Withering Cash: Is Sweden Ahead of the Curve or Just Special?*

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Cash in circulation has increased in most countries but has fallen dramatically in Sweden. We explore the drivers behind this development using panel data consisting of 129 countries. In line with the previous literature, we find that GDP, demography, and the interest rate are key explanatory variables. A new finding is that lower corruption is associated with lower demand for cash in developed countries. Our empirical model performs relatively well in explaining the developments in most OECD countries. However, our model cannot explain the divergent Swedish development. We argue that a unique combination of events and policy measures have led to the decline of cash in Sweden.

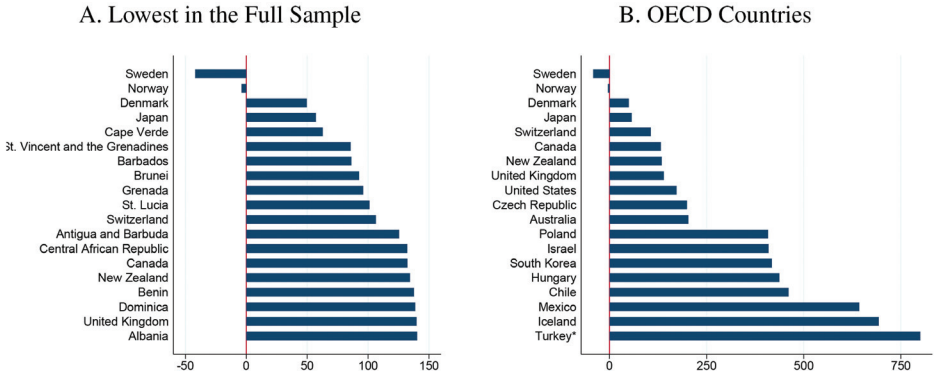
JEL Codes: E41, E42, E51.

1. Introduction

There is much in our increasingly digitized economies to suggest that the use of (physical) cash should be falling. For example, the number of online purchases is increasing; digital payments at physical points of sale are widespread; and payment applications for smartphones

*We would like to thank Niklas Amberg, Thomas Jansson, Franz Seitz, two anonymous referees, and the participants in the seminars held at the Sveriges Riksbank for comments and suggestions. Armelius conducted most of her work on this paper while employed at Sveriges Riksbank. The opinions expressed in this article are the sole responsibility of the authors and should not be interpreted as reflecting the views of Confederation of Swedish Enterprise, or Sveriges Riksbank or its Executive Board. Author e-mails: hanna.armelius@ekonomifakta.se; carlandreas.claussen@riksbank.se; andre.reslow@riksbank.se.

Figure 1. Percentage Change in Currency in Circulation between 2001 and 2018



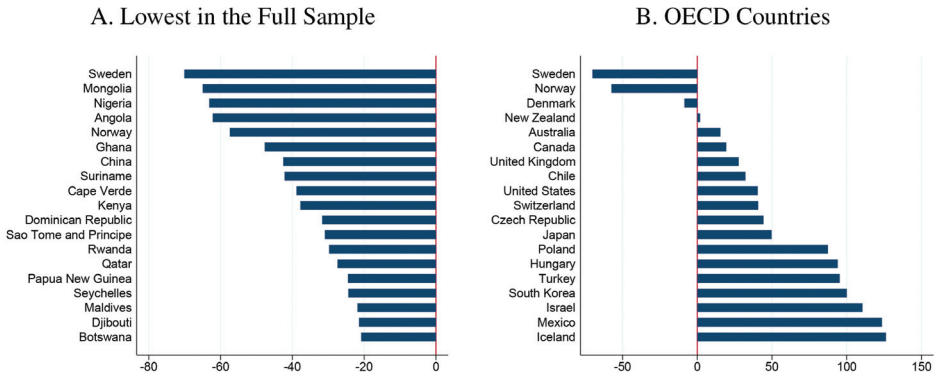
Note: In graph A we show the development for the 19 countries with the lowest increase in our sample, while graph B shows the development for all the OECD countries in our sample. *For illustrative purposes, the graph shows an increase of 800 percent for Turkey, while the actual increase was 2,864 percent.

and other mobile devices are advancing fast. This makes digital payments cheaper and more convenient, and also allows for non-cash payments in situations where cash used to be the only option.

However, the amount of cash in circulation keeps increasing (Figure 1). In many countries—for instance, the United States—the increase has been more than 170 percent since 2001. The growth in cash has even surpassed the growth of the economy in most countries (Figure 2). Sweden stands out as a notable exception since cash in circulation has fallen by almost 50 percent there. Cash as a share of GDP has fallen by even more and now stands at less than 1.5 percent. Neighboring Norway has experienced a similar, but less pronounced, development.

How can we explain the differences in the growth of cash in circulation in different countries? Are Sweden and Norway just ahead of the others, or is there something special about them? Can other countries expect a similar development in the near future? What drives the demand for cash more generally? In this paper, we address these questions. They have become even more relevant during the COVID-19 pandemic when the use of cash for transaction purposes

Figure 2. Percentage Change in the Cash-to-GDP Ratio between 2001 and 2018



Note: In graph A we show the development for the 19 countries with the lowest increase in our sample, while graph B shows the development for all the OECD countries in our sample.

has fallen in many countries, while the use of cash for store of value has increased.[1]

Understanding what drives the development of cash is important for several reasons. One is that cash payments can be more costly for society than digital payments (see, e.g., Schmiedel, Kostova, and Ruttenberg 2012).[2] Another is that cash might facilitate criminal activity. Some countries may therefore want to understand how they can reduce the use of cash. Conversely, cash may be fundamental to our monetary systems, as it enforces the uniformity of money and makes commercial bank money appear less risky (see, e.g., Armelius, Claussen, and Hendry 2020). Furthermore, cash facilitates anonymous payments and competition in the payment market; cash enhances economic resilience and seigniorage revenues; and cash makes it possible for everyone to make their daily payments. Some

[1] See, for example, Ashworth and Goodhart (2020a) and Heinonen (2020) for a global survey. However, Sweden continues to be an outlier with non-increasing cash in circulation (Sveriges Riksbank 2020).

[2] For an alternative view, see Carbo-Valverde and Rodriguez-Fernandez (2019).

also argue that cash protects against "digital dollarization."[3] Countries may therefore want to stop a potential marginalization of cash. Whatever the reasons may be, if we want to influence the development of the amount of cash in circulation, we need to understand what drives it.

We use an extensive data set consisting of 129 countries and covering the years 2001 to 2018 to explore if econometric models can explain the development of cash in general, and the Swedish divergence in particular. Panel regressions using the full sample suggest that economic development is a key explanatory variable. In general, richer countries have less cash in circulation relative to GDP. In line with the previous literature, we also find that increases in the opportunity cost of cash (the interest rate) reduce cash demand, while a higher average age of the population increases cash demand. When we limit the sample to OECD countries, higher corruption is associated with higher demand for cash.

