ECONSTOR
Make Your Publications Visible.

A Service of
ZBW
Leibniz-Informationszentrum Wirtschaft
Leibniz Information Centre for Economics

Miller, Callum

Conference Paper

Addressing the limitations of forecasting banknote demand

International Cash Conference 2017 - War on Cash: Is there a Future for Cash? 25 - 27 April 2017, Island of Mainau, Germany

Provided in Cooperation with:
Deutsche Bundesbank

Suggested Citation: Miller, Callum (2017) : Addressing the limitations of forecasting banknote demand, International Cash Conference 2017 - War on Cash: Is there a Future for Cash? 25 - 27 April 2017, Island of Mainau, Germany, Deutsche Bundesbank, Frankfurt a. M.

This Version is available at:
https://hdl.handle.net/10419/162912

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

WWW.ECONSTOR.EU

Mitglied der Leibniz-Gemeinschaft

ADDRESSING THE LIMITATIONS OF FORECASTING BANKNOTE DEMAND

Abstract

Central banks need to forecast banknote demand. It determines the number of notes they need printed and the future distribution network required. Yet forecasting demand is an inherently complex problem - banknotes are anonymous bearer instruments and so many of the sources of demand are difficult to research.

This paper sets out a framework for identifying and assessing drivers likely to influence banknote demand. It presents, for the first time, the findings from an econometric model, looking at the past relationship between demand for Bank of England notes and a range of economic variables and cash industry statistics, to help forecast future demand.

But this approach has its limitations. There will be determinants of demand not included in the model. Furthermore, what is to say that past relationships will hold into the future? Perhaps we are now approaching a point of inflection - a paradigm shift in the demand for cash that causes the pre-existing relationships to break down.

To account for this, central banks must continue to research cash demand, its current and future drivers, and how significant they might be going forward. They must look for leading indicators that suggest a break with the past, and attempt to understand how, and when, the impact of technological change may significantly change the trajectory of cash use. This paper will set out a structure for capturing all of this information and using it to make judgements on the future of cash.

Whilst it might improve central bank's forecasting capability, and thus the basis for policy decisions, it will not eliminate all uncertainty. Therefore, central banks must retain flexibility, and ensure the wider cash industry does as well. There is a future for cash but we must constantly be alert to events that might change what that future looks like.

I would like to thank Carleton Webb who constructed the forecasting models described in this paper and provided much advice and guidance on their interpretation.

I would also like to thank Roy Whymark, Cordelia Kafetz, Martin Etheridge and Victoria Cleland for their comments on earlier drafts of this paper. The views expressed in this paper are those of the author, they do not necessarily reflect the views of the Bank of England and should not be reported as such. The author is solely responsible for any errors.

1. Introduction: The curious case of cash

Despite regular reports of its demise, cash demand is stronger than ever. In the run-up to Christmas 2016, the total value of Bank of England notes in circulation (NIC) peaked at over £70 billion for the first time (an increase of 10% on a year earlier). This represents over £1,100 for every man, woman and child in the UK.

Demand has grown despite the fact that cash's popularity as a transactional payment method is gradually declining. In 2015, cash accounted for less than half of consumer payments for the first time. Clearly some other factors are driving this growth.

Whilst this may be unexpected to the lay observer, it is a pattern consistently seen across the world. From Australia to the United States, parts of Europe to Canada, the paradox of falling cash use in transactions alongside strong overall growth persists.

Why do central banks need to forecast demand?

Central banks need to maintain public confidence in the availability, quality and security of the currency to meet their objectives of monetary and financial stability. In order to do so they need to forecast what demand for their banknotes will be. This helps them determine:

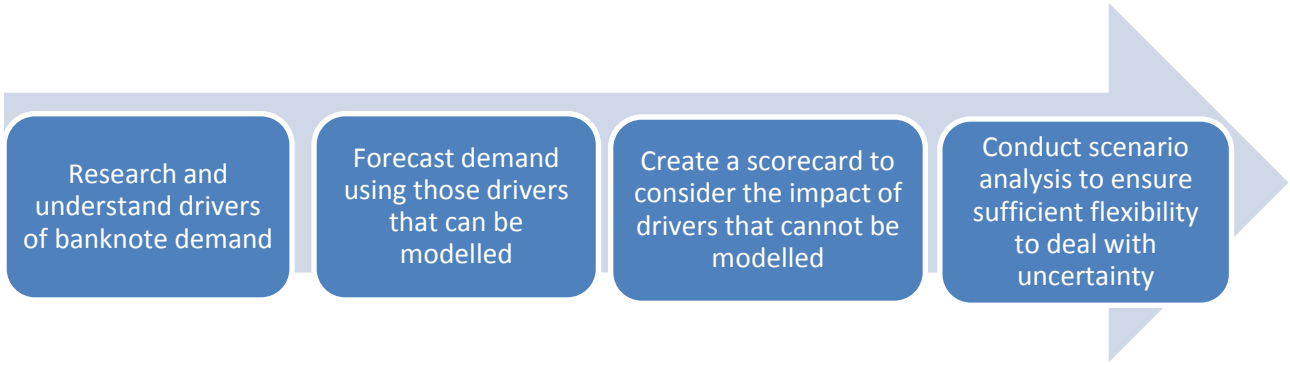
i. How many notes to print
   - Central banks need to know volumes of notes to print in advance because many components have significant lead-times.
   - New notes are printed to both replace old notes deemed 'unfit' for circulation and to meet increases in overall demand. This paper focuses on forecasting changes in overall demand, rather than unfit returns, which are forecast separately.

ii. The infrastructure needed
   - Whilst exact distribution models and outsourcing arrangements differ internationally, the wider distribution system serves broadly the same functions in each country. Central banks need to ensure the system has sufficient capacity to: distribute new notes to where they are needed, sort and recirculate used notes, and destroy old notes when they become unfit for use.

Central banks need to balance the inherent risk aversion to running out of banknotes with controlling costs, and responsibly managing public funds.

