LUISS

Department of
Economics and Finance

Bachelor thesis
in
Money and Banking

Towards a cashless society: economic analysis and measurement issues

Candidate: Tommaso De Portu (Student ID 208471)
Tutor: Professor Paolo Paesani

A.Y. 2018-2019

Table of Contents

Introduction

Governments and central bank authorities are becoming increasingly concerned with the risks of using cash. Although not all economists agree, cash has always been the payment method favoured by criminals to pursue illicit activities because of its anonymity. More in general, there is a link between cash and shadow economy activities. The first two sections of the next chapter bring two examples in recent years of central banks and governments trying to tackle criminal activities by modifying the supply of cash: the first is the end of issuance of the 500€ note by the European Central Bank (ECB), the second the 500 and 1,000₹ notes' demonetisation by the Indian government.

However, the idea of a society that does not use cash has been around for quite a long time, precisely since 1887, when Edward Bellamy wrote about it in his novel *Looking Backwards*. Although economies in the modern world are far from being pure cashless societies, progress in this sense in undeniable. Whether such progress would bring an improvement in living standards, ease of payment or other aspects of our lives is still an open discussion.

This thesis studies the state of the art of the European area economies with respect to their progression towards a cashless economy, considering recent technological developments.

The thesis is divided in two parts: the first chapter focuses on the idea of a cashless society, its history and concept, also with reference to the economic literature. The second chapter deals with empirical research on the shadow economy and its relationship with cash; it also studies the current situation and progression towards a cashless society of European economies, laying out the framework for a synthetic numerical index as means to measure such progression. Such index will allow to measure, through observable macroeconomic variables, how an economy stands with respect to its use of payment instruments.

The main conclusions drawn from this research may be summarised as follows:

1. Electronic means of payments are spreading in developed countries and emerging technologies are facilitating their use in day-to-day transactions. The progressive abandonment of cash is indeed taking place in several countries.
2. Whilst many problems are being solved by abandoning cash, cashless economies have their contradictions and most societies are not ready to leave cash entirely, not even those countries in which cash is already present in a minimal amount: a fraction of consumers may still demand cash and they cannot be left out, both from a social and ethical perspective.
3. From the basic Quantity Theory of Money (QTM) equation, we develop the *Cashless Velocity Index (CVI)*, to estimate how an economy is doing with respect to its use of cash. Such index aims to give theoretical economic support to recent measurements of cash circulation levels. The index relies on different estimates of velocity as weights to measure the effective usage of different payment instruments in an economy.
4. Cash shares a strong relation with the shadow economy. With instrumental variable analysis we prove (still with some limitations due to data availability) that the shadow economy has a positive causal effect on the quantity of cash transactions in a given economy.

1. Moving towards a cashless society

A cashless society defines an economic system in which financial transactions are not settled with money in its physical form (i.e. banknotes and coins). To give a historic perspective, cashless societies have existed long before the development of electronic means of payment, in societies based on barter and other methods of exchange. In recent times, cashless transactions have become possible using digital currencies and electronic forms of payments. Relentless technological development in recent years has brought the idea of a cashless society in the spotlight of economic discussion (Rogoff, 2014). For example, the economist David Birch argues that the idea of "identity" and that of money are changing equally profoundly. He suggests that because of technological change, the two trends are converging so that all that will be needed for transacting will be our identities, captured in the unique record of our online social contacts (Birch, 2014).

This thesis will discuss and focus on recent developments: the term *cashless society* will indicate a society in which currency exists but is replaced by its digital equivalent. That is, money as legal tender exists, is recorded, and is exchanged only in electronic and digital form. Moreover, this thesis will not consider non final transactions in which an exchange is made in a cashless way (without granting "finality of payment"). A transaction involving a contract that postpones payment, for example, will not be considered cashless, as to conclude the economic transfer of goods and/or services, an additional transaction (which may involve cash) is needed.

1.1 Incentives to the shadow economy: is cash one of them?

As introduction to the topic, the two following sections analyze two recent episodes aimed at reducing the shadow economy and/or the funding of illicit activities such as terrorism via the control of cash. The first case is the end of issuance of the 500€ note by the European Central Bank (ECB) in 2018. The second is the November 2016 demonetisation of the 500 and 1,000₹ notes by the Indian government.

1.1.1 The 500€ Note and the Eurozone

When the euro was launched on 1 January 1999, it became the currency of more than 300 million people in Europe. For the first three years it was only used for accounting purposes. Cash was not introduced until January 2002, when it replaced, at fixed conversion rates, the banknotes and coins of the national currencies of the Euro states. Today, euro banknotes and coins are legal tender in 19 of the 28 Member States of the European Union, including the overseas territories and islands which are either part of, or associated with, euro area countries. Cash payments are now made in the same currency by 340 million people — euro banknotes and coins have become a tangible symbol of European (economic) integration.

Aside from Denmark and the United Kingdom[1], which have an opt-out, all EU countries are expected to join the monetary union and to introduce the euro as soon as they fulfil the convergence criteria of the Maastricht Treaty (1991).

Legally, both the European Central Bank (ECB) and the central banks of the Eurozone countries have the right to issue the 7 different euro banknotes: €5, €10, €20, €50, €100, €200, and €500. In practice, however, only the national central banks of the Eurozone physically issue and withdraw euro banknotes. The ECB does not have a cash office and is not involved in any cash operations.

The peculiarity of the 500€ note is that its value is several times greater than many of the largest circulating notes of other major currencies, such as the United States 100-dollar bill. Thus, a large monetary value can be concentrated into a small volume of notes. This facilitates crimes that deal in cash, including money laundering, drug dealing, and tax evasion (Sands, 2016, p. 1).

When the euro went into circulation in 2002, 3.5% of the total €500 notes were in Spain (13 million notes). But the number has grown steadily since then, peaking at 26% of all €500 notes in circulation in 2007 (OECD Economic Surveys: Spain, 2007, p. 110). This concentration of €500 note is far greater than expected for an economy of Spain's size, as prior to conversion to euro the largest banknote was 10,000 Spanish pesetas

[1] As of the 23 June 2016 referendum, the United Kingdom (UK) opted to leave the EU. At the time of this writing, the United Kingdom is still trying to find an agreement defining the terms for UK's exit from the European Union (Brexit) and the outcome of this situation is very uncertain, as it could both lead to UK's exit as well as more complicated outcomes, including finding a way to a second referendum to remain part of the EU.

(Encyclopaedia Britannica , 2005), worth around 60€ (Banco de España, *Peseta banknotes and coins*). The number of 10,000 pesetas notes in circulation in 2000 (at its supply's peak) was 564 million (Banco de España, *Peseta banknotes in circulation: Breakdown denomination*), roughly corresponding to 34 billion Euros (without accounting for inflation); however, in 2007 Spain counted around 50 billion Euros in €500 notes[2]. These notes are rarely seen in every-day transactions – they have been nicknamed "Bin Ladens"[3]. British and Spanish police are using the bills to track money laundering. This sharp growth and the suspicions that it is linked to illicit activity have led to calls that the bills be withdrawn from circulation.

As of 20 April 2010, money exchange offices in the United Kingdom were banned from selling 500€ notes due to their use in money laundering. The Serious Organised Crime Agency (SOCA)[4] claimed that "90% of all €500 notes sold in the UK are in the hands of organised crime" (King, Walker, & Gurulé, 2018).

The EU directive 2005/06/EC *"on the prevention of the use of the financial system for the purpose of money laundering and terrorist financing"* tries to prevent such crime by requiring banks, real estate agents, tax and business advisors or agents, casinos and more companies to investigate and report usage of cash in excess of €15,000. Retail stores and shops in the EU also have a cash limit they can accept upfront, per payment; however, since all member states have their own autonomy, each country sets its own limit. On average, restrictions begin from 2-3,000€, but Eastern EU countries set higher limits (European Consumer Centre Germany, n.d.).