Our main specification performs well in explaining the development in most OECD countries. However, it cannot explain the development in Sweden, where the model fit is more than twice as bad as for any other country. We therefore discuss potential explanations as to why Sweden is "unexplained" by the model. More specifically, we discuss Swedish policy measures to reduce tax evasion; an aggressive banknote and coin changeover; the introduction of a new mobile payment application; as well as a few other recent events in Sweden. These policy measures and developments appear to have affected access to, and demand for, cash. Thus, while our estimations do not indicate that all countries will soon see a reduction in cash in circulation, the Swedish experience suggests that countries that simultaneously implement a combination of reforms that make cash less attractive and electronic payments more convenient may see a significant reduction in the use of cash.

This paper contributes to the literature in the following ways. First, our study covers a large number of countries, providing results for both developed and developing countries. Second, we consider variables that are often excluded in cash demand studies, such as

[3] "Digital dollarization" is a situation in which the national currency is supplanted by a digital platform's currency rather than another developed country's currency (Brunnermeier, James, and Landau 2019).

corruption, trust, and technology adaptation. Third, we provide a thorough discussion of events and institutional settings that can help us understand the divergent development in Sweden relative to other countries. The latter is highly policy relevant, since the development in Sweden is often in the spotlight in international policy discussions.

The paper proceeds as follows. The next section provides an overview of the relevant literature. Section 3 describes the data, while Section 4 explains the empirical strategy. Section 5 presents the main estimation results, and Section 6 discusses the predictions of the model in comparison to actual developments. Section 7 discusses potential reasons why the model cannot explain the development in Sweden, and Section 8 concludes.

2. Related Literature

Theories of cash demand often start from the Baumol (1952)–Tobin (1956) inventory model and predict that cash demand will be increasing in income or spending, decreasing in the opportunity cost of holding cash, and increasing in the cost of acquiring cash. Keynes's (1937) three motives for holding cash give similar predictions and also suggest that people will hold higher cash balances when there is increased uncertainty.

The empirical literature on money demand, taking theory as a starting point, is vast. Most relevant for us are the more recent papers where researchers estimate cash demand relations.[4] A robust finding in these papers is that cash in circulation increases with GDP and falls with the interest rate, in line with what theory predicts. Evidence is mixed for the cost of acquiring cash; some find negative effects of the number of ATMs and bank branches and some find positive effects. There is scarce empirical evidence to support that increased uncertainty would increase cash balances. Furthermore, there is evidence that increased penetration of electronic payment

[4]See, for example, Amromin and Chakravorti (2009); Arango-Arango and Suárez-Ariza (2019); Ashworth and Goodhart (2020b); Assenmacher, Seitz, and Tenhofen (2019); Bech et al. (2018); Cusbert and Rohling (2013); Huynh, Schmidt-Dengler, and Stix (2014); Jobst and Stix (2017); Seitz, Fischer, and Köhler (2004); Shirai and Sugandi (2019).

alternatives reduces the demand for cash. Papers that include proxies for the informal sector tend to find positive effects, albeit not always significant. Finally, papers that include some measure of the average age of the population usually find that it has a positive effect on cash demand. We summarize all these potential explanatory factors often used in the empirical literature, and variables used to capture these factors, in Table 1.[5]

3. Data

Our variable of interest is currency in circulation (CiC), specifically the ratio between CiC and GDP.[6] This ratio is convenient since it allows us to compare countries without worrying about exchange rates, and it has a simple theoretical interpretation as the inverse of money velocity. Our data span the period 2001–18, and consist of 129 countries, out of which 19 are OECD members. We exclude countries for which we could not find key data and countries in the European Monetary Union. The sample period is mainly defined by the CiC data availability in the International Monetary Fund (IMF) database. All the countries in our final sample are listed in Table A.1 in the appendix.[7]

In addition to CiC and GDP, we collect a large number of potential explanatory variables, both standard variables from the existing literature and some new ones. Among the variables in Table 1, we have collected data on GDP per capita, the interest rate, the share of self-employed, uncertainty, and the old-age dependency ratio.[8] We

[5]Other related studies, but somewhat less relevant for our study, include empirical papers using microdata and theoretical papers that study consumer behavior and cash usage (see, e.g., Alvarez and Lippi 2009; Attanasio, Guiso, and Jappelli 2002; Bagnall et al. 2016; Wakamori and Welte 2017; Wright et al. 2017). See also Bartzsch, Rösl, and Seitz (2013) for the role of foreign demand.

[6]Currency (or cash) in circulation refers to the outstanding amount of money in the form of notes and coins issued by the central bank and/or government.

[7]We focus on those countries where we observe CiC throughout 2001–18. For Djibouti, we extrapolate using a spline function to obtain a missing value in 2001.

[8]We use the short-term interest rate from the OECD database. When the OECD interest rate data are unavailable, as they are for most countries in our full sample, we create a measure that is the mean of four different short-term interest rates (the deposit rate, the money market rate, rates on government T-bills, and the central bank policy rate) from the IMF's International Financial Statistics (IFS) database. For many countries, only a subset of the four rates is

Table 1. Explanatory Factors in the Literature

Explanatory Factor	Variables	Estimated Coefficient
Scaling Factor	GDP, GDP per capita	+
Alternative Cost	Interest Rates	–
Cost of Withdrawing Cash	Number of ATMs, Number of Bank Branches	+/–
Uncertainty	"Uncertainty Index," Crisis Dummy	+/No Effect
Ease of Electronic Payments	Number of EFTPOS Terminals	–/No Effect
Informal Sector	Share Shadow Economy	+/No Effect
Small Business	Ratio of Self-Employed	+
Age Structure	Life Expectancy, Old-Age Dependency Ratio	+

Note: The signs refer to the factor and not the variable. As the elasticities in different studies are not directly comparable, we only refer to the signs. The listed variables represent a selected sample of commonly used variables.

have also considered variables like the number of ATMs, commercial bank branches, and debit/credit card ownership, but decided to leave them out of our final data set, for two main reasons. First, these variables are likely to be determined in tandem with cash demand and will therefore lead to simultaneity bias in the estimations. Second, when included in the estimations, we find no clear relationships, and our main coefficients are robust to the inclusion of these variables.

Some of the new variables that we consider are motivated by the fact that cash provides anonymity and leaves no electronic traces—features that can be desirable for illegal activities. We therefore include measures of corruption and organized crime. We may also notice that higher crime rates may, on the one hand, raise the cost of distributing cash, and thereby the cost of getting hold of cash, and thus increase cash holdings. On the other hand, it might induce people to hold less cash for security concerns. The anonymity provided by cash might also be desirable in oppressive regimes. Hence, we include a variable measuring human rights and a variable measuring trust in politicians. In addition, trust in politicians (and crime rates) matters for the development of cash in circulation more broadly since it influences the investment climate in general and, therefore, investments in ATMs and infrastructure for electronic payments.

People who do not trust banks to protect their integrity might prefer cash to commercial bank deposits. People might also prefer cash because they do not trust retail banks to be sufficiently safe. This hypothesis is supported by monetary theory, which suggests that people will prefer cash or other forms of central bank money over private money if institutions that facilitate trust in commercial bank money are weak (see, e.g., Armelius, Claussen, and Hendry 2020). Therefore, we include a variable measuring trust in the financial sector and a variable measuring the regulatory quality in each country.