This paper presents a framework to help enable central banks to understand the demand for their banknotes and how this can be forecast to help steer policy decisions. The framework considers: (i) the drivers of banknote demand, (ii) how demand can be modelled using these drivers, (iii) how to account for drivers that cannot be modelled and (iv) how uncertainty about the future and potential shocks can be managed. The framework is flexible, and allows for the analysis to be refined and updated regularly so that conclusions on the future of banknote demand can evolve.

The framework is as follows:

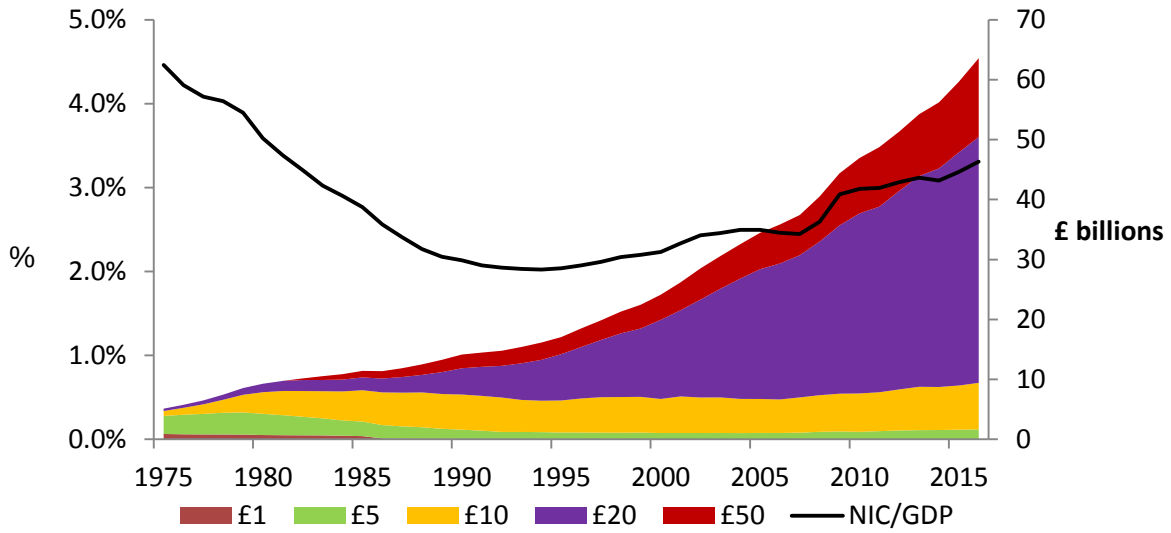


The remainder of this paper is structured as follows. Section 2 sets out a simple extrapolation approach for forecasting demand, by looking at demand for Bank of England (BoE) notes. Section 3 sets out a conceptual approach for classifying the sources of banknote demand. Section 4 presents a longlist of potential drivers in each market. Section 5 describes how some of these drivers can be incorporated into an econometric model, presenting for the first time a drivers-based model for assessing demand for BoE notes. Section 6 discusses the limitations of this model and what this means for how models should be used. Section 7 sets out an approach to combine the outputs from a model with data on the other drivers of demand that were not suitable for inclusion in the model using a 'scorecard' approach. It also presents the supporting evidence for two of those drivers. Section 8 concludes with how central banks can use this framework to help to plan for the future: how to manage uncertainty and maintain an orderly, effective and future-proof distribution model for banknotes.

2. Extrapolating from the past

One way to forecast future demand for banknotes is to look at the past. The chart below shows how BoE NIC has grown since 1975. Growth has persisted throughout the period, with NIC as a proportion of GDP falling swiftly from 1975 before starting to climb gradually in the mid-1990s. It also shows that growth since then has been largely driven by the £20 and £50.

Chart 1: Value of Notes in Circulation (£billions) and as a proportion of GDP (%)



Source: Bank of England, ONS[1]

When forecasting based on historic data, typically one would place more weight on the recent past because, ceteris paribus, recent changes can be expected to persist as the majority of the drivers of those changes will continue at their recent trajectory. As is demonstrated later, this reasonably simple extrapolation can help forecast NIC growth over the short-term. For example, based on recent trends it would tell us to expect strong growth in demand for BoE notes to persist.

But this methodology gives few insights into what is driving changes in demand. From a forecasting point of view, if the factors driving growth change, a model that simply extrapolates recent growth is unlikely to perform well until those factors' effects on growth have stabilised. For example, because interest rates determine the opportunity cost of holding cash, they are likely to be negatively related with growth in NIC. Some of the growth seen since 2008 in BoE NIC may reflect the large cuts in interest rates around that time. A model that could not foresee or account for these cuts would have under-forecast growth.

Unless enhanced, such a simple model does not offer central banks the opportunity to factor in possible changes to variables that may drive demand.

3. Classifying the drivers of banknote demand

When considering the drivers of demand, it is helpful to consider where notes might be held and for what purpose. This paper uses the conceptual framework described by Whymark & Fish in 2014[2], which considers that banknotes are demanded for two uses[3]: (i) as a medium of exchange (for

[1] (a) Data are based on the last day in February each year.
(b) GDP figures based on nominal GDP, GDP figures used for 2016 are Q3 2015 - Q3 2016 as full 2016 data was not available at time of publication.

[2] **Fish T and R Whymark (2015),** 'How Has Cash Usage Evolved in Recent Decades? What Might Drive Demand in the Future?' *Bank of England Quarterly Bulletin*, Vol. 55, pages 1–12, available at http://www.bankofengland.co.uk/publications/Pages/quarterlybulletin/2015/q3.aspx.

[3] Money as a unit of account is for our purposes captured by use as a medium of exchange and store of value.

transactional use); and (ii) as a store of value, across three markets: (a) the domestic legitimate economy; (b) overseas; and (c) the shadow economy.

As anonymous bearer instruments, central banks cannot know exactly where their notes are or how they are being used, but this framework provides a structure for considering what drives banknote demand.

Transactional demand

Cash is used in the domestic economy to facilitate transactions for goods and services; it circulates between financial institutions (in branches and ATMs), consumers (in wallets) and merchants (stored in tills or safes waiting to be banked). It is the source of demand that is most easy to identify, and is of most importance to central banks.