There are also limits for travelling with cash: on 21 December 2016, the European Commission proposed new rules on cash controls. Following discussions between the Council, Parliament and the Commission, the Council and Parliament provisionally agreed on the proposed text on May 23 of 2018. On October 2 of 2018, the Council formally adopted the proposed text. If you plan to enter or leave the EU with 10,000€ or more in cash**,** you must declare it to customs, failing to do so can result in the cash being confiscated and being fined (European Commission, n.d.).

---

[2] The result is obtained from 26% of the total supply of euro 500 notes in 2007 (European Central Bank, 2007).

[3] Such nickname was given by the populace as the presence and appearance of the notes are well-known, but the notes themselves are very difficult to find (Casciani, 2010).

[4] In June 2011, SOCA's operations were merged into a larger National Crime Agency to launch in 2013. The new agency, created through the Crime and Courts Act (2013), became operative on 7 October 2013.

The European Central Bank is closely monitoring the circulation and stock of the euro coins and banknotes. It is a task of the ECB to ensure an efficient and smooth supply of euro notes and to maintain their integrity throughout the euro area.
Initially, the high denomination notes were introduced very rapidly so that in the first 7 years (up to December 2008) there were 530,064,413 five hundred-euro banknotes in circulation. The €500 banknotes in circulation from the end of 2008 to mid-2011 represented more value than any other banknote in circulation. Since then, the banknote circulation declined: in August 2018, there were approximately 515M banknotes in circulation (decreased from 614M in 2015) (European Central Bank, 2019), until on 4 May 2016 the European Central Bank announced that it would stop issuing the 500-euro notes:

"Today the Governing Council of the European Central Bank (ECB) […] has decided to permanently stop producing the €500 banknote and to exclude it from the Europa series, taking into account concerns that this banknote could facilitate illicit activities. The issuance of the €500 will be stopped around the end of 2018, when the €100 and €200 banknotes of the Europa series are planned to be introduced. The other denominations – from €5 to €200 – will remain in place" (European Central Bank, *"ECB ends production and issuance of €500 banknote"*)

It was decided that Eurosystem's central banks will stop distributing banknotes on 26 January 2019. To ensure a smooth transition and for logistic reasons, the Deutsche Bundesbank and the Oesterreichische Nationalbank opted for longer period and issued banknotes until 26 April 2019. Circulating 500€ notes will remain legal tender and can continue to be used as a means of payment and store of value until further notice. Banks, bureaux de change and other commercial parties can keep recirculating the existing notes (European Central Bank, *"Banknotes"*).

1.1.2 The 500 and 1,000₹ notes' demonetisation

On 8 November 2016, the Government of India announced the demonetisation of all ₹500 and ₹1000 banknotes. The government claimed that the action would curtail the shadow economy and reduce the use of illicit and counterfeit cash used to fund illegal activity and terrorism (India Today, 2016 November 8; Firstpost 2017, November 8).

The announcement of demonetisation was followed by prolonged cash shortages in subsequent weeks, which created significant disruption throughout the economy (Ghosh, 2017, p. 76). People seeking to exchange their banknotes had to stand in lengthy queues, and several deaths were linked to the rush to exchange cash.

According to a 2018 report from the Reserve Bank of India, approximately 99.3% of the demonetised banknotes were deposited with the banking system, leading analysts to state that the effort had failed to remove black money from the economy (Reserve Bank of India, 2018, p. 219).

The plan to demonetise the ₹500 and ₹1000 banknotes was initiated between six and ten months before it was announced and was kept confidential. The Union cabinet was informed about the plan on 8 November 2016 in a meeting in the evening called by the Indian Prime Minister Narendra Modi.

Soon after the meeting, Modi announced the demonetisation in an unscheduled live national television address to the nation. He declared circulation of all ₹500 and ₹1,000 banknotes of the Mahatma Gandhi Series invalid, effective from the midnight of the same day, and announced the issuance of new ₹500 and ₹2,000 banknotes of the Mahatma Gandhi New Series in exchange for the demonetised banknotes (Firstpost 2017, November 8).

Stock indices had a sudden fall on the day after the announcement. Whilst there is no certainty about the fact that demonetisation is the only factor that reduced growth, Gross Domestic Product (GDP) growth fell by almost 0.5 percentage points from 2016 to 2017, following a +1.392% increase from 2015 to 2016 (the first positive trend since a sharp fall from 2010) (The World Bank, *"Inflation, GDP deflator – annual %"*).

Initially, the move received support from several bankers as well as from some international commentators. However, the move was also criticised as poorly planned and unfair, and was met with protests, litigation, and strikes against the government in several places across India.

Following the announcement of demonetisation, businessmen stated that they had received warning of the move, allowing them to convert their money into smaller denominations. A Member of the Legislative Assembly of the *Bharatiya Janata Party* ("Indian People's Party"), Bhawani Singh Rajawat, claimed in a video that wealthy businessmen were informed about the demonetisation before it occurred. He later

denied said comments, claiming that the conversation was "off the record" and that his comments had been distorted.

India's Prime Minister decided to pursue demonetisation to tackle terrorism and illicit activities. However, the counterfeit banknotes in denomination of old ₹500 and ₹1000 saw increase in 2016-17 and decline in 2017-18 because they were already demonetised and not because of the demonetisation being successful. Consequently, in 2017-18, there was both an increase in counterfeit banknotes of new ₹500 and ₹2000 denomination and an increase in the counterfeit of banknotes in small denomination of ₹100 and ₹50. There has been no significant change in the number of detections of counterfeit banknotes detected. In 2017-18, the number of detections was close to that before demonetisation. In addition to the (in)effectiveness of demonetisation, there is another major factor to be analysed, that is, the cost of withdrawing the banknotes from circulation and issuing the new denomination: it means new design expenses, security, printing and transport expenses, to name a few. The total expenditure incurred on security printing during the year 2016-2017 stood at ₹79.65 billion as against ₹49.12 billion in 2017-18 (Reserve Bank of India, 2018, pp. 150-151). Assuming that most of the difference is imputable to demonetisation and the issuance of the whole new lot of 500 and 2,000₹ banknotes, which seems reasonable, that would put the cost of the operation in the order of ₹30 billion, which is roughly equivalent to €390 million.

For obvious reasons, the Indian PM's announcement is certainly not comparable to that of the European Central Bank regarding the end of issuance of the 500€ banknote.

The demonetisation of the 500 and 1,000 Rupees was unexpected and, it would also seem safe to assume, not very well planned: cash shortages added chaos to what was already an unstable situation.

We must also bear in mind the difficulties of the population: the 500- and 1,000-rupees notes would not be legal tender from midnight of the same night and could only be deposited to a post office or bank account, within 30 days, to be exchanged with smaller notes. This deadline was quite demanding, considering that in 2014 only 53% of Indian adults had a bank account. That number rose from 2011 (35%) and would still rise in 2017, hitting 80%. However, when the announcement of the demonetisation came about, in late 2016, that number had to be between 53 and 80% (The World Bank, 2019).

Be that as it may, the demonetisation was hard on the population and presumably was the main cause of the slowdown in India's GDP growth rate. Following the slowdown, the average growth rate oscillated between 2017 and the first part of 2018 and showed again a positive trend in the second quarter 2018, recouping 2.1 points from the second to the fourth quarter 2018 (Indian Government - Ministry of Statistics and Programme Implementation, 2018).

Authorities and governments around the world have become increasingly aware and concerned regarding counterfeit banknotes and the relation that cash has with the shadow economy and illicit activities. But changing banknotes does not appear to be a final solution, as the Indian demonetisation seems to have proven.

1.2 Problems related with the use of cash

It is often assumed that anonymous transactions are almost exclusively of the illegal kind and, in turn, that these illegal activities are predominantly undertaken by cash. However, this is not *always* the case. About withdrawing the €500 banknote from circulation, ECB Executive Board Member Yves Mersch said:

"European Central Bank officials want to see evidence that high-denomination euro banknotes facilitate criminal activity rather than relying on unproven assertions" (Schneeweiss, 2016).