As a country-specific measure of uncertainty, we use the World Uncertainty Index by Ahir, Bloom, and Furceri (2019). Measuring digitization and technology adaptation is not straightforward, and the data that exist are often not observable for many countries or

available, and for many countries, the rates are not observed in all the years. We therefore use the mean of the available rates. In our OECD sample, the correlation between the OECD interest rate and our mean of the IMF rates is 0.97.

an extended period of time. We collect data on Internet usage as a proxy for general attitudes towards technology adaptation. It will also capture technological possibilities and ease of making electronic payments.

All collected variables and their descriptive statistics are presented in Table 2. Given the large heterogeneity among the countries in our sample, we also consider a subsample, limited to the OECD countries in our data set. Table 2 shows that the average CiC/GDP is 7 percent in the full sample, while it is 5.57 in the OECD subsample. The standard deviation presented in the table is the overall variation. It is worth noting that for some of the variables (e.g., Self-Employed, Human Rights, Regulatory Quality, Control of Corruption) most of the variation comes from between countries such that they display less variation within countries. With 129 countries and 18 years, we have a potential maximum of 2,322 observations for each variable. However, for most variables, we do not have observations for all countries and all years, resulting in a number of missing observations.[9]

4. Empirical Strategy

We estimate the following fixed-effects reduced-form cash-demand model,

$$C_{i,t} = \alpha_i + \delta_t + \boldsymbol{\beta}\mathbf{X}_{i,t} + \varepsilon_{i,t}, \tag{1}$$

where i is a country indicator, t a year indicator, $\mathbf{X}_{i,t}$ a set of explanatory variables, and $\varepsilon_{i,t}$ is a random error with mean zero. We use the natural logarithm of the cash-to-GDP ratio (*log* CiC/GDP) as the dependent variable $C_{i,t}$. As mentioned before, this ratio is convenient since it allows us to compare countries without worrying about exchange rates. Although our main specification will be a fixed-effects model, we will also estimate the model replacing the country fixed effects, α_i, with a common constant.

[9] We treat all missing observations as "missing at random."

Table 2. Descriptive Statistics

	Full Sample			OECD		
	Obs.	**Mean**	**Std. Dev.**	**Obs.**	**Mean**	**Std. Dev.**
Panel A						
CiC/GDP	2,322	7.00	4.16	342	5.57	3.91
Interest Rate	2,206	6.18	5.49	342	4.20	5.79
log GDP per capita	2,322	1.32	1.47	342	3.32	0.76
Self-Employed	2,232	45.15	27.15	342	17.71	9.04
Age Dependency Ratio	2,286	10.93	7.03	342	20.95	6.50
Individuals Using Internet	2,227	29.86	28.30	342	68.29	23.16
Human Rights	2,286	0.40	1.46	342	1.61	1.65
Regulatory Quality	2,320	48.75	25.50	342	86.45	11.32
Control of Corruption	2,320	47.25	27.94	342	83.51	17.45
Panel B						
World Uncertainty Index	1,782	0.18	0.16	324	0.21	0.13
Confidence in Financial Sector	1,072	58.03	16.40	222	53.29	15.75
Public Trust in Politicians	1,043	3.05	1.19	209	3.82	1.33
Organized Crime, 1–7 (Best)	1,043	4.87	1.02	209	5.55	0.88

Note: CiC is collected from the IMF (IFS), Bank of England, the People's Bank of China, the Reserve Bank of India, the National Bank of Switzerland, and Singapore Department of Statistics. Interest rates are collected from the OECD and the IMF (IFS). From the World Bank we collect GDP (local currency), GDP per capita (1,000 USD), Self-Employed (% of total employment), Individuals Using Internet (% of the population; we interpolate and extrapolate to obtain nine missing observations in the OECD sample), and the Age Dependency Ratio (old as % of the working-age population). Control of Corruption (percentile rank; we extrapolate to obtain values for 2001) and Regulatory Quality (percentile rank) are collected from the Worldwide Governance Indicators (Kaufmann, Kraay, and Mastruzzi 2011). Organized Crime (1–7, with 7 being the best) and Public Trust in Politicians (1–7, with 7 being the best) are collected from the Global Competitiveness Index (World Economic Forum). Human Rights score is collected from Fariss (2019); we extrapolate to obtain values for 2018. Confidence in Financial Sector (% responding yes) is collected from the Gallup World Poll, and the Uncertainty Index is from Ahir, Bloom, and Furceri (2019).

In the absence of sharp identification, the panel data structure is essential since it allows us to utilize two sources of variation: variation across countries within each year and variation within countries across years. The year fixed effects capture any common time trend and are important since they absorb global trends and global shocks—such as the global financial crisis (2007–08). Some of our variables display less variation within countries than between countries. Hence, estimations excluding country fixed effects should be interpreted as cross-country estimates that compare cash demand factors between countries. In contrast, specifications that include country fixed effects allow for within-country interpretations since country fixed effects control for different levels and for omitted time-invariant elements (e.g., culture and religion).[10]

One concern regarding the estimation of Equation (1) is stationarity. Testing for stationarity in a panel like ours can be a bit problematic, and therefore we use a number of different tests. Using a Harris and Tzavalis (1999) unit-root test, we cannot reject the null hypothesis that the panels (countries) contain unit roots. However, we can reject (at the 0.1 level) that the panels contain unit roots when we include a time trend. Hence, the panels appear to be trend stationary. One drawback with the Harris and Tzavalis (1999) test is that it is based on the assumption that all panels have the same autoregressive parameter. To combat this limitation, we turn to alternative tests. Using the Im, Pesaran, and Shin (2003) unit-root test, we reject the null that all panels contain unit roots. However, using a Hadri (2000) Lagrange multiplier (LM) test, we also reject the null that all panels are stationary. Hence, some countries seem to be stationary, while others are not. One caveat with the country-specific unit-root tests is that they assume that both N (the number of countries) and T (the number of years) tend to infinity. In our data, $N = 129$ and $T = 18$. Therefore, while the assumption might be fine for N, it is likely less so for T. Hence, we should interpret the tests with some caution.[11]

[10] In all estimations we consider standard errors clustered at the country level to account for likely error correlation within each country (see, e.g., Abadie et al. 2017; Angrist and Pischke 2008; Cameron and Miller 2015).

[11] On the other hand, the Harris and Tzavalis (1999) test assumes that N approaches infinity while T is fixed, but has the drawback of assuming a common unit root.

Nevertheless, in order to ensure that our results are robust and not contested due to non-stationarity, we also estimate the following model,

$$\Delta C_{i,t} = \alpha \Delta C_{i,t-1} + \delta_t + \boldsymbol{\beta} \Delta \mathbf{X}_{i,t} + \varepsilon_{i,t}, \tag{2}$$

using generalized method of moments (GMM), where Δ denotes first differences.