That is because central banks have sight of notes that return to the national distribution system; and have strong contacts with stakeholders in this market. In 2014 it was estimated that, at any one point in time, between 21% and 27% of the value of Bank of England NIC was held within the domestic transactional cycle[4].

It is the most important market, because it largely determines the infrastructure the distribution system needs to maintain. Notes used in the transactional cycle tend to be carried, spent and banked more often and thus determine much of the processing activity the distribution system needs to meet.

Hoarding

Cash is hoarded in the domestic economy, where savings are kept as cash, often at home as opposed to in a bank account. Hoarded cash is more difficult to research, central banks can draw on survey data but we suspect that underreporting occurs.

A 2014 survey into the uses of cash[5] suggested that 18% of people hoarded cash[6]. Extrapolating the results indicated that a minimum of £3 billion was hoarded domestically — around £345 per hoarder. However, these results are highly sensitive to methodology. A more recent survey[7] found that 41% of people[8] reported that they kept money in their home as savings but, on average, a much lower amount of £78. This range demonstrates that surveys provide an indication of hoarding but should not be solely relied upon. As an illustrative example, if one in every thousand adults in the United Kingdom were to hoard as much as £100,000, this would account for a further £5 billion (nearly 10% of NIC)[9].

[4] **Fish T and R Whymark (2015)**
[5] An unpublished survey commissioned by the Bank of England's Notes Directorate and conducted by GfK NOP involving 1,000 respondents
[6] Hoarding was defined as money kept at home for saving but that was not used for regular spending.
[7] Face-to-face survey commissioned by Cash Services, carried out by Optimisa Research of 1,945 individuals.
[8] 22% of people chose not to say, so the true figure may be higher.
[9] **Fish T and R Whymark (2015)**

Overseas

Banknotes are demanded outside of their country of origin: for tourists to facilitate spending, and as a store of value for overseas investors. Central banks may have visibility of some of these flows and demand sources, but not all. Due to the challenges with disentangling overseas transactional and hoarded cash demand, this paper treats all overseas demand as one classification.

Shadow

Banknotes are also used in the shadow economy. The shadow economy can be broadly defined as "those economic activities and the income derived from them that circumvent government regulation, taxation or observation"[10]. This definition covers a wide range of unreported income, from both legal and illegal activities and in this paper all cash demand from the shadow economy is treated as one source.

4. Identifying the drivers of banknote demand

Central banks cannot always differentiate between the various uses, and there are likely to be regular movements between each category. Nonetheless, this framework is useful for identifying, researching and unpicking the drivers of banknote demand.

It is possible, based on research, literature and experience, to select a longlist of drivers likely to influence banknote demand. These drivers will be sensitive to many factors specific to individual currencies such as cultural issues; exposure to international markets; domestic financial structure; and national banknote distribution system. The table below identifies drivers of demand for Bank of England notes. It is based on international literature, primary research, data from the distribution system, economic theory and experience.

[10] **Schneider and Buehn (2016),** 'Estimating the size of the Shadow Economy: methods, problems and open questions', *IZA Discussion paper series,* No. 9820.
This definition is taken from **Del'Anno (2003**), **Del'Anno Schneider (2004)** and **Feige (1989)**.

Table 1: Drivers of banknote demand

<table>
<tr><th colspan="3" rowspan="2"></th><th colspan="2">Use</th></tr>
<tr><th>Transactional
(Medium of exchange)</th><th>Hoarded
(Store of value)</th></tr>
<tr><td rowspan="5">Market</td><td rowspan="3">Domestic</td><td>Consumers</td><td>Availability of alternatives to cash

Acceptability and cost of those alternatives

Overall consumer spending:
○ Consumption
○ Unemployment

Attitudes to cash versus alternatives, in terms of:
○ Security
○ Ease of use
○ Budgeting implications

Self-employment</td><td rowspan="4">Trust in financial institutions
(eg influenced by cyber attack, or national/global financial crisis)

Interest rates

Security concerns to storing cash at home

Perceived need to hold money outside of the financial sector

Alternatives to cash as a store of value</td></tr>
<tr><td>Merchants</td><td>Cost of payment methods

Consumer attitudes to cash

Safety and fraud concerns

Attitude to cash from a business continuity perspective

Interest rates</td></tr>
<tr><td>Financial institutions</td><td>Interest rates

Industry structure
○ Number of ATMs
○ Number of bank branches</td></tr>
<tr><td>Overseas</td><td></td><td colspan="2">Exchange rates/perceived changes in future exchange rates
Tourism levels
Migration
Status as an international reserve currency</td></tr>
<tr><td>Shadow</td><td></td><td colspan="2">Tax and social security contribution burdens
Quality of institutions
Labour market regulations
Tax morale
Deterrence
Self-employment</td></tr>
</table>

5. How do these drivers help forecast demand for banknotes?

Once a longlist of drivers that influence demand for banknotes has been identified, central banks need to have a process for assessing how they will combine in the future to affect overall demand.

This paper sets out two approaches that, which used in conjunction, should comprehensively capture the prevailing influences on banknote demand:

i) An econometric model
ii) A 'scorecard' of indicators

An econometric model

Econometric modelling can be used to assess the past relationship between changes in these drivers and changes in banknote demand. In order to be included in an econometric model, the indicators must be robust, statistically significant, and regularly produced – but not all drivers meet these criteria.

There are a variety of models that central banks could use and the indicators included will depend on data available to them at the time. This paper presents the results from a model produced to forecast demand for Bank of England banknotes.

Bank of England experience

Building on previous work[11], an error correction model was constructed to forecast NIC growth.

The model estimates a long run relationship between the level of NIC and the drivers of demand that, when tested, proved to be statistically significant. This includes macroeconomic measures such as the interest rate, exchange rates and nominal consumption, as well as variables covering industry structure such as number of ATMs, which help control for changes in the opportunity cost of accessing cash. For completeness, other variables included in the model are: the number of bank branches, self-employment, and the number of regular payments made in cash. The number of regular payments made in cash should proxy for the popularity of alternatives to cash amongst consumers, accounting for the availability and acceptance of, and attitudes towards those alternatives.

