In fact, currency is better viewed as perpetual debt with a put option that the holder can choose to exercise with no expiry date. If inflation and interest rates were to rise, the hoarding demand will likely prove much less sticky than classical transactions demand. In conclusion, to view the rapid rise in currency as a huge bonanza, as many policymakers appear to do, is naïve.

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