Indeed, the correlation between cash circulation and the size of the shadow economy has been inferred and discussed for many years. Philip D. Cagan's Currency Demand Approach (CDA), originally proposed in 1958, relates the size of the shadow economy with an excess demand in cash. This method is still widely used and taught as the main "indirect" method. Other methods (used, for example, by recent OECD estimates) include the Multiple Indicators Multiple Causes model (MIMIC), which assumes a relationship between the unobserved shadow economy and a set of observable variables (mostly monetary ones), and the Household Electricity Approach[5], using the presumed

[5] Developed by Maria Lacko as a method to determine the size of the hidden economy in a country, the Household Electricity Approach assumes that undeclared economic activity still needs to use resources, such as electricity. Since electricity consumption is known it can be used as an indicator of economic activity that is not otherwise declared.

relationship between household electrical consumption and a country's GDP (European Commission, 2014, p. 40).

1.2.1 The shadow economy and a cashless society

The shadow economy is a complex phenomenon that can have various causes and consequences. According to one commonly used definition it comprises "all currently unregistered economic activities that would contribute to the officially calculated gross national product if the activities were recorded." (Schneider & Williams, 2013, p. 23)
The European Commission gives a similar definition in its 2014 quarterly report: "the shadow economy includes those economic activities and the income derived thereof that circumvent or avoid government regulation or taxation." (European Commission, 2014, p. 39)
As Mastercard Advisors report in the paper entitled *Reducing the Shadow Economy through Electronic Payments*, the shadow economy includes: (1) illegal activities where the parties are willing partners in economic transactions, (2) activities where the transactions themselves are not unlawful, but are unreported to avoid controls, and (3) informal activities with typically no records (Dybka, et al., 2016).
Within each of these categories, unreported cash transactions can be divided into two subcategories: the "passive" and "committed" shadow economy. The first is the part of the shadow economy that, according to the authors, can be reduced by promoting electronic payments and limiting the use of cash in consumer transactions, as most of EU countries already did. When paying for settling a transaction, the seller may not register the transaction more easily if the payment is made in cash. Since cash leaves no electronic trace, it is extremely difficult to retrace cash to a particular transaction. For this reason sanctions are rare and cash provides an incentive for vendors and sellers not to report a transaction, because there is virtually no loss at a marginal personal level (neglecting society's benefit from taxes). Indeed, the fraud may even result in a benefit for the seller in the time saved not reporting the transaction, the paper for the receipt, etc. This part of the shadow economy is defined as the "passive shadow economy", because one of the parties (the consumer, buyer) is "passive", meaning that he/she has no active role in non-reporting the transaction and does not benefit from it,

and may not even be aware that he/she is contributing to illicit activities through his/her behaviour (Dybka, et al., 2016)[6].

For "committed" shadow economy participants cash is not the reason, but rather the consequence of not reporting the transaction. Indeed, as both parties (seller and buyer) want to either evade tax liability or buy/sell illegal products and services, cash might still be required to hide the transaction, but cash is no longer the cause or incentive. This part of the shadow economy is the "committed shadow economy", because the parties are "committed" to using cash in order not to report the transaction, that is, both parties have an active role in concluding the illicit activities.

As cash is the main incentive for the "passive" shadow economy, reducing or controlling the use of cash (e.g. by substituting cash with electronic means of payment) would limit the number of transactions not being reported. However, these policies would not influence the behaviour of the committed shadow economy participants, that is, of those who would actively decide to continue to use cash payments in order to benefit from unreported transactions.

A high level of shadow economy is obviously undermining for the economic system, and results in, amongst other problems, reduced tax gains for governments, lower supply of public goods (resulting from lower government income), the decay (moral and physical) of economic and social institutions, and – as a result – lower economic growth (Dybka, et al., 2016, p. 1). Government agencies and financial institutions track closely money demand and, in particular, demand for cash, as it constitutes a crucial part for the analysis of shadow economy levels: patterns and uses of payment instruments have been changing continually over the years.

In recent times technological developments, the spreading of internet and home banking, contactless cards and mobile applications as well as the significant growth in online shopping changed consumers' behaviour with respect to cash. The use of cash declined in many countries (although the variations in the pace of change vary largely

[6] This is not the case when, for example, the seller offers a discount to the consumer if he/she pays in cash, therefore allowing the seller not to report the transaction. However, we may still consider it as described by Dybka et al., as if the seller did not have any benefit it could not offer it to the buyer. It is only when the seller gains enough from not reporting the transaction (accounting for the probability of being caught) that he/she can offer compensation to the buyer for not exposing him and to choose cash as the payment instrument.

from country to country). Cash transactions in Sweden made up as little as 2% of the value of all payments in 2015 and Sweden is expected to go completely cashless by 2023 (Gohd & Leary, 2017).[7] In the United Kingdom the number of payments made in cash fell by 15% between 2015 and 2016 while in Germany and Austria the rate of change is much slower (OECD, 2017, p. 16).

In a 2015 report entitled *Why is cash still king?*, the Europol Financial Intelligence Group reported that, although the use of non-cash payment methods was growing, the demand for high denomination notes, such as the 500€ note, has been sustained (EUROPOL, 2015). Approximately €1 trillion banknotes were in circulation as of end-2014 (the 500€ note alone accounts for over 30% of the value of all euro banknotes in circulation).[8] Here is what Europol director Rob Wainwright said:

"The EUR 500 note alone accounts for over 30% of the value of all banknotes in circulation, yet most people have never seen one. This raises questions about the purpose for which they are being used and whether this could be linked to criminal activity. I welcome the decision of the ECB to discontinue the production of the EUR 500 note. This is good news for the fight against organised crime and terrorism. Further work now needs to be done by police and banking authorities to identify and monitor the criminal use of these notes which could still be in circulation for many years" (EUROPOL, 2016).

Although anti-money laundering regulations require monetary financial institutions to report unusual or suspicious transactions in cash, as well as transactions made using cash over a certain amount, smaller transactions will often be entirely invisible. As such, cash facilitates shadow economy and illegal activity. Finally, whilst recorded cash transactions decrease, the use of cryptocurrencies[9] is starting to emerge. While overall usage of such cryptocurrencies is limited at present and their use is mainly that of

[7] The case of Sweden is discussed in detail in section 1.4.

[8] European Central Bank, 2019. See also *Preface, The 500€ note.*

[9] Definition: "A digital currency in which encryption techniques are used to regulate the generation of units of currency and verify the transfer of funds, operating independently of a central bank." E.g.: "Decentralized cryptocurrencies such as bitcoin now provide an outlet for personal wealth that is beyond restriction and confiscation" (The Oxford English Dictionary)

financial speculation, there is a risk that such cryptocurrencies may take the role of cash in illicit activities (OECD, 2017, p. 17), as it has been already suggested[10].

1.2.2 Business Risk

Businesses and shops that rely mostly on cash for the settlement of their transactions have additional risks compared to similar activities that opt for cashless payments.

1. Counterfeit banknotes. The problem arises when a customer pays for a service (willingly or not) with counterfeit banknotes. The problem worsens when high denomination banknotes are used and the cashier, unknowingly, gives the customer change: in this case, the damage for the business comes both from accepting a banknote that is not valid (and thus unusable), and from the loss in value represented by the genuine banknotes it gave the consumer for change. Anti-counterfeit measures are often implemented in shops that are a part of chains of businesses or retailers of a trademark. This is most likely the result of agreements between the main business and the anti-counterfeit service providers, in the form of large-scale contracts. For smaller shop owners and local firms, however, implementing methods to detect counterfeit banknotes may be a major problem. The technology is quite expensive[11] and must be updated to follow new counterfeit measures and new banknotes issued. One major example is the new Europa Series banknotes. When first issued, all anti-counterfeit machines had to be renewed and/or updated, not to mention all machines for self-service payments (such as those found at gas stations) to accept the new banknotes.
2. Theft. Theft of cash by employees, and burglary or robbery of cash are completely eliminated once a firm or business goes cashless.[12]

[10] An FBI Intelligence Assessment published as early as 2012, defined Bitcoin as "distinctly susceptible to illicit money transfers". In late 2015 the Dutch Police arrested six people for suspicions of Bitcoin-related money laundering, followed in early 2016 by a further arrest of ten men on suspicion of laundering Bitcoins worth up to €20 million (Brown, 2016).