It was not possible to include variables for a number of drivers identified in Table 1. For example, whilst data on alternatives to cash, such as payments made by contactless cards, are available, they are not recorded over a sufficient time frame to be included. Others factors[12] were identified but when modelled, they were found to not be statistically significant. However, they can still be of use in understanding future demand and this paper will later discuss how they can be combined with the forecast model.

[11] **Cusbert T and T Rohling (2013**), 'Currency Demand during the Global Financial Crisis: Evidence from Australia', *RBA Research Discussion Paper*, No 2013-01.

[12] Other variables tested included the unemployment rate, the proportion of workers born in Eastern Europe, (ONS estimates of) the shadow economy, the sterling effective exchange rate, official foreign holdings of sterling, the VIX measure of stock market volatility, a measure of sterling-dollar volatility, tourist expenditure, the number of state benefit payments per person and the number of students in the UK.

The model's long run relationship is (in logarithms)[13]:

$$NIC_t = c_0 + \beta_1 Cons_t + \beta_2 BankRate_t + \beta_3(LinkATMs_t - Pop_t) + \beta_4(BankBranches_t - Pop_t) + \beta_5 SelfEmp_t + \beta_6 CashRegPay_t + \beta_7 URate_t + \beta_8 ER_t$$

This relationship passes the Johansen test for cointegration, indicating a long run relationship between the variables. The model calculates a level of NIC consistent with its long run determinants and the forecasts return NIC to its long-term equilibrium over time, with some short-term deviation dependent on recent changes in the variables. So if NIC is above the equilibrium, the model forecasts weaker NIC growth, conversely if NIC is below, it forecasts stronger growth. Given the speed of adjustment coefficients in the total and denominational models are around -0.1 to -0.25, the equilibrium adjustment should be almost complete after around 4 to 10 quarters (mostly within 1-2 years).

The total NIC model is useful for discussing what influences cash demand but central banks also have to model by denomination in order to determine note orders. Denomination-specific models are more sensitive to series changeovers and policy interventions and these exogenous shocks must be accounted for. For example, in 2010, the Bank of England responded to concerns about the deteriorating quality and availability of £5 notes in circulation. As a result, the Bank asked the ATM operators to increase the number of £5 notes dispensed. To account for this, a dummy variable had to be included in the model, so as not to attribute this change in demand to other factors. From the model it appears that the policy change raised £5 NIC by 9%.

Generally, the financial crisis period triggered a shift in the coefficient estimates (β_n) – the patterns observed before the crisis between various indicators and NIC were impacted by it. While some seem to have subsequently drifted back toward their pre-crisis values, others have remained at notably different values. This may be because the volatility around the crisis induced enough variation in the data to distinguish the effects of certain variables. For example, the large cuts in Bank Rate were unprecedented and helped to uncover the strength of the relationship between NIC and Bank Rate.

The full list of coefficients is in appendix 1.

The results indicate a number of intuitive relationships, focussed on in the table below.

[13] Where *Cons* is nominal consumption, *BankRate* is Bank Rate (or Base Rate): the rate set by the Monetary Policy Committee of the Bank of England, *LinkATMs-Pop* is the number of ATMs per person aged 16+ (as in the Labour Force Survey data), *BankBranches-Pop* is the number of bank, building society or Post Office branches per person, *SelfEmp* is the proportion of self employed in employment, *CashRegPay* is the number of regular payments made in cash per person per year, *URate* is the unemployment rate and *ER* is the sterling effective exchange rate index, all at time *t*. Nominal consumption captures both the transactional demand for cash, and the effect of inflation on demand for cash through rising prices.

Table 2: Relationship between explanatory variables and NIC

Variable	Impact and possible rationale
Consumption	Cash demand rises with nominal consumption. The coefficient is slightly less than one, implying that a 1% rise in consumption leads to a slightly less than 1% rise in cash demand. Consumption growth disproportionately drives demand for £20 notes, while boosting £10 demand less than one for one. This might reflect a substitution effect from £10 notes into £20 notes due to inflation.
Interest rates	Higher interest rates reduce cash demand, a relationship that became clearer during the financial crisis when rates were cut significantly. The contagion effect following the financial crisis may be captured both by lower rates and the exchange rate – which may over-attribute growth in cash demand to these variables. The relationship shows that a 100 basis point increase in Bank Rate is estimated to push down on cash demand by 2%. Bank Rate was not statistically significant for the £5 note but was for the £10. The clearest effects are on the £20 and £50 notes. For the £50 the US Federal Reserve's policy rate has been included as international demand is larger for this denomination. The 450 basis point reduction in Bank Rate and 500 basis point cut in the Federal Reserve's policy rate between 2007 and 2009 explains a fifth of the £6 billion increase in £50s since.
Exchange rate	A fall in sterling's exchange rate increases demand for cash. This was highlighted by an immediate increase in demand for the £50 note following the fall in sterling's exchange rate in summer 2016 in the aftermath of the results of the UK's referendum on EU membership. Acquiring BoE notes when the pound is cheap makes sense for foreign visitors to the UK who are in essence bringing forward spending even when those notes will not be spent for a number of months or even years. We also have intelligence that there are individuals who hold a basket of currencies as cash and, for whom, a fall in sterling's exchange rate allows them to purchase BoE notes cheaply.
Number of cash payments	The number of regular payments made per person per year in cash increases demand for cash, although this variable lost significance when updating the model using 2015 data. This variable captures payments like household utility bills, made in cash but may also proxy the long run decline in cash usage overall for all types of payments. The number of spontaneous payments made in cash was also tested but was not significant. This might be because regular payments made in cash are of higher value than spontaneous cash payments.
Self-employment	Self-employment appears to raise demand for cash, consistent with small businesses receiving a larger proportion of their transactions in cash compared to large businesses. However for £50 notes there is a negative effect, although it is unclear what drives this.