When deciding on the final set of variables to include in $\mathbf{X}_{i,t}$, we face several trade-offs. If we were to include all of our collected variables, we would reduce the risk of omitted-variable bias. Still, at the same time, we would drastically reduce the number of observations, since many variables are observed only for some scattered years. A second concern is multicollinearity. Many of our variables are correlated, although we do not have any variables that have a very high correlation (above 0.9).[12] We have chosen to focus on variables where we have a large amount of data. In Table 2, the variables in panel A are the ones included in $\mathbf{X}_{i,t}$ in our main specification (net of CiC/GDP that serves as our dependent variable). By excluding the variables in panel B, we obtain a set of variables that will constitute a fully balanced panel for the OECD sample, and we limit the multicollinearity concerns. However, we are still interested in assessing the relationship and importance of the variables in panel B. Hence, we also estimate

$$\Delta C_{i,t} = \alpha \Delta C_{i,t-1} + \delta_t + \boldsymbol{\beta} \Delta \mathbf{X}_{i,t} + \gamma \Delta z_{i,t} + \varepsilon_{i,t}, \tag{3}$$

where $z_{i,t}$ is each of our additional explanatory variables (those not included in $\mathbf{X}_{i,t}$) added one at a time.

5. Empirical Results

We estimate Equations (1) and (2) using both the full sample of all countries and the subsample of OECD countries. The estimated coefficients are presented in Table 3. Columns 1 and 4 suppress the country fixed effects, while the full specification of Equation (1) is

[12]We have performed a variance inflation factor (VIF) test to assess the multicollinearity problem. All VIF values are below the rule-of-thumb threshold of 10, indicating that we do not have any severe multicollinearity problems.

Table 3. Cash Demand Estimation Results

	Full Sample			OECD		
	OLS (1)	**FE (2)**	**GMM (3)**	**OLS (4)**	**FE (5)**	**GMM (6)**
Interest Rate	–0.035***	–0.007**	–0.004***	–0.043***	–0.013***	–0.008***
	(0.006)	(0.003)	(0.002)	(0.009)	(0.004)	(0.002)
log GDP per capita	–0.271***	–0.155**	–0.174***	–0.115	–0.017	0.034
	(0.074)	(0.078)	(0.055)	(0.276)	(0.136)	(0.039)
Age Dependency Ratio	0.034***	0.003	0.007	0.075***	0.011	0.008
	(0.008)	(0.010)	(0.006)	(0.018)	(0.019)	(0.005)
Self-Employed	–0.004	–0.005	–0.003	0.005	–0.041**	–0.000
	(0.003)	(0.006)	(0.003)	(0.016)	(0.015)	(0.008)
Individuals Using Internet	0.003	0.000	–0.000	–0.005	0.008	–0.000
	(0.003)	(0.001)	(0.001)	(0.006)	(0.005)	(0.001)
Human Rights	–0.055*	0.033	0.008	–0.107*	0.078	0.024
	(0.032)	(0.028)	(0.018)	(0.056)	(0.052)	(0.021)
Regulatory Quality	–0.002	–0.003	–0.001	0.000	–0.007	–0.002
	(0.003)	(0.002)	(0.001)	(0.011)	(0.007)	(0.002)
Control of Corruption	–0.003	0.000	–0.001	–0.016*	–0.008*	–0.004**
	(0.003)	(0.002)	(0.001)	(0.008)	(0.004)	(0.002)
Observations	2,010	2,010	1,780	342	342	304
R^2	0.335	0.910		0.636	0.940	
R^2 Adjusted	0.326	0.903		0.607	0.931	
Year FE	√	√	√	√	√	√
Country FE		√			√	

Note: The dependent variable is the natural logarithm of the cash-to-GDP ratio. In columns 1 and 4 the country fixed effects have been suppressed and replaced by a common constant. Standard errors robust to clustering at country level are in parentheses. *, **, and *** represent the 10 percent, 5 percent, and 1 percent significance level, respectively.

presented in columns 2 and 5. Columns 3 and 6 present the GMM estimations of Equation (2).

In line with earlier studies, we find a negative and statistically significant effect of the interest rate on cash demand. Between countries, a 1 percentage point higher interest rate is associated with a 3.5 to 4.3 percent lower cash-to-GDP ratio. When adding country fixed effects, the coefficients are attenuated to around –0.01 but are still significant, such that a 1 percentage point higher interest rate is associated with around 1 percent lower cash-to-GDP ratio. In line with, for example, Bech et al. (2018), we find that richer countries have a lower cash-to-GDP ratio. The coefficient on *log* GDP per capita is negative and significant for the whole sample, but insignificant (and attenuated) for the OECD subsample. In the full sample, a 1 percent increase in GDP per capita is associated with a 0.3 percent lower cash-to-GDP ratio between countries and 0.16 percent lower in the within-country estimates.

As expected, and in line with earlier findings, we find that age matters. The coefficient is positive in all specifications and highly significant in models without country fixed effects. Countries with a 1 percentage point higher age dependency ratio will have a 3.4 percent higher cash-to-GDP ratio in the full sample and 7.5 percent higher in the OECD sample. When adding the country fixed effects, the age variable becomes smaller and insignificant. This could be because much of our variation is between countries, while the variation within countries over time is limited. This is not very surprising since demography does not change that much over time. The same pattern holds for the human rights variable. We observe a significant (negative) relationship when we exclude the country fixed effects. When adding the country fixed effects or estimating in first differences, the coefficient becomes insignificant. The fact that coefficients and significance change when adding fixed effects is not surprising. Many variables have different amounts of variation between and within countries. It is important to note that by including country fixed effects we control for and absorb time-invariant differences between the countries.

In all estimations, Internet usage and regulatory quality turn out to be insignificant and close to zero. The number of self-employed is generally insignificant and not consistently estimated. Our estimates suggest that better control of corruption reduces the amount of cash.

A one-unit increase in the control of corruption is associated with a 0.8 to 1.6 percent lower cash-to-GDP ratio in the OECD estimation. Hence, a one-standard-deviation increase of 17.45 in control of corruption would imply a decrease in the cash-to-GDP ratio of 16 to 30 percent.

The results so far have omitted the variables listed in panel B of Table 2. We are still interested in assessing their relationship and importance for cash demand. As described in Section 4, we therefore also estimate Equation (3). The results are presented in Table A.2 in the appendix. All variables in panel B turn out to be insignificant and close to zero, and adding these variables does not alter the main takeaways from Table 3. We may note that the old-age dependency ratio turns significant in the OECD sample due to increased precision.

As noted earlier, there is some scarce evidence in the previous literature that uncertainty positively affects the amount of currency in circulation. This seems to be visually supported for some countries in our data. There appears to be, for some countries, a more pronounced increase during 2007–18, following the global financial crisis, compared with 2001–07. However, looking at the estimated year effects, we do not find any evidence that the years associated with the financial crisis would significantly differ from the other years in our sample. One caveat with this approach is that the year effects assume that all countries had a homogeneous exposure to the crisis. Therefore, when assessing uncertainty, it is preferable to include variables that capture each country's heterogeneous exposure. However, as shown in Table A.2, we do not find any significant relationship between the World Uncertainty Index by Ahir, Bloom, and Furceri (2019) and the cash-to-GDP ratio.