[11] This is true, of course, in relation with the size of the business. A big retailer that carries out thousands of transactions a day will have a smaller cost as a percentage value and thus may be more inclined to implement such services. A small shop/firm, having a limited number of transactions a day (where maybe half is settled by cards) will have a higher cost for the equipment as a percentage value. In the latter case, the shopowner might be more easily inclined to risk accepting counterfeit banknotes.

[12] Police data show robbery crimes decreasing in most countries; however, decreasing rates are mostly between 0 and 10% (Eurostat, 2018).

3. Cash handling and storage costs. The costs of physical security, physically processing cash (withdrawing from the bank, transporting, counting) are also reduced in a cashless environment.
4. Change. The risk that the business does not have enough cash on hand to give change. This risk is inexistent when using cashless transactions as there is no need for change at all.

1.2.4 Household risk

1. Diseases. Money consisting of currency notes and coins, due to its frequent circulation in daily life, could easily get contaminated. Human pathogens can be transmitted to money due to the personal unhygienic habits, e.g., touching currency after coughing, sneezing or handling food. Studies revealed that 70–94% of banknotes and coins harbour various bacteria and viruses on the surface in different nations such as the United States, China, India, etc. (Sharma & Sumbali, 2014). Furthermore, the transmission of pathogenic species and bacteria with antibiotic resistance on currency notes has been reported around the world. It was indeed suggested that banknotes could serve as a vehicle for transmission of drug resistant pathogenic (Yoshitaro Heshiki et al., 2017). It is verified by laboratory simulations that bacteria and viruses can survive on the surface of banknotes or coins up to 13 days (Kramer, Kampf, & Schwebke, 2006). When using cashless payments, transfers are made in seconds and are now conducted via wireless methods (also known as contactless), therefore drastically reducing the possibility of transmitting diseases.
2. Bank Runs. A bank run is typical of a period of crisis. It describes what happens when consumers believe a bank will become insolvent, that is, unable to pay up its debts and obligations. Those include, on the liability side of a bank's balance sheet, consumer deposits. Because of this fear, the bank's account holders will "run to the bank" (literally) to withdraw their money. As the banks' structure relies on a minimum amount of cash being stored within the bank (reserves) the more consumers require cash the more the bank will find itself in financial distress. The more the bank has cash shortages, the more account holders' fears will rise. A bank run is strictly related to liquidity: an asset is defined as liquid

when it can be exchanged easily and promptly in the market, without affecting its price. The more liquid assets a bank has, the less it is likely that it will find itself in financial distress, being able to sell said assets for cash. Whilst liquidity risk would still be something to take care of, in a cashless society, bank runs could never occur.

3. In addition to the previous two points households, like businesses, face the risk of theft and all the costs associated with cash handling.

1.3 E-money

A cashless society would resolve all problems associated with the use of physical cash: no cash means no risk of theft (although identity theft and cybercrimes are still a problem), no risk of counterfeit banknotes, no cash handling charges and no risk of transmitting diseases through cash movements. The natural substitute for cash is electronic money (e-money). Electronic money may be broadly defined as an electronic store of monetary value on a technical device. That device may be widely used for making payments to entities other than the e-money issuer. The ECB defines electronic money as "*a monetary value represented as a claim on the issuer which is stored on an electronic device and accepted as a means of payment by undertakings other than the issuer (by contrast with single-purpose prepaid instruments, where the issuer and acceptor are one and the same). E-money can be either hardware-based (i.e. stored on a device, typically a card) or software-based (i.e. stored on a computer server). E-money can be regarded as a means of settlement rather than a payment instrument, since the creation or reimbursement of e-money is effected using one of the core payment instruments – cash, payment cards, direct debits or credit transfers*" (European Central Bank, 2010, p. 30).

Electronic money thus includes credit and debit cards, electronic wallets as well as virtual currencies. Digital wallets are a way of paying cashless for goods and services, typically involving a smartphone; most of digital wallets service providers are subject to many of the same regulations that banks are subject to. Examples of digital wallets providers include Google Wallet, PayPal and ApplePay. E-money has usually a control mechanism or an authority in charge of the system. Such organization is proper of centralized systems. Decentralized systems, on the other hand, have no control on the

issuance and circulation of money. The last systems of e-money are virtual currency schemes, which, in turn, may be centralized or decentralized systems. There are three types of virtual currency schemes, as mentioned in an ECB paper of 2012: Type 1, Type 2 and Type 3.

Type 1 is money issued virtually and may be used only for virtual goods and services. In-games coins and currency such as *Mario Kart* money or *Fast & Furious* money are an example of virtual currencies of Type 1: they cannot be bought with real economy money and can be used only in-game.

Type 2 is similar to Type 1 but may be bought with real economy money (European Central Bank, 2012, p. 16). Examples are *Clash of Clans* money or Airline points which may be both earned or bought with real money.

Type 3 virtual currencies allow changing from real economy money to virtual currency and back, and may thus be used to buy real goods and services. Such a possibility is what is making things difficult as these currencies are expanding the money supply in an uncontrolled (decentralized) way. Cryptocurrencies belong to Type 3 virtual currency schemes, e.g. Bitcoin, Litecoin, Ethereum and are often decentralized systems, that is, there is no control over the supply and demand of virtual money.

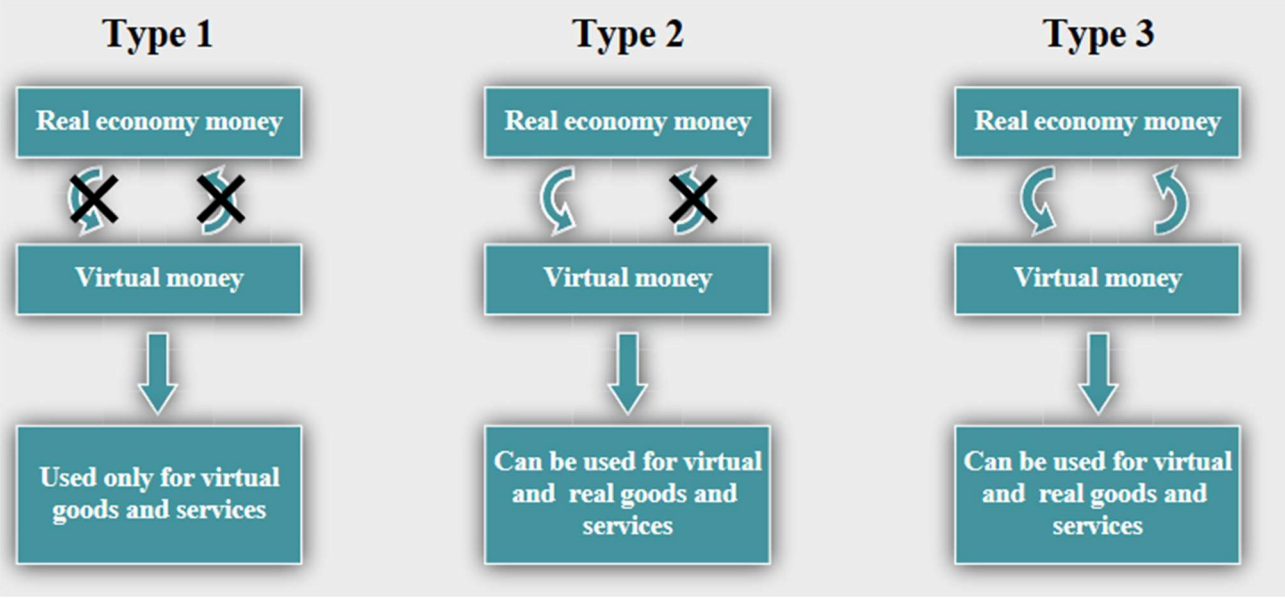


Figure 1.1: Virtual currency types (European Central Bank, 2012, p. 15)

Whilst there are many forms of e-money, the easiest and most widespread example of e-money transaction is that of credit and debit cards. These payment methods, as

mentioned above, belong to the category of centralized e-money, as the digital equivalent of money used to settle the transaction is controlled at a higher level by a Bank of State, a Central Bank, etc.