Other findings revealed by the use of dummy variables in the model are that:

- There was a 2.9% increase (around £1.2 billion) in NIC in 2008-09 not associated with the other variables that may be related to the shocks hitting the economy – especially the financial sector – at that time. That could be interpreted as precautionary holdings of cash.
- The £50 note appears to be affected by series changeovers in a way that other denominations are not, reflecting the note's store of wealth use and the fact that returned £50 notes are more likely than other notes to be exchanged for electronic payment as opposed to a new series note.
- Concerns about electronic payments and bank computer systems around the year 2000 appear to have temporarily boosted cash demand by a little over 1%.

But there are a number of patterns implied by the model's results that are more complex to explain:

A rise in unemployment appears to push down on NIC. One might expect unemployment to boost cash demand as households often use cash for budgeting (given that reduced spending should be captured by the consumption variable). This holds true for demand for £5 notes, but higher unemployment lowers demand for £20 notes, explaining the negative effect on overall NIC. The negative coefficient might capture some cyclical factor not fully accounted for by consumption. Or it may reflect some people drawing on previously hoarded cash, already in circulation, when they become unemployed in order to smooth consumption.

A rise in the number of ATMs per person pushes up demand for cash. This might reflect the fact that the banking sector requires extra cash to stock the ATMs, which more than offsets the reduced need for consumers to hold larger stocks of cash if cash is easier to access. Conversely, it could reflect the fact that consumers withdraw more cash when ATMs are more readily available. This coefficient suggests that around 5% of cash is stocked in ATMs or their supply chains, which seems reasonable given the value of cash withdrawn from ATMs. Before 2008, the coefficient implied that over a quarter of cash was associated with ATMs which is an unrealistically high proportion. It has since reduced and it is possible that variation in the other variables since 2008 has revealed a weaker underlying relationship between ATMs and NIC.

For individual denominations, the picture is even less clear. ATMs per person reduce £5 and £10 NIC, but push up on the £20.

In contrast to ATMs, a rise in the number of bank branches per person reduces demand for banknotes. The increase in cash stocked is more than outweighed by changing behaviour. The coefficient implies that if around 200 branches close (or 1% of the total), NIC increases by 0.4% as households stock higher amounts of cash. Small businesses may also play a significant role in holding larger amounts of cash. The role of branches was insignificant before 2008, perhaps because there were so many branches at that time that closing some made little difference.

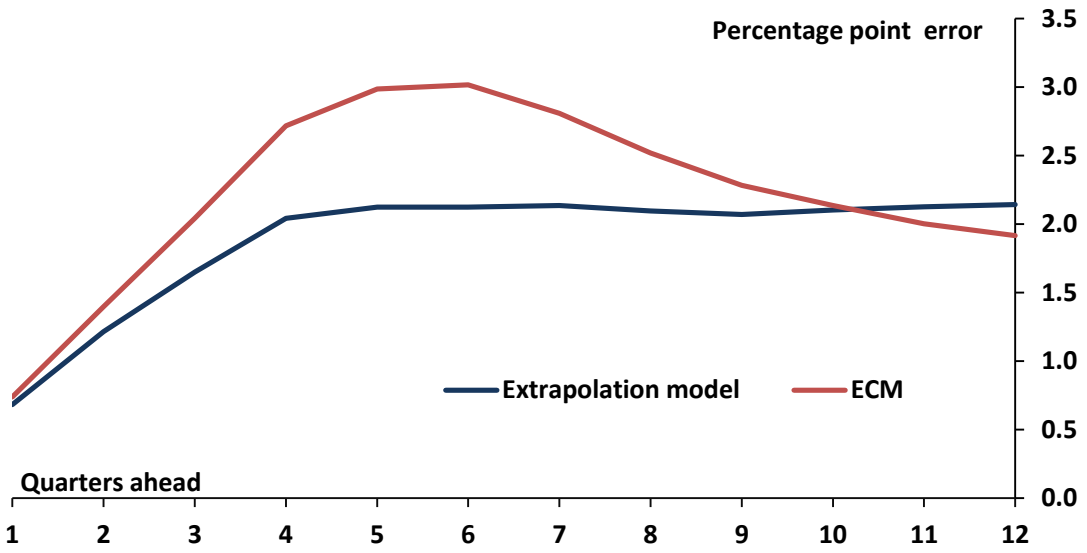
Projecting forward

Once the past relationship between different variables and changes in demand for each denomination is known, it is then possible to produce and use forecasts for these variables to calculate forecasts for NIC growth by denomination.

How accurate is the model?

It is also possible to measure how accurately the model would have performed in the past given the data available at the time. The chart below compares the performance of the error correction model (ECM) with a simpler extrapolation model[14] by calculating the root mean squared error (RMSE) of the forecasts.

Chart 2: Comparison of RMSE (annual growth rate for sum of denominations)



The extrapolation model tends to perform better over the short-term, with evidence that the ECM's economic determinants help it to perform better after that. Both models still exhibit relatively large forecast errors, of 2-3 percentage points in terms of annual growth rates up to three years ahead[15]. In terms of NIC levels, it should be noted that this annual errors would compound over time.

6. Modelling challenges

There are three key challenges to producing an effective forecast model that help explain this inaccuracy and also provide insights into how to supplement this forecasting approach:

(i) specification challenges with the model itself;
(ii) inaccuracies in our forecasts for the variables included; and
(iii) concerns that past relationships may be disrupted going forward.

Specification challenges

Specification challenges have to be overcome with any forecasting model. In the model above, judgement was used, based on the evidence, to remove variables deemed responsible for spurious relationships. For example, the inclusion of point of sale terminals in the model suggested an unrealistically large proportion of NIC growth was driven by cash obtained as part of a sale hence

[14] The exact type of model is an autoregressive (AR) model, which regresses current growth on the last period's growth rate (or the last few periods'). These models tend to revert to the mean, but the short term dynamics are driven by the observed persistence of changes in growth over time.
[15] These results are specific to the sample period and may not hold for the future.

this variable was removed. As the complexities interpreting some of the coefficients demonstrate, it is often not clear whether or not to include certain variables.

Models may also suffer from omitted variable bias: the model may not have captured all the factors that influence cash demand. For example, as stated above, demand from overseas and the shadow economy are important components of NIC yet we do not have the data to measure and model the drivers of this demand.