5.1 Robustness

As a test for the robustness of our model selection, we perform an exercise using a *lasso*-model selection (Hastie, Tibshirani, and Wainwright 2015; Tibshirani 1996). We allow the lasso selection to choose from our main set of variables in $\mathbf{X}_{i,t}$ (i.e., panel A of Table 2), but force the selection of year and country fixed effects. The results from this exercise reveal that the final model selection differs from our main specification for both the full and the OECD samples.

In the full sample, the variables capturing self-employment, Internet usage, and corruption are excluded in the lasso selection. In the OECD sample, the *log* GDP per capita and the human rights variable are excluded. However, the estimation of the remaining coefficients aligns very well with the results from our main model presented in Table 3.

We further assess the robustness of our results by removing countries where foreign demand for the (physical) currency is large. We first remove the United States since the U.S. dollar is widely used outside of the United States for daily transactions and store of value. We then perform a second estimation where we also remove Switzerland, Japan, and the United Kingdom—countries whose currencies also are used abroad for daily transactions and store of value. From these tests, we conclude that our results are robust to these exclusions.

As a final robustness check we also perform estimations where we replace Self-Employed, Human Rights, Regulatory Quality, and Control of Corruption with their averages. This exercise provides some additional observations, as we average out some missing values. Note that these variables are then omitted in the fixed-effects and GMM estimations. Again, the results are robust to these alternative specifications.

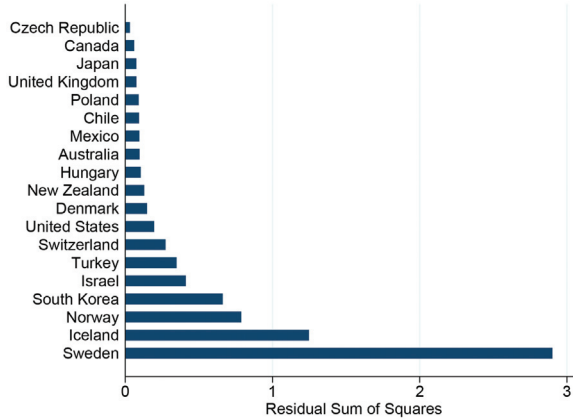
6. Can the Model Explain the Divergent Development?

In this section, we analyze if our empirical model can predict ("explain") actual outcomes. We limit the analysis to the OECD sample, and we use the estimation presented in column 5 of Table 3.[13] Based on this estimation, we calculate the residual sum of squares (RSS) for each country. We report these RSS values for each country in Figure 3, where we have ordered the countries from best to worst model fit.

The figure shows that the model has a very good fit for countries like the Czech Republic, Canada, and Japan. The countries

[13]We limit this analysis to the OECD countries since, in that sample, we have a fully balanced panel using our main specification and we believe that the OECD sample is more homogeneous.

Figure 3. Residual Sum of Squares



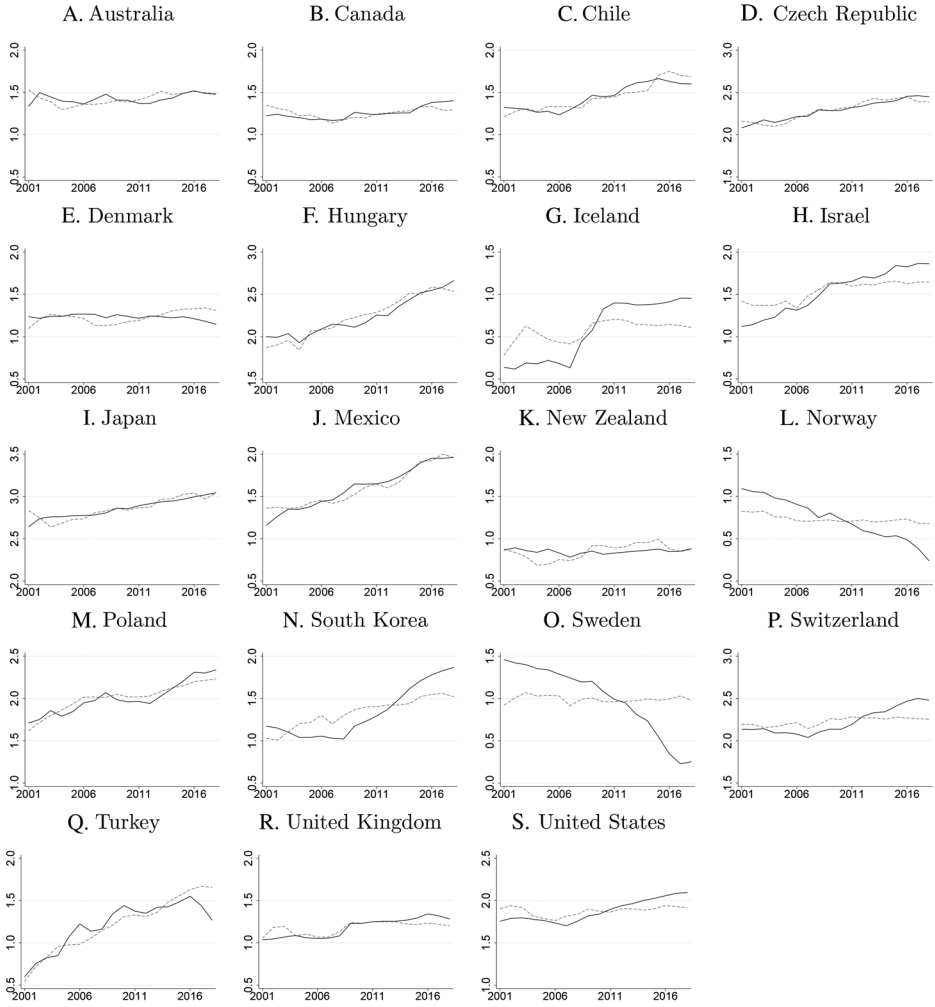
Note: The graph shows the residual sum of squares (RSS) based on the estimation in column 5 of Table 3.

that stand out as being poorly predictable are Iceland and Sweden. The low predictability for Iceland is likely due to the global financial crisis, which hit Iceland particularly hard and led to a substantial increase in the cash-to-GDP ratio. We notice that the development in Sweden has been exceptionally hard to predict; the RSS value is more than twice as large as for any other country, indicating that Sweden is, indeed, special.[14] An interesting observation is that Norway, which also stands out with a fall in CiC (Figure 1), is better explained by the model than Sweden—although relatively poorly explained compared with the rest of the sample.

In order to visualize the model's fit and explanatory power over time, we plot the fitted values (as dashed lines) and the actual values (as solid lines) for each country in Figure 4. The figure shows that the model has a good fit for most countries. It predicts an increase in cash in circulation in several countries. The increase in actual *log* CiC/GDP in Iceland after the financial crisis, which gives the high RSS value, is evident from the figure. We can also notice that South Korea, Switzerland, and the United States are countries where the

[14]It is worth noting that the RSS value for Sweden is the largest in the full sample as well.