The idea of a credit card, however, is not that new: indeed, the theory of creating a physical object, whose holder should be extended credit to, goes back well into the 19th century: the concept was first described in 1887 by Edward Bellamy in his utopian novel *Looking Backward*:

"[…] A credit corresponding to his share of the annual product of the nation is given to every citizen on the public books at the beginning of each year, and a credit card issued him with which he procures at the public storehouses, found in every community, whatever he desires whenever he desires it. This arrangement you will see totally obviates the necessity for business transactions of any sort between individuals and consumers." (Bellamy, 1888, p. 119)

However, for that abstract idea to become reality, we will have to wait about a century. The most common pre-plastic credit instruments at the time were charge plates, celluloid "coins" and charge coins. Used until the early '60s, charge plates were made of aluminium or white metal plates. They were about the size of a dog tag and were embossed with the customer's name and address. The back side had a paperboard insert with the issuer's name and the cardholder's signature. Charge-plates were issued mostly by department stores, but also by a few oil companies and associations of stores. An early charge coin, whose bearer could stay at Chicago's Hotel La Salle is believed to have been first issued around 1865. At first, they were made of celluloid whilst later ones were made of copper, aluminium, steel or white metal, which is when they became known as charge coins (American Credit Cards Collectors Society, "*Cards Classifications"*).

Later in 1934, American Airlines and the Air Transport Association simplified the process even more with the advent of the Air Travel Card, the first charge card issued (Flying Magazine, 1953). They created a numbering scheme that identified the issuer of the card as well as the customer account. This scheme was renamed in 1936 as Universal Air Travel Plan (UATP), and the original numbering is the reason modern UATP cards still start with the number 1. With an Air Travel Card, passengers could

"buy now and pay later" for a ticket against their credit and receive a discount at any of the accepting airlines. By the 1940s, all major US airlines offered Air Travel Cards that could be used on 17 different airlines. By 1941, about half of the airlines' revenues came through the Air Travel Card agreement. The airlines had also started offering instalment plans to lure new travellers into the air. In October 1948, the Air Travel Card became the first internationally valid charge card within all members of the International Air Transport Association.

The revolution towards a cashless society began in the 90s when internet banking became popular, thanks to the spreading and ease-of-access of the internet and, for the first time, debit and credit cards were used in most developed countries for daily purchases. However, it took time for those payments to become widespread and accepted amongst firms and consumers.

By the 2010s digital payment methods were widespread in many countries, with examples including intermediaries such as PayPal, digital wallet systems operated by companies like Apple, contactless and Near Field Communication (NFC) payments by electronic card or smartphone, and electronic bills and bank transfers (Sheffield, 2015). See also section *1.4.1 Smartphones, call centres, 5G*.

1.4 Technology

Technological progress is a major contributing factor to economies' progression towards a cashless society. Technology's rapid development and breakthroughs help make a cashless society a closer possibility rather than a utopia. E-wallets such as PayPal are now extremely easy to access and utilize, and are free for consumers to use.

1.4.1 Smartphones, call centres, 5G

Credit, debit and prepaid cards are easier to manage than they were when first issued, thanks to applications on smartphones that allow total control of the credit balance, as well as the ability to see movements in real time and block the cards if lost or damaged. The same functions are available, in most cases, through the issuers' website as well. As for people that do not want to use electronic devices to administer their funds, assistance via calls is now a very widespread service amongst banks. An automated voice will usually guide the user through the basic operations such as movements' lists,

balance, etc., whilst an operator may be required for assistance on more elaborate problems. The user still has the possibility to go to one of the bank's offices, if located near him/her.

With reference to the technology involved in cashless payments, Near-field communication (NFC) has made cards and phone payments much faster in the latest years. NFC is a set of communication protocols that enables two electronic devices to communicate between each other when relatively close together (within 4 cm), without the aid of a wired connection. NFC devices are used in contactless payment systems and can be compared to the technology used in credit cards and electronic ticket smartcards. NFC technology is also used to support POS (Point of Sale) payment systems in shops and stores.

Card payments via POS systems are now widespread and used in all developed countries. In countries where cash is preferred, governments have adopted laws to require businesses to use POS. In Italy, law 208/2015 tried to introduce the right for consumer to request payment via electronic cards for purchases of 5 euros or more.[13] In Greece, a new domestic law was adopted in December 2016 by which mandatory card acceptance for firms and sole proprietors (as of 27 July 2017) has been imposed with a 1,500 euro fine for non-compliant businesses. Some concerns about the POS requirement stem from missing reliable internet connection in remote and rural areas. However, in just a few years, thanks to 5G, almost all areas will have a strong and reliable internet connection, allowing all economic activities to adopt electronic payments.[14]

1.4.2 Blockchain Technology

Blockchain was invented in 2008 by a person using the pseudonym Satoshi Nakamoto to serve as the technology behind the cryptocurrency named Bitcoin (Nakamoto, 2008).

[13] The Italian Ministry of Economics and Finance (MEF), following the Council of State's interrogation in answering to the financial commission of the House of Representatives (parliament interrogation no. 5-02936) admitted that the interpretation of the law (as suggested by the National Lawyers Council) did not seek to set the POS requirement as a legal obligation but rather as an incentive, therefore the law does not identify sanctions for firms and local shops who did not accept POS payments.

[14] 5G is the fifth generation of mobile cellular communications. It will replace 4G LTE and will improve speed, reliability and coverage whilst consuming less. 5G is currently being tested in some Italian cities and will soon become operative for consumers in the EU (TIM). 5G is already available for some US consumers.

With blockchain, contracts are embedded in digital code and stored in transparent, shared databases, where they are protected from deletion, tampering, and revision. Indeed, by design, a blockchain is resistant to modification of the data. Every transaction and its associated value are visible to anyone with access to the system. Each node, or user, on a blockchain has a unique alphanumeric address that identifies it. Users can choose to remain anonymous or provide proof of their identity to others. Blockchain technology works as follows (Crosby et al., 2016):

a. Distributed Database: each party on a blockchain has access to the entire database and its complete history. No single party controls the data or the information. Every party can verify the records of its transaction partners directly, without an intermediary.
b. Peer-to-Peer Transmission: communication occurs directly between peers instead of through a central node. Each node stores and forwards information to all other nodes.
c. Records are irreversible: once a transaction is entered in the database and the accounts are updated, the records cannot be altered, because they're linked to every transaction record that came before them (hence the term "chain"). The process of verifying and adding transactions to the ledger is called "mining". Various computational algorithms and approaches are deployed to ensure that the recording on the database is permanent, chronologically ordered, and available to all others on the network.
d. Computational Logic: the digital nature of the ledger means that blockchain transactions can be tied to computational logic and in essence programmed. So, users can set up algorithms and rules that automatically trigger transactions between nodes.

Blockchain technology is often associated with Bitcoin or other cryptocurrencies; however, the technology could be used for many and various applications (Swan, 2015, p. 27). Blockchain could, for example, serve as the technology for a cashless society, providing a way of keeping anonymity and privacy for private users and firms.

For use as a distributed ledger, a blockchain is typically managed by a peer-to-peer network collectively adhering to a protocol for inter-node communication and validating new blocks: designated government servers could serve as nodes for the network. Such

framework is known as "central bank e-money" (Paesani, 2018). An example of the sort is that of th e-Krona, a project the central bank of Sweden (Sveriges Riksbank) is working on, which is analysed in more detail in section 1.6.

The ECB, national banks and other Monetary Financial Institutions (MFIs) could issue new currency using a verifiable electronic signature and introduce the new currency in the network (economy).