Input forecast inaccuracies

A model can only be as accurate as the information inputted. The model's outputs are likely to be incorrect, if the forecasts for the explanatory variables are. For example, forecasts for variables like consumption are normally subject to certain conditioning assumptions, which may not materialise and forecasts for other variables are based on simple extrapolation. But as discussed below, one of the main benefits of the model is that it allows us to conduct scenario analysis for a number of possible future states, making it less reliant on identifying just one set of inputs.

Reaching a paradigm shift when past relationships no longer hold

The model is based on historic relationships and so can only forecast based on relationships that have held true in the past. Whilst it can incorporate past trends, it is not able to take into account paradigm shifts that fundamentally alter existing relationships or new relationships that may emerge.

There is the added complexity that drivers are interrelated and changes to one could have knock-on effects on others. For example, if transactional demand continues to fall whilst non-transactional demand rises, will there be a tipping point where banknotes no longer have the same utility as a store of value if it was extremely difficult to bank and spend them? This model will not be able to predict such a point of inflection. In countries with falling transactional demand and falling NIC, it is possible that 'de-hoarding' has occurred already.

Moreover, non-linearities may exist in a number of relationships (for example, with the exchange rate or interest rates) that have not been modelled.

7. How can models be supplemented?

Given models' theoretical and practical limitations, it is important to develop an approach that takes account of a broader range of drivers.

This paper uses a scorecard approach to help collate information on these drivers and weight them based on:

- The likelihood of a change in one of the drivers occurring;
- The market and use for cash affected, and thus;
- The magnitude of the potential impact; and
- The time lag between a change in a driver and the resultant impact on cash demand.

Research has helped to identify which indicators to monitor, as set out in earlier in Table 1, as well as to understand the transmission mechanism through which these drivers influence demand.

Below is the evidence used in two instances to judge the potential impact various drivers could have on i) merchant demand for BoE notes, and ii) hoarding demand for BoE notes. It explains why a driver is influential, the potential impact it might have, and how it can be monitored whether through inclusion in the model or in the scorecard. This evidence is then used to inform the scorecard below.

Merchants' use of cash

Merchants are responsible for a significant portion of NIC[16]. Cash may be held by merchants as takings before being banked, in tills as floats or for business continuity purposes. As set out in Table 1, drivers for merchants' use of cash are: cost of payment methods, consumer attitudes to cash, safety and fraud concerns, cash in transit costs and interest rates.

One might expect that historically low interest rates, compared with the costs of cash-in-transit (CiT) services for banking takings would mean that merchants would hold onto cash for longer before banking it. This is somewhat evidenced by the fact that the value of notes returned to wholesale cash distribution centres has fallen 13% in the last two years[17]. This has partly led to the increase in NIC as notes have been held in the transactional cycle by financial institutions and retailers for longer. Merchants are also keeping cash in the transactional cycle by refilling ATMs in their stores directly from their tills. Due to this increasing trend, in 2013, to encourage these notes to be authenticated before use, the Bank of England, along with the industry[18], introduced the Code of Conduct for Authentication of Machine-Dispensed Banknotes.

To understand whether merchant's had a strategy for encouraging or discouraging the use of cash, we at the Bank of England undertook qualitative research[19] with a range of large, cash-intensive businesses. The research found that many businesses had seen a steady but significant fall in proportion of cash sales in recent years which they expected to continue into the future, reflecting changing consumer attitudes. Some of this was driven by changing behaviour, such as a shift in the point of sale from in person to online. Businesses in other industries reported a stable cohort of cash users (in one example accounting for 20% of sales) for whom alternatives did not appear popular. This is accounted for in the model by the variable which measures the number of regular payments made in cash, and the forecasts will cover a trend over time. To inform the forecast, it is also necessary to monitor leading indicators that may signify an acceleration or deceleration of this movement away from cash going forward.

Banking policies were thought to be relatively unresponsive to falling cash volumes and decisions on how often to bank takings were driven by practical concerns such as safety and insurance limits and CiT costs. Interestingly, merchants said they were not strongly influenced by the potential interest they could earn.

[16] In our 2014 quarterly bulletin article we estimated that this could amount to up to £5 billion.
[17] From £15.25 billion in July 2014 to around £13.31 billion in July 2016.
[18] The Code has broad industry support and is sponsored by the British Retail Consortium, Cash Services, LINK, the Association of Commercial Bank Issuers and Payments UK. See http://www.cashservices.org.uk/what-we-do/codes-conduct
[19] 12 interviews were conducted with large, cash-handling businesses, across different sectors, broadly representative of total cash spending as reported in Payments UK, 2016 UK Consumer Payments.

Cash was still the cheapest form of payment for most merchants but the differential between cash and debit card was narrowing. This matches with industry-wide data provided by the British Retail Consortium survey, which shows that as a proportion of tender value, cash is the cheapest payment method although debit card costs are falling, with possible further reductions to come once the full impact of interchange fee reductions are realised[20]. Cash costs on the other hand, such as the cost of a business account with cash services, have stayed fairly stable. The relative costs of card and cash will depend on the individual merchant because a significant share of cash processing costs are fixed, and card processing requires initial investment. Thus costs per transaction are dependent on scale of the business.

Table 2: Costs of collection as a % of tender turnover, 2011-2015

	2011	2012	2013	2014	2015
Cash	0.14%	0.16%	0.14%	0.14%	0.15%
Debit cards	0.32%	0.32%	0.32%	0.36%	0.22%

Source: BRC Payments Survey 2015

This is emphasised by research with small businesses[21], which found that majority of businesses not currently offering electronic payments are unlikely to change their approach. Four in five of these businesses 'probably' or 'definitely will not' offer debit/credit card, contactless, or mobile payments in the next 2-3 years. An aversion to change and cost were cited as the top barriers.

Overall, whilst larger businesses are responsive to costs, merchants interviewed reported that they would continue to offer as many methods of payment as consumers wanted, and that they would not push customers away from cash. However, around a third of the merchants interviewed said that they may attempt to "nudge" customers if cash became too costly. Smaller businesses appear more resistant to card payments although they are similarly motivated by cost.