Figure 4. *log* CiC/GDP, Actual Value and Model Prediction



Note: The figure shows the model predictions (fitted values) based on the estimation in column 5 in Table 3 as dashed gray lines, and the actual outcomes as solid black lines. The graphs show the *log* CiC-to-GDP ratio.

financial crisis might have had a substantial impact on the trend in actual *log* CiC/GDP. Looking at Sweden, we see that the model fails to capture the sharp decline in cash in circulation, since the model

predicts an unchanged level. The model also fails to fully predict the decrease in Norway, although we notice that Norway is the only country where the model predicts a decline.

7. Discussion: What Is Special about Sweden?

Having explored what we can learn from cross-country data, we now discuss some Swedish policy measures and developments that may help explain why the model cannot explain the divergent development in Sweden. More specifically, we suggest that the combination of Swedish policy measures to reduce tax evasion, an aggressive banknote and coin changeover, and the introduction of a new mobile payment application could be important for the development of CiC in Sweden. While these types of events and changes are not unique to Sweden, the fact that they were all implemented within a short period could have reinforced their effects. The timing of these events is illustrated in Figure 5. We also discuss, in Section 7.4, a few other aspects that could help explain why Sweden is special.

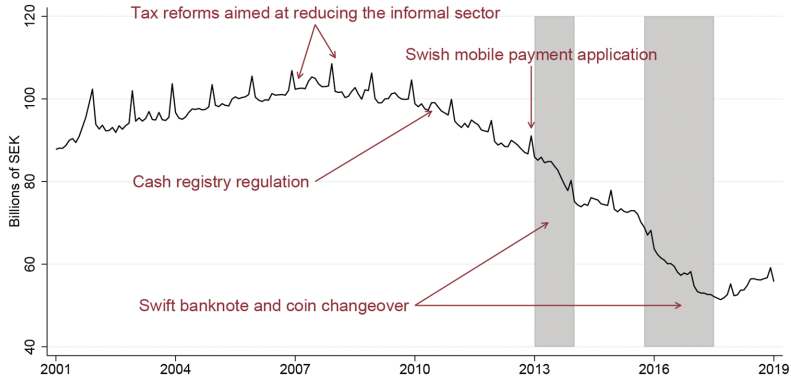
7.1 Reduced Tax Evasion and a Smaller Informal Sector

Starting in 2007, the Swedish authorities introduced measures aimed at transferring jobs from the informal to the formal sector and reducing tax evasion.

In 2007 a substantial tax deduction for the purchase of household services, such as cleaning, was introduced. In 2008 a similar tax deduction for services related to house repairs and maintenance was introduced. The objective of the schemes was to reduce undeclared work. The measures appear to have had an effect. Tillväxtanalys (2019) used microdata on Swedish firms to create a control group consisting of firms that had similar characteristics to the firms that were eligible for the deductions prior to the reform. They then ran fixed-effects regressions and found that the tax reform for household services had increased the amount of formal work in the household services sector by around 10 percent.

In 2010 it became mandatory for firms selling goods or services in return for cash to have a certified cash register and report the cash register to the Swedish Tax Agency. The provisions also involved an

Figure 5. Events that Help Explain the Decline in CiC in Sweden



Note: The graph shows monthly currency in circulation (in billions of SEK) in Sweden.

obligation to produce and offer the customer a receipt. In addition, the Tax Agency was allowed to conduct more supervision and inspection visits. The combination of the new law and the increased number of inspections made it more difficult for businesses to withhold income by receiving payments in cash. The number of fines levied by the Tax Agency when irregularities were discovered increased from 500 in 2010 to 2,900 in 2012. Swedish Tax Agency (2012) conducted a study that exploited differences in timing in the submission of the first report by different companies to the Tax Agency. The study found that reported turnover was 5 percent higher in the months following the notification of a tax register as compared with the turnover by similar companies that had not submitted a report.

These measures are not directly captured by the explanatory variables of our model. Although variables such as regulatory quality and corruption might capture some of the effects, the reforms are likely to be too narrow to be proxied by the broader measures that we observe on a country level. Here we would also like to note that although Swedish Tax Agency (2012) and Tillväxtanalys (2019) report that the measures have reduced the informal sector and tax evasion, it is hard to disentangle the measures' effect on

cash demand empirically. A key reason is that we do not have sector-specific cash demand data. Moreover, as noted by Engert, Fung, and Segendorf (2019), numerous countries in the last 10 to 20 years have experienced a general trend of declining underground economies.

7.2 An Aggressive Banknote and Coin Changeover

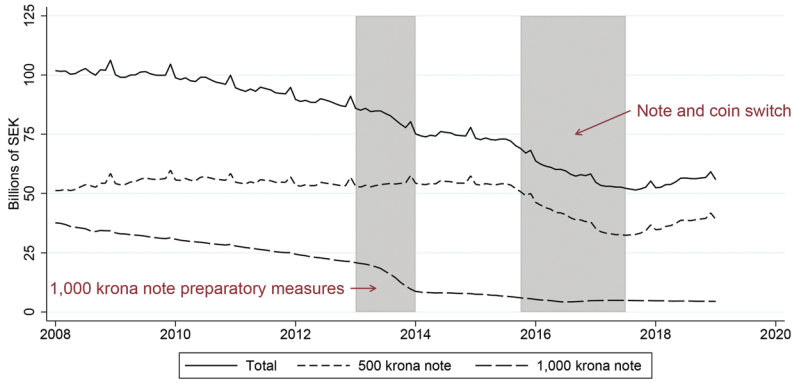
During two intervals between 2012 and 2017, the Riksbank conducted a changeover of banknotes and coins. A particular feature of this changeover was that the window for exchanging old notes for new ones was short, only nine months. Furthermore, the Riksbank applies relatively strict redemption rules. Invalid notes can only be redeemed at the Riksbank's main office in Stockholm for a fee, and only if proper documentation of their origin is presented (in order to avoid money laundering).

The changeover started in November 2012 when, as a preparatory measure before new notes would be introduced, older 50- and 1,000-krona notes without a foil strip still in circulation were declared to be invalid from year-end 2013. At the same time, Sveriges Riksbank (2012) announced that the versions of the 50- and 1,000-krona notes with foil strips, which had been introduced in 2006, would be valid only until June 2017. This meant that anyone holding the oldest version of, for example, the 1,000-krona banknote knew that they would have to do at least one more switch in the near future.

After these preparatory measures, the changeover was conducted in two steps. The first began in October 2015, when the Riksbank issued new 20-, 50-, 200-, and 1,000-krona banknotes. In September and October 2015, the Riksbank sent out information brochures to the general public and also informed the public about the banknote and coin changeover through other channels. This information included the announcement that the old versions of the respective notes would become invalid after nine months.[15] The second step was initiated in October 2016, when the Riksbank issued new 100- and 500-krona banknotes and new 1- , 2- , and 5-krona coins. The procedure was once again that the old banknotes and coins were valid for only nine months after the new ones had started to be

[15]The Riksbank's communication measures regarding the banknote and coin changeover are documented in Sveriges Riksbank (2018b).