Blockchain has its limitations, amongst which (Swan, 2015, pp. 81-85):

a. Size: the blockchain weights 25 GB (Gigabytes) and grew by 14 GB in the last year. So, it already takes a long time to download. If throughput were to increase by a factor of 2,000 to VISA standards, for example, that would mean an increase of 3.9 GB/day, possibly posing data storage issues.
b. Latency: it takes at least 10 minutes for a transaction to be verified. The more secure or large the transactions the longer it will take for them to be verified.
c. Wasted resources: mining wastes a lot of energy, and estimates are in the order of 15$ million a day.

1.5 Open issues of a cashless economy

Although a cashless society can seem a huge improvement in all directions, that is not the case. We must consider a variety of issues, whilst keeping in mind that all considerations are purely hypothetical and rely on expectancies and hypothesis rather than facts, since there are no examples of a (pure) modern cashless economy to refer to.

1.5.1 Demand for cash

As a general matter, cash plays no role in large-value payments (European Central Bank, 2010, p. 28; European Consumer Centre Germany), so its disappearance would have little to no impact on the large-value payments system and related considerations. Moreover, most EU countries already define clear value limits for cash usage (see *Introduction*).

However, cash plays a much more important role in small-value transactions: on average in the euro area, the value of a cash transaction in 2017 was €12.38, and 78% (on average) of all transactions in Europe were made in cash (Esselink & Hernández, 2017, p. 20).

There are segments and groups of the population that might still demand cash in a cashless economy. Those groups of people would probably find themselves worse off than before, possibly leading to financial exclusion[15]. Examples are people in poverty, who may find themselves incapable of opening a bank account so to have access to money as an instrument (the "unbanked"). Another example are elderly people, for whom it may be difficult to access the technology. On this last issue, however, phone banking is now much more widespread even amongst the elderly and bank branches close to households can process and help with more complicated operations. Although it might be feasible, such a hypothesis must consider the cost of getting used to (or teach a minimum level of understanding of) the technology.

1.5.2 Privacy and centralized control

A big issue is that of privacy. Cashless transactions mean that authorities and third parties have access to sensible consumer data and could, in theory, see everything a person does. Such beliefs are fostered and grow particularly because of scandals of data breaches, such as the Facebook-Analytica scandal[16], giving people reason to think their data are not safe and can be stolen at any moment. This is true to a certain extent.
End-to-end technology (by which only the sending and receiving device have a key to read the transmitted data), blockchain technology to keep records (incorruptible by design) and more technological advances are making this type of data breaches almost impossible. It is true, however, that in a cashless society in which all registries and transactions records are kept digitally, the technological infrastructure must be well-thought and protected. No data breaches are to be possible in a society in which governments handle all personal data. There are means to design such an

[15] Financial inclusion is defined as the availability and equality of opportunities to access financial services. Financial inclusion intends to help people secure financial services and products at economical prices such as deposits, fund transfer services, loans, insurance, payment services, etc. It aims to establish proper financial institutions to cater to the needs of the poor people. Of late, financial inclusion has assumed a development policy priority in many countries. For a cross country study and index, see Nanda & Kaur, 2016.

[16] The Facebook–Cambridge Analytica scandal was a huge scandal burst in early 2018 when it was revealed that Cambridge Analytica had collected personal data of millions of people's Facebook profiles without their consent and used it for political purposes. Via a Facebook app, Cambridge Analytica arranged an informed consent process for research in which Facebook users would agree to complete a survey only for academic use. However, Facebook's structure allowed this app not only to collect the personal information of people who agreed to take the survey, but also the personal information of all the people in those users' Facebook social network (Cadwalladr & Graham-Harrison, 2018).

infrastructure, provided that it is maintained up to date against possible cyber-attacks. Enquiries on personal data must be authorized with warrants when there is the need for it, to ensure a higher level of security for everyone, without risking a society in which the central authority abuses of its power.

1.5.3 Consumer awareness in spending: the credit card effect

It is argued that, whilst having many problems, cash has one huge advantage against any other form of payment: it is physical. The argument is that cash makes consumer more attentive when spending money. Indeed, a study published in 2001 by Prelec and Simester proved that consumers tend to have increased willingness to pay when instructed to use credit card payments (the so-called "credit card effect") (Prelec & Simester, 2001). Whilst it is not proved causality between the two situations, or it may be just a matter of customs, the fact is that, when using credit cards, consumers tend to spend more, and that must be considered.

1.6 Living in the first (almost) cashless economies

In some countries, most notably Sweden, the United Kingdom and Denmark, the demand for cash has declined steadily over a sustained period.

1.6.1 Sweden

Sweden is the country with the lowest cash usage. Why that is so is explained in an article of the World Economic Forum, linking cash abandonment both to adapting habits and laws: "Swedish legislation makes it possible for retailers, restaurants and other companies to refuse to accept cash, for instance by putting up a sign at the entrance or by the till. Together with banks that stop offering cash services, refusal of cash is an increasingly widespread phenomenon. Furthermore, Swedes on average are happy to adapt to new technologies, so cards are widespread and the instant payment app Swish has been downloaded by more than half of the population." (Skingsley, 2018). As households rely less and less on cash, merchants could be expected to become unwilling to accept cash as payment for goods and services, which would tend to further discourage the demand for cash. Indeed, this is what has been happening in Sweden. Furthermore, financial institutions generally are reducing their cash operations to reduce costs, and in Sweden it has become increasingly difficult for the public to even obtain cash from banks. Many bank branches in Sweden have become cashless. Clearly, such developments tend to be mutually reinforcing. (Engert, Fung, & Scott, 2018, p. 3)
At the same time, technological advances in electronic money and payment methods are rapidly growing. The Riksbank (Sweden's central bank) is therefore investigating whether Swedish kronor need to be made available in electronic form, the so-called e-krona. No decisions have yet been taken on issuing an e-krona. The Riksbank is trying to design a technical solution for an e-krona in order to test which solutions are practicable and possible to realise, drawing up proposals for legislative amendments needed to clarify the Riksbank's mandate and an e-krona's legal standing (Sveriges Riksbank, 2018, *"e-krona"*). Indeed, legal and social aspects are not to be undervalued: even if a technical solution that solves all problems is to be found in short time (unlikely so), it is the role of the government and of the central bank to ensure a smooth transition to a cashless society, considering society's problems (some of which have been discussed in the previous section). Indeed, the Riksbank's website declares:

"Even though cash use is declining, cash remains an important means of payment for many people, not least for those who do not wish to or cannot manage their payments electronically. It is the Riksbank's assessment that Sweden will not become cashless in the foreseeable future and as long as there is a need for cash, the Riksbank will continue to issue notes and coins." (Sveriges Riksbank, 2018 Oct. 22)

But at the same time, several years ago, Stockholm's public transport stopped accepting cash. Tickets are pre-paid, bought by debit/credit card from the driver (or a ticket machine) or paid by using a mobile application. Residents usually buy a monthly travel card, which is both more convenient and less expensive than buying individual tickets. Even though the original transaction might have been carried out in cash (to buy the prepaid ticket) the move certainly discouraged the use of cash. And walking down the street many shops are, in fact, cashless and do not accept cash for payment.
Whilst legally the government and the central bank are trying to find a solution to prevent trouble for part of the population, it is a fact that cash transactions in Sweden where almost inexistent in the past year: only 13% of consumers declared they used cash for their last purchase (Sveriges Riksbank, 2018, *"Payment Patterns"*), and cash in circulation in 2017 already accounted only for 1.3%, and has been steadily decreasing of Sweden's GDP (Bank for International Settlements, 2017).

1.6.1 The United Kingdom and progressive abandonment of cash

In the UK, over two-thirds of UK adults used online banking and nearly half used mobile banking in 2018. As for mobile payment instruments, one in six UK adults are now registered for payment services such as Apple Pay and Google Pay, an eightfold increase since 2016. Popularity of contactless payments continues to grow: four in ten payments in the UK were made by debit card as Cash remains the second most frequently used payment method but usage continues to fall, with one in ten UK adults choosing to live a largely cashless life (UK Finance Press Release, 2019).
Just like in Sweden, the machinery that makes cash available is disappearing across the UK. More than 3,000 bank branches have been shut down in Britain in just over four years, and are closing at a rate of almost 70 each month (Shaw, 2019). ATMs (Automated Teller Machines) are vanishing at an even faster rate, at about 300 per month (Robbins, 2018).