Hoarding

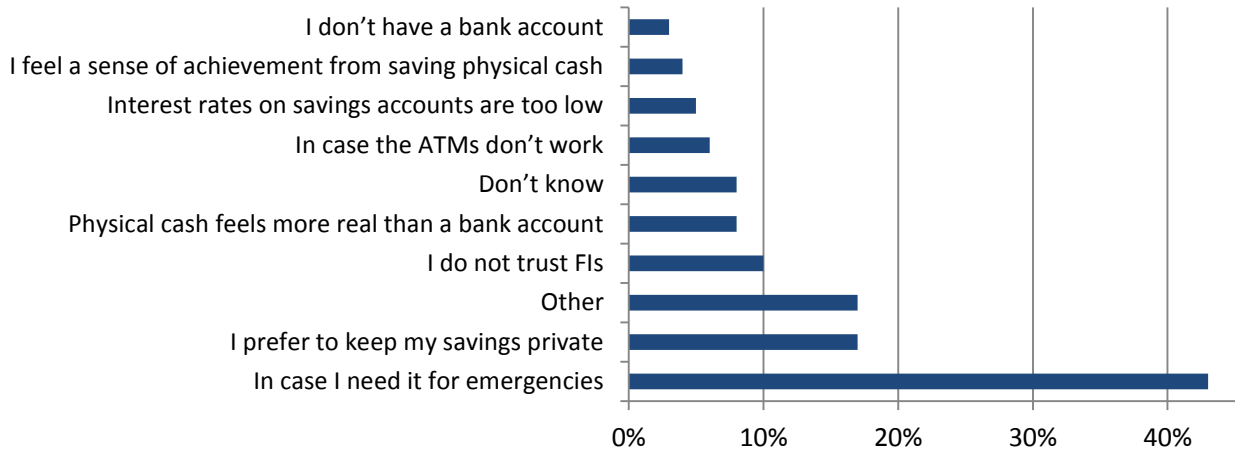
There are many motives for hoarding cash. One would think interest rates are an important factor, as presumably there is a level at which the opportunity cost of foregone interest outweighs the perceived benefit of cash. However, the only available information on hoarding comes from surveys, and they have found that people keep cash mainly to provide comfort against potential emergencies.

As can be seen in the chart below, issues about privacy, trust and access to cash in emergencies were the most important drivers. It is not clear if these drivers will persist into the future or what might influence them. Perhaps greater knowledge of deposit insurance limits would reduce hoarding. A widely-publicised cyber-attack, on the other hand, might reduce trust in financial institutions to keep data private and increase the incentive to hoard. These are events we can monitor, although measurable indicators are more difficult to determine. Stability of earnings, as measured by wage levels for example, could be used to proxy the need for cash in emergencies.

[20] The Interchange Fee regulation is EU legislation that came into effect in June 2015. In the UK, this means that on average debit interchange cannot exceed 0.2% of transaction value.

[21] **Tu, T & Salmon, C (2016)** Uses of cash and electronic payments, *Ipsos Mori Research Report 432.*

Chart 3: Why do you keep cash at home rather than in a bank, building society, or credit union?



Source: GfK NOP survey of 1,000 respondents into the uses of cash, 2014

Similarly central banks can monitor whether an alternative to cash as an anonymous store of value is developed and adopted. Whilst take-up is hard to predict, such a product would seemingly have to be anonymous, widely accepted, exist outside of the traditional banking system and be controlled by some other trusted party. It is unlikely such a product will be developed in the near-future.

Nevertheless, the impact of these factors will be limited given that 42% of those who hoard reported that "nothing" would influence them to put cash in a bank account in the future. Of those that could be influenced, interest rates and perceived access to cash were the most important factors[22]. Interest rates are in the econometric model and the variables on ATMs and bank branches are included to account for access to cash. This finding appears to contradict the data in the chart – highlighting the shortcomings of surveying about future intentions.

Scorecard

The drivers not included in the forecast model have been assessed in the scorecard below. Continued research and analysis will help refine the scorecard, which should be considered preliminary at this stage. Whilst the ratings assigned in the scorecard are subjective, they are informed by the evidence.

Once the scorecard has been fully specified, central banks can decide whether to deviate from a model's central forecast and the extent to which they should do so. There needs to be a robust process for how this is done in practice, with sufficient checks, challenges and balances to ensure that bias is removed from the decision. The scorecard should, therefore, be used as a tool to help to ensure that the full range of potential impacts are discussed and taken into account.

[22] When asked "What would influence you to put the cash you are keeping at home in an account with a bank, building society, or credit union?" 42% replied "Nothing", 20% "Higher interest rates on savings accounts" and 14% "Easier to withdraw the cash again if I need to."

Table 3: Preliminary scorecard for drivers of banknote demand

Indicator	Market and use, rough proportion of overall demand	Brief description of transmission mechanism	Rating of potential impact (1-5, where 5 is high impact)	Feedthrough time Lagging or leading indicator	Likelihood of change occurring
Interchange fee	Domestic transactional (21-27% of stock of notes)	Determines cost of accepting card (and thus relative cost of cash) for merchants.	2	Leading Likely to take 6-12 months for changes in legislation to feed through to cost changes and further lag to influence merchant behaviour.	Unlikely in the next year
Use of alternative payment methods	Domestic transactional (21-27% of stock of notes)	Reflects changing use of payment methods.	4	Lagging Data will reflect substitution away from cash.	Trend likely to continue but deviations possible
Cash costs (Cash in transit, business banking)	Transactional – merchant demand	Increases cost of banking cash takings and encourages cash to remain in circulation.	2	Leading Uncertain as to how quickly merchants would respond to cost changes, likely to be dependent on magnitude of change. Should lead to a step change in level of NIC as opposed to impacting growth in long run.	No indication of significant change in the next year
Safety and fraud concerns	Transactional – merchant demand	If potential cash losses are deemed more likely than card, merchants will nudge customers away from cash.	2	Leading Merchants will take time to react to changes, although data may not be produced regularly enough to be considered a leading indicator.	Unlikely
Cyber attacks	Transactional and hoarding	Influences attitudes to cash due to safety concerns of alternatives	3	Leading Public response to cyber attack dependent on scale and reporting of incident.	Unknown

Alternatives to cash as a store of value	Hoarding	Potential substitution from cash hoarding to 'saving' via an alternative product.	1	Leading Uncertain as to how quickly developments would influence behaviour.	Low Attachment to cash for hoarding is attitude unlikely to change
Stability of earnings/wage growth	Hoarding	Influences perceived need of cash in case of emergencies	1 (stock market volatility not significant)	Leading Unknown given absence of information on hoarding behaviour	Low
Deposit insurance limit	Hoarding	Influences need for cash in case of emergencies, unlikely to have significant impact.	1	Leading Unknown given absence of information on hoarding behaviour	No indication of a change.
Tourist spending	Overseas	Increased tourist spending reflects greater demand for cash, either acquired abroad or once entered the UK.	0 (not significant in model)	Lagging Indicative of future patterns but data produced fairly regularly.	Uncertain
Status as a reserve currency	Overseas	If sterling was to be considered less valuable as an international reserve currency, overseas demand for BoE notes would fall.	2	Leading However changes in 'status' role will probably only materialise as reduced demand for sterling.	Uncertain
Migration	Transactional/ shadow	Migrants to UK are likely to be more cash-dependent than residents.	2	Lagging Migration will have already impacted NIC once migration statistics reported.	Unknown
Tax and social security contribution burdens Quality of institutions Labour market regulations Tax morale Deterrence	Shadow	If taxes, contributions or regulations increased then cash demand would be expected to rise, although clear link with self-employment variable. Increased deterrence for using cash in shadow economy will reduce cash use, as would higher morale.	3	Leading Lag unknown	Uncertain Taylor review on modern employment practices may report on some of these drivers Tax morale difficult to predict and deterrence changes unknown

8. Conclusion: helping to plan for the future

This paper sets out a framework for understanding banknote demand. Following extensive research, it seeks to identify the drivers of demand for Bank of England banknotes. It describes how a forecast model was developed, using the relationship between changes in some of these drivers and changes in NIC to predict demand going forward. It also sets out how this can be supplemented with broader research and information that could not be properly accounted for in the model. Together, this information can be used to help determine a forecast for NIC.

However, calculating a central forecast for banknote demand, by denomination, is a rather narrow output. As central banks, it is the range of possible outcomes that interests us. For example, demand can be forecast based on interest rates rising sharply, the pound depreciating and the number of bank branches falling sharply. It can also be forecast based on a cyber threat causing a reversal of the trend away from cash for transactions whilst consumption was growing strongly.

This is arguably the more important output. It allows central banks to assess future infrastructure needs against a range of stretch scenarios, and to ensure they are resilient to a combination of exogenous shocks.

Practically, this can be done by negotiating agile and flexible contracts with suppliers to guarantee sufficient flexibility to banknote production. Central banks can also hold contingency stocks of banknotes to meet demand under a range of severe but plausible events. These stock levels can be set according to a broad risk appetite dependent on the range of scenarios they want to mitigate against.

It is not possible to know exactly what demand for banknotes will be in the future, but this paper sets out a framework for understanding what demand might be and how it might be influenced. It also describes how to identify leading indicators that may signify a change of demand in the future. With this knowledge, processes can be put in place to manage uncertainty to ensure confidence in the currency is maintained.

References

Cusbert T and T Rohling (2013), 'Currency Demand during the Global Financial Crisis: Evidence from Australia', *RBA Research Discussion Paper*, No 2013-01.

Dell'Anno, R. (2003), *'*Estimating the shadow economy in Italy: A structural equation approach', *Working Paper 2003-7*, Department of Economics, University of Aarhus, Aarhus, Denmark.

Del'Anno, R. and F. Schneider, (2004), 'The shadow economy of Italy and other OECD countries: what do we know?*', Discussion Paper*, Department of Economics, University of Linz, Linz, Austria.

Feige, E.L. (ed.) (1989), *'The Underground Economies. Tax Evasion and Information Distortion',* Cambridge University Press, Cambridge.

Fish T and R Whymark (2015), *'How Has Cash Usage Evolved in Recent Decades? What Might Drive Demand in the Future?'* Bank of England Quarterly Bulletin, Vol. 55, pages 1–12, available at http://www.bankofengland.co.uk/publications/Pages/quarterlybulletin/2015/q3.aspx.

Schneider and Buehn (2016), 'Estimating the size of the Shadow Economy: methods, problems and open questions', *IZA Discussion paper series,* No. 9820.

Tu, T & Salmon, C (2016), 'Uses of cash and electronic payments', *Ipsos Mori Research Report 432.*

Appendix 1: ECM estimates for total NIC

	1993Q4-2008Q2	1993Q4-2015Q4 without crisis dummies	1993Q4-2015Q4 with crisis dummies
Constant	14.798***	14.204***	14.204***
Consumption	0.908***	0.85***	0.85***
BankRate	-0.002	-0.022***	-0.022***
LinkATMs	0.288***	0.052*	0.052*
Branches	-0.049	-0.524***	-0.524***
SelfEmp	0.917***	0.865**	0.865**
CashRegPayments	0.136***	0.046	0.046
UnemploymentRate	-0.009**	-0.008**	-0.008**
ExchangeRate	-0.048**	-0.091***	-0.091***
Speed of adjustment	-0.658***	-0.194***	-0.183***
d(NIC(t-1))	0.335***	0.27***	0.202**
d(Consumption(t))	0.453***	0.103	0.232**
d(ExchangeRate(t))	-0.055*	-0.085***	-0.059**
Crisis 2008Q4			0.015***
Crisis 2009Q1			0.014**
Crisis 2009Q2			
Millennium (1999Q4)	0.015***	0.011**	0.011**
Adjusted R-squared	0.43	0.28	0.36
Standard error	0.005	0.005	0.005

****, ** and * indicate p-values less than 0.01, 0.05 and 0.10 respectively*