Figure 6. The Swedish Banknote and Coin Changeover



Note: The graph shows monthly currency in circulation (in billions of SEK) for different denominations in Sweden. The "Total" series corresponds to all coins and banknote denominations available.

issued. However, this validity limit had already been announced in September 2015.[16]

Having to exchange notes is inconvenient for cash holders. In addition, large-denomination notes were already cumbersome to use since many shops did not accept them. Furthermore, by 2013 it had become harder to exchange notes at bank offices. The number of bank offices had declined, and many of the remaining ones had become cashless.

Looking at the timing of the changeover and the time series, we can see clear drops in the largest denominations during the two changeover periods. In Figure 6, we see that the preparatory period of 2013 coincides with a significant drop in circulation of the 1,000-krona banknote, while the main changeover period coincides with a large decline in circulation of the 500-krona banknote.[17]

[16]There is still SEK 5.4 billion worth of banknotes outstanding that have not been redeemed. See also Sveriges Riksbank (2018a) for a summary and evaluation of the banknote and coin changeover.

[17]During the changeover period, the 500-krona banknote made up around 70 percent of the total amount of currency in circulation.

Banknote and coin changeovers are not uncommon elsewhere, but the recent Swedish ones were aggressive in an international comparison. Internationally, old notes are often legal tender for a very long time after the introduction of new notes and sometimes even indefinitely. In the United States, for instance, all notes issued since 1861 are legal tender. In Denmark, all banknotes issued after 1945 are legal tender. The bank of Canada did not get the power to remove legal tender status of banknotes before 2018. After that, legal tender status has only been removed for banknotes that had not been produced for at least two decades. Compared with these economies, the window given in Sweden was short. We may add to this that, historically, Swedish changeover periods have been much longer than this one. Engert, Fung, and Segendorf (2019), who compare the development of cash in Sweden and Canada, assess that the relatively aggressive banknote and coin changeover is likely to have reduced the demand for larger notes in Sweden relative to Canada.

A very aggressive banknote changeover will probably not on its own reduce the demand for cash permanently, as is evidenced by, for instance, the measures taken in India in 2016. There, currency in circulation showed a large drop immediately following the announcement that some large-denomination notes would become invalid and exchangeable for new notes for only 50 days. However, a couple of years later, currency in circulation was back at the old level, and it has continued to grow with the old trend since. In the Swedish case, it is possible that the changeover had a larger effect since there were attractive digital substitutes for cash available when the changeover took place.

7.3 An Attractive Mobile Payments Application

In December 2012 a new payment application for smartphones called *Swish* was introduced in Sweden. The application offers digital real-time payments (person-to-person and person-to-business) between commercial bank accounts in different banks.[18] Its user-friendliness,

[18]The service is only available for SEK accounts in banks operating in Sweden and is therefore not available to foreign tourists and others not holding a Swedish bank account.

real-time properties, and broad reach made digital payments possible in essentially all areas where cash payments have previously been the only option. More than 80 percent of the adult Swedish population now has the app installed. Since this corresponds to the latest available estimate of the share of smartphone ownership, Swish has essentially reached full market penetration in the adult population.

The introduction and rise of Swish as an alternative to cash are not captured directly by any of the explanatory variables in our model. However, including variables like the number of Swish users as an explanatory variable would lead to spurious estimation results. Swish and CiC are likely to be just mirrors of each other since both are determined by the same exogenous variables—for instance, age of the population, regulatory quality, and technology adaptation.

Other countries have implemented similar services, but Swish differs from most of these in that it essentially covers the whole banking sector and has, in principle, universal reach. In most countries, the services appear to be more piecemeal. The fact that Swedish banks were able to develop a common solution is in line with a long tradition in Sweden. Swedish banks are used to setting up jointly owned, infrastructure-related companies that provide services for all banks while still promoting competition among them. One example is *Bankomat AB*, which operates the vast majority of ATMs in Sweden, and is jointly owned by the major banks. Another example is a common digital identification system supplied by the banks (called *BankID*) and used by all banks for online banking services, by Swish, and by public authorities. This is different from the workings of banking sectors in many other countries and is hard to measure and include in the empirical estimation.

7.4 Other Aspects that Could Explain the Fall in CiC

As noted above, Swedish banks have reduced their cash services over the studied period. Between 2011 and 2016, the number of bank offices offering cash services more than halved.[19] The number

[19]Sometimes there can be an ATM in (or close to) a cashless bank office. They do not, however, offer cash services over the counter, and in particular they offer no means of depositing cash.

of ATMs fell by 14 percent, and the number of cash service boxes (that smaller businesses use for handling their daily takings) fell by 15 percent from 2011 to 2017 (The Riksbank Committee 2018). Engert, Fung, and Segendorf (2019) notice that Sweden has fewer bank branches that handle cash per inhabitant than Canada and suggest that access to cash through banks can play a role. As noted in Section 3, we have not included any variables for bank branches accepting cash in our empirical model. This is partly due to lack of data (it would be close to impossible to gather time series for that variable for all of our countries) and partly due to econometric (simultaneity) reasons. As in the case with ATMs, the number of bank offices offering cash services is likely to be determined in tandem with cash demand.

During the 1990s and early 2000s, the Riksbank reduced the number of cash distribution centers and thus withdrew implicit subsidies for cash. By 2014, the Riksbank only had one banknote distribution center. This differs from the situation in many other countries, where the central bank often has a much more prominent role in cash distribution. Since most of the reduction in the Riksbank's cash distribution centers happened prior to our sample period, it is impossible to include in the estimations. However, it could still be important, and could also have contributed to the reduction in commercial bank offices offering cash services.

Finally, it is worth noting that the increase in cash in circulation in many countries since the financial crisis is often due to higher demand for large-denomination notes—as documented by Engert, Fung, and Segendorf (2019) and Judson (2018)—while demand for small-denomination notes has fallen. The increased demand for cash is thus likely to be at least partly for store-of-value purposes. In Sweden, there was no similar increase in demand for cash during the financial crisis, nor has demand increased during the COVID-19 pandemic (Sveriges Riksbank 2020). This could be because there is strong trust in the ability and willingness of the Swedish government to protect money held in banks in times of crisis. Sweden has experienced two systemic banking crises during the last three decades, and public authorities have proven willing and able to protect commercial bank deposits. The payment systems have been up and running without interruptions, and no reductions have been applied to the value of commercial bank deposits. In other countries, which

have not experienced similar systemic banking crises, there might be weaker trust in commercial bank money and, therefore, higher demand for cash for store-of-value purposes in times of financial turmoil.

We may conclude our discussion of why the model cannot explain the divergent development in Sweden, and what is special in Sweden, as follows. Several events and policy measures that have had mutually reinforcing effects on cash demand that are not captured in our model may explain the divergence. These include measures to reduce tax evasion and the informal sector, an aggressive banknote and coin changeover, the introduction of Swish, and the withdrawal of central bank subsidies to cash distribution. These factors are, however, hard to capture in an econometric time-series model covering multiple countries.