The UK's Access to Cash Review published findings in December indicating that physical notes and coins are "an economic necessity" for around 25 million people in Britain, and nearly half of people it surveyed said a cashless society would be problematic for them (Access to Cash Review, 2018). Although the UK are not abandoning cash at the same rate as Sweden is, whilst the Sveriges Riksbank considers the issue of a central bank e-currency and the issues related to the abandonment of cash, Britain has yet to formalise a plan of action.

2. Empirical Analysis, Indicators

No economy at present can be defined as a "pure" cashless economy yet, that is, an economy in which cash is not supplied. When or which country will get there first, if any, is yet to be seen. However, as we have seen above, many countries are shifting towards cashless-oriented systems of payments, whilst maintaining cash as an alternative.

The aim of this chapter of the thesis is to conduct an empirical analysis to give some perspective on what was discussed in the first chapter:

In the first two sections we will provide theoretical support for the measurement of the use of cash in a given country, developing an index to rank countries depending on how prominent is their use of which payment instrument.

In the third section of this chapter, we will analyze the correlation between cash and the shadow economy, proving what seems to be intuitive and that was assumed to be true in chapter 1, that is, that there is a strong correlation between cash and the underground economy. Then, we will try to determine a causality link between the two, defining its direction (which one causes the other) and its magnitude, fitting the data in a two-stage least squares regression model.

2.1 A theoretical measurement: developing the Cashless Velocity Index

We begin by looking at the Quantity Theory of Money (QTM) equation. There are many versions of the QTM, amongst which the one from Irving Fisher and the one proposed by Arthur Cecil Pigou. The two are mathematically equivalent, however, their interpretation is different (Arcelli & Dongili, 1977, p. 84).

We will use Irving Fisher's "equation of exchange" (1911) (Friedman, 1987, p. 3) in its simplified version:

$$Y \cdot P = V \cdot M \tag{2.1}$$

where Y is real GDP[17], P is the price level, $(Y \cdot P)$ is nominal GDP, V is money velocity and M is the money supply[18]. We know that GDP is the measure (monetary value) of all finished goods and services produced within a country's borders in a given time period. In other words, GDP is a measure of all transactions occurred to pay for final goods in a given time period regarding a country's economy.[19] Each transaction could be seen either from the point of view of the buyer or from that of the seller. Regardless, a transaction, in order to be settled, requires a payment method which, in turn, could be cash or cashless.

Money velocity (V) is the average amount of times that money changes hands. Velocity plays a fundamental role in this reasoning, as it will be shown shortly. Many factors determine velocity, amongst which: money supply (inversely proportional with respect to velocity), frequency of transactions (exogenous) and other variables affecting transactions such as the payment system (the framework in which transactions are carried out) or regularity of income, enabling people to spend their money more freely. Still, there are several other factors that may affect velocity, including trade, credit facilities, economic cycles, etc. In the assumptions of the QTM (see note 17) we established that, for the purposes of our analysis, we assume velocity to be constant.

For example, suppose we can observe two economies, Country A and Country B, in which there are no banks (and therefore no bank money). That is, the money supply M, from now on termed M^s, is equal to M_0, the monetary aggregate that includes physical

[17] Note: GNP (Gross National Product, GDP – Net Investment) may also be used, depending on the aim of the measurement.

[18] The QTM rests onto five assumptions. It assumes (1) that V is constant and is not affected by the changes in the quantity of money, or the price level. Velocity depends upon population, trade activities, habits, etc. It is assumed that these factors have nothing to do with the changes in the value of money; (2) the volume of goods and services remains constant. Y depends upon a natural resources, climatic conditions, techniques of produc-tion, productivity of labour, transportation etc. All these factors, it is assumed, have nothing to do with the changes in the quantity of money. Hence, Y remains constant (in turn based on full employment assumption; (3) price is a passive factor. Price is changed or affected by other factors in the equation but does not affect or cause changes in those factors; (4) Long-run applicability: V and Y are assumed to be constant over a long period. In the short run there can be transitory adjustments but, when this short period or the period of transition is over, other variables will become constant so that a change in M or V will be followed by a proportionate change in P.
(5) All transactions take place through money; money alone and only acts as a medium of exchange and no part of it is hoarded by people.

[19] In this way, we are measuring payment methods on the side of consumers as intermediate goods (and thus payment from businesses for production purposes) are not included in GDP.

money (coins and banknotes). Both economies have the same money supply, but different velocities, as described in the table below:

Table 2.1 Example of two economies in which cash is the only form of money.

	$M^s = M_0$ (€ Mil)	Velocity (V)	Nom. GDP (€ Mil)
Country A	1,000	2	2,000
Country B	1,000	10	10,000

It is evident from the table above that even though both economies have the same money supply, Country B has a larger economy, with a higher GDP. This is true because of differences in velocity, that is, in economy B money circulates more quickly and such circulation adds up to a higher GDP value.

In the real world though, cash is far from being the only payment instrument. In more complex economies than the one illustrated in *Table 1*, various payment instruments coexist. Indeed, in recent times, cash is not seen as equivalent to other methods of payments by many consumers who sometimes prefer cash, sometimes prefer, say, electronic means of payments such as debit or credit cards (Esselink & Hernández, 2017). Such preferences in the payment instrument depend on many variables, amongst which government policies, geographical collocation, habits. It is therefore natural to express the money supply M^s as M_0 plus the summation of the i-th monetary aggregate minus the preceding (to avoid double counting):

$$M^S = M_0 + \sum_1^N (M_i - M_{i-1}) \tag{2.2}$$

Then, for each additional monetary aggregate portion a different velocity will be assumed, since each monetary instrument has a different circulating speed.

Knowing the above, we can express GDP in terms of the payment forms as follows:

$$GDP = M_0 \cdot V_c + (M^S - M_0) \cdot V_b \tag{2.3}$$

where M_0 is the money aggregate defined above (the same notation used by the ECB), V_c is the velocity associated to M_0, $(M^s - M_0)$ is the money supply *minus* M_0, that is, "bank money" and all the other forms of money not included in the aggregate M_0 and, finally, V_b is the velocity associated with $(M^s - M_0)$.

Equation (2.3) shows that total output, measured by summing up all transactions' value in a given time period, can be split in two parts based on the instrument chosen by the parties to settle those transactions. The first part refers to cash, whilst the second to cashless means of payment and, more in general, all the "money" that is not strictly included in M_0.

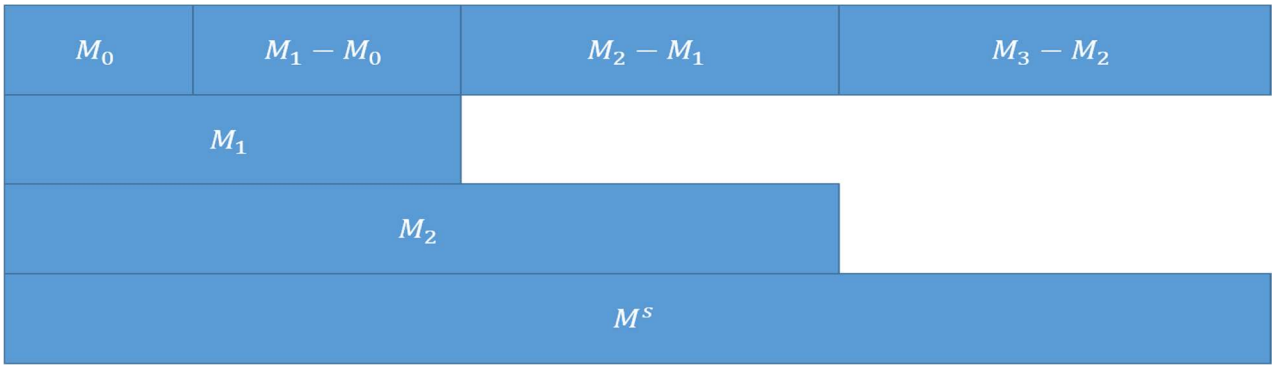


Figure 2.1 Blocks showing the composition of the money supply with respect to four monetary aggregates, as defined by the ECB. M_0 is physical paper and coins; M_1 is all of M_0 plus traveller's checks and demand deposits; M_2 is all of M1, plus money market shares, and savings deposits; M_3 includes M_2 plus large time deposits, institutional money market funds, short-term repurchase agreements and larger liquid assets.

As a practical example, money market shares or saving deposits do not circulate at the same speed as physical money does, and money in form of cash does not circulate at the same speed as bank money does. For example, cash could be circulating at a much slower pace than bank money in an economy such as Sweden, whilst in a less developed economy, like that of Zimbabwe or Venezuela, the opposite may be true. Following the same reasoning, additional velocity measures could be introduced to track all the different instruments (defined by the difference in monetary aggregates).

In the simplified QTM equation, velocity V is the same as there is no distinction between different forms of money; however, splitting up V into V_c and V_b as in eq. (2.3), allows to differentiate velocity depending on the payment instrument.

By dividing both part of equation (2.3) by GDP, we get:

$$1 = \frac{M_0 \cdot V_c}{GDP} + \frac{(M^S - M_0) \cdot V_b}{GDP} \tag{2.4}$$

Naturally the two fractions, being each a complementary share of GDP, will always add up to the full value of GDP (i.e. GDP/GDP = 1). The first ratio of the equation could

summarize the state of an economy with respect to its use of cash, whilst the second with respect to its use of all the other monetary aggregates. The same reasoning could be repeated with a (virtually) infinite number of monetary aggregates, keeping in mind that for each monetary aggregate defined and used separately there is a need for a velocity measurement relative to that monetary aggregate:

$$1 = \frac{M_0 \cdot V_c}{GDP} + \frac{(M_1 - M_0) \cdot V_1}{GDP} + \frac{(M_2 - M_1) \cdot V_2}{GDP} + \cdots + \frac{(M^S - M_{i-1}) \cdot V_i}{GDP} \qquad (2.5)$$

or, equivalently,

$$1 = \frac{M_0 \cdot V_c + \sum_{i=1}^{N}[(M_i - M_{i-1}) \cdot V_i]}{GDP} \qquad (2.6)$$

where N is the number of defined monetary aggregates.

The velocity resulting from this measurement will not, however, be the velocity relative to the total monetary aggregate but rather of the elements the monetary aggregate in question adds to the preceding one. For example, the velocity V_3, relative to M_3 is, in fact, the velocity associated to $M_3 - M_2$, except, naturally, for the case of M_0.

For the purposes of this study, the analysis will be limited to M_0 and $M^S - M_0$, that is, cash and cashless payments, respectively.

What is clear from the passages above is that velocity does indeed play a crucial role in determining the state of the use of cash in an economy. Let us now go back to the initial example of two economies, this time splitting money supply into cash and other monetary aggregates.

Table 2.2 Example of two economies with supply both of cash (M_0) and other payment instruments ($M^S - M_0$).

	M_0 (€ Mil)	V_c (Velocity of M_0)	$M^S - M_0$ (€ Mil)	V_b (Velocity of $M^S - M_0$)	Nom. GDP (€ Mil)
Country A	500	2	500	8	5,000
Country B	500	5	500	5	5,000

In this example, as before, both economies have a money supply of 1,000 € Mil.

Leaving aside all issues relating with the money multiplier, it is clear that measuring M_0 over GDP is not enough to measure how an economy is doing with respect to cash. If we did use such ratio, in the example provided by table 2.2 the two economies would be the same on paper, whilst it is clear that they are not: the former uses more cashless than cash payments whilst the latter uses the two in equal share. Money velocity determines an economy's GDP distribution between the monetary aggregates. At the same time, velocity alone is not enough to measure the level of cash usage. What can give useful insight, though, is a combination of the two measures with velocity as weight to the monetary aggregate with respect to the total level of output.

We may derive such measurement from equation 2.4: since we are interested in the ratio to the right, expressing the equation in its term yields the desired measure.

We will call such measurement the Cashless Velocity Index:

$$Cashless\ Velocity\ Index\ (CVI) = 1 - \frac{M_0 \cdot V_c}{GDP} \tag{2.7}$$

The cashless velocity index will range from 0 to 1, where 0 represents an economy in which cash is the only payment method, and 1 represents a fully cashless economy.[20] Applying this formula to the example reported in *Table 2*, Economy A will have a Cashless Velocity Index of:

$$CVI_A = 1 - \frac{M_0 \cdot V_c}{GDP} = 1 - \frac{500 \cdot 2}{5{,}000} = 1 - 0.2 = 0.80$$

Whilst Economy B will have a CVI of:

$$CVI_B = 1 - \frac{M_0 \cdot V_c}{GDP} = 1 - \frac{500 \cdot 5}{5{,}000} = 1 - 0.5 = 0.5$$

What the CVI tells us is that Economy A is based on cash by a 20% share, whilst Economy B's GDP is made by cash and cashless transactions in equal share of 50%.

This is just another way of measuring the share of payments made by cash as a share of GDP. Nevertheless, seen this way, the index gives useful insight. Rather than taking a sample and counting how many cash transactions are made, we can infer the level of

[20] In the latter instance, cash may still be in circulation (for example, being used to settle interbank loans). That is, even if the index has a value of 1, cash is not necessarily inexistent.

use of cash in any given economy starting from three macroeconomic variables. Indeed, GDP and the monetary aggregates are easily observed variables and often included in central banks or governments' reports. On the other hand, velocity is not that easily observed, even less if multiple definitions and measurements of velocity are needed. Indeed, we cannot derive V from equation (2.1) because the velocity we defined is not, strictly speaking, the velocity of the aggregates (see note 18 on page 30). Moreover, defining velocity this way, since the monetary aggregate M_i is computed as $M_{i-1} + Z$, where Z may be any form of money we are adding to M_{i-1} (and therefore $M_i > M_{i-1}$), it is clear that velocity would be decreasing the larger the monetary aggregate:

$$V_i \downarrow = \frac{GDP}{M_i \uparrow} \tag{2.8}$$

Therefore, this definition holds only for *total* money supply, M^S.
However, defining the cashless transactions as a residual from cash transactions, we only need one measurement of velocity, that is, cash velocity (V_0, the velocity of M_0). This is true since in equation (2.4) we know GDP, M_0 and M^S, leaving only V_0 and V_b to be found. Since equation (2.4) is an identity, one of the two will be enough.[21]

2.2 A practical measurement: countries' cash usage and progression towards a cashless society

As we mentioned, it is quite difficult to find estimates for velocity in order to use the CVI defined in the previous section. Luckily, there are proxies for such measurement. The ratio defined in the CVI, equation (2.7), is none other than the ratio of payments made in cash over GDP. In the ECB occasional paper series No. 201 entitled *The use of Cash by Households in the Euro Area* (Esselink & Hernández, 2017, p. 20), there are estimates of such measurement, which are reported in table 2.3.

[21] Since it is impossible to use an indirect measurement of velocity as the one derived from the QTM (it would be a tautology), a direct measurement is needed. Velocity may also be defined as the share of income that is spent rather than saved, that is, the share of income that circulates. Algebraically, such definition may be expressed as the reciprocal of the saving rate for the saving instrument i:

$$V_i = 1/s_i$$

where s_i is the saving rate associated with the i-th instrument.
For example, if households prefer to hold 20% of their income in cash, s=0.2 and cash velocity V= 1/0.2=5. Unfortunately, such estimates for velocity are not available, mainly because statistics consider cash and deposits as interchangeable.

The last column is a measurement equivalent to that of the CVI discussed above.
In the same paper, there seems to be enough evidence to suggest a correlation between the use of cash and the smaller value of the transaction (Esselink & Hernández, 