Interestingly, Norway—a country that also has a downward trend in cash demand that is not fully explained by the model—has had similar developments. Norway had a relatively aggressive banknote changeover, introduced an attractive mobile payments application, and has seen a reduction in bank offices. The Norwegian mobile application (Vipps) is almost identical to Swish, and it was introduced around the same time (2015). It has also reached the same degree of market penetration. However, regarding the other factors, development in Norway is somewhat less clear-cut or came later than in Sweden. The reduction in bank offices was somewhat less pronounced in Norway, and during our sample period Norwegian bank offices—in contrast to Swedish ones—were legally obliged to provide cash services. The Norwegian banknote changeover was also quite restrictive but happened later in our sample period.[20] Notice also that Norway had less cash in circulation in 2001 than Sweden, but the two countries are now at approximately the same level. We leave further comparative analysis of the developments in Norway and Sweden for later work.

[20]The Norwegian changeover started in 2017. In Norway, the old notes became invalid one year after the announcement date; the 100- and 200-krone note became invalid in May 2018, the 50- and 500-krone note in October 2019, and the 1,000-krone note in November 2020.

8. Conclusions

In this paper, we have analyzed developments in the amount of cash in circulation using a data set consisting of 129 developed and developing countries. Our main specification performs well in explaining cash developments for most OECD countries. We find that economic development, demography, and the level of the interest rate are key explanatory variables. We also find that better control of corruption is negatively related to the demand for cash in developed countries.

The development in Sweden consistently stands out. It is one of few countries where cash in circulation has decreased over the past couple of decades, not only as a share of GDP but since 2008 also in nominal terms. We find that our model cannot explain the divergent development in Sweden, while it performs relatively well for neighboring Norway, where cash in circulation has also declined. We discuss some events and policy measures that could have accelerated the decline in cash usage in Sweden. These include measures to fight tax evasion and an aggressive banknote and coin changeover. The combination of these measures, which had a negative influence on the incentives to hold and accept cash, combined with the rise of an electronic peer-to-peer alternative to cash (the mobile application Swish) has probably been decisive for developments in Sweden. However, it is not possible to reach a firm conclusion regarding the effects of these measures and events, as more detailed data is lacking.

With this paper, we have shed some light on the divergent development of cash in circulation in Sweden. Our empirical results and our discussion of some recent events in Sweden suggest that the demand for cash is shaped not only by general economic conditions but also by central bank policies, such as banknote and coin changeovers, government policies targeting tax evasion and the informal sector, and the competition in and the general workings of the banking sector.

Appendix

Table A.1. Country List

Non-OECD			OECD
Albania	Egypt	Papua New Guinea	Australia
Algeria	Equatorial Guinea	Paraguay	Canada
Angola	Eswatini	Philippines	Chile
Antigua and Barbuda	Fiji	Qatar	Czech Republic
Armenia	Gabon	Romania	Denmark
Azerbaijan	Georgia	Russia	Hungary
Bangladesh	Ghana	Rwanda	Iceland
Barbados	Grenada	Samoa	Israel
Belarus	Guatemala	Sao Tome and Principe	Japan
Belize	Guinea Bissau	Senegal	Mexico
Benin	Guyana	Serbia	New Zealand
Bhutan	Haiti	Seychelles	Norway
Bolivia	Honduras	Sierra Leone	Poland
Bosnia and Herzegovina	India	Singapore	South Korea
Botswana	Indonesia	Solomon Islands	Sweden
Brazil	Jamaica	South Africa	Switzerland
Brunei	Kazakhstan	Sri Lanka	Turkey
Bulgaria	Kenya	St. Kitts and Nevis	United Kingdom
Burkina Faso	Kuwait	St. Lucia	United States
Burundi	Kyrgyzstan	St. Vincent and the Grenadines	
Cambodia	Lesotho	Sudan	
Cameroon	Macao	Suriname	
Cape Verde	Malaysia	Tajikistan	
Central African Republic	Maldives	Tanzania	
Chad	Mali	Thailand	
China	Mauritius	Togo	
Colombia	Moldova	Tonga	
Comoros	Mongolia	Trinidad and Tobago	
Congo, Dem. Rep.	Morocco	Tunisia	
Congo, Rep.	Mozambique	Uganda	
Costa Rica	Myanmar	Ukraine	
Cote d'Ivoire	Namibia	United Arab Emirates	
Croatia	Nepal	Uruguay	
Djibouti	Nicaragua	Vanuatu	
Dominica	Niger	Zambia	
Dominican Republic	Nigeria		
	North Macedonia		
	Oman		
	Pakistan		

Table A.2. Adding Panel B Variables

	Full Sample				OECD			
	GMM (1)	**GMM (2)**	**GMM (3)**	**GMM (4)**	**GMM (5)**	**GMM (6)**	**GMM (7)**	**GMM (8)**
Interest Rate	–0.003**	–0.010***	–0.013***	–0.013***	–0.007***	–0.012***	–0.008**	–0.007*
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.004)
log GDP per capita	–0.136**	–0.134**	–0.231***	–0.229***	0.070*	0.024	0.027	0.021
	(0.059)	(0.058)	(0.059)	(0.060)	(0.038)	(0.036)	(0.040)	(0.034)
Age Dependency Ratio	0.008	0.005	0.009	0.009	0011**	0.008*	0.012*	0.012**
	(0.006)	(0.006)	(0.006)	(0.006)	(0.005)	(0.004)	(0.006)	(0.006)
Self-Employed	–0.001	–0.004	–0.002	–0.002	0.004	–0.007	–0.011	–0.011
	(0.003)	(0.003)	(0.003)	(0.003)	(0.006)	(0.005)	(0.009)	(0.008)
Individuals Using Internet	–0.001	0.000	0.001	0.001	–0.001	–0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
Human Rights	0.004	–0.001	0.036*	0.035	0.018	0.018	0.043	0.040
	(0.021)	(0.017)	(0.022)	(0.022)	(0.021)	(0.022)	(0.031)	(0.028)
Regulatory Quality	–0.002*	–0.001	–0.002	–0.002	–0.001	0.002	–0.002	–0.002
	(0.001)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.003)	(0.002)
Control of Corruption	–0.001	0.000	–0.001	–0.001	–0.004***	–0.002	–0.004**	–0.004**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)	(0.002)
World Uncertainty Index	–0.013				0.004			
	(0.029)				(0.022)			
Confidence in Financial Sector		–0.001				–0.001		
		(0.001)				(0.001)		
Public Trust in Politicians			0.001				0.002	
			(0.012)				(0.019)	
Organized Crime, 1–7 (Best)				0.006				–0.010
				(0.009)				(0.016)
Observations	1,455	831	893	893	288	190	190	190
Year FE	√	√	√	√	√	√	√	√

Note: The dependent variable is the natural logarithm of the cash-to-GDP ratio. Standard errors robust to clustering at country level are in parentheses. *, **, and *** represent the 10 percent, 5 percent, and 1 percent significance level, respectively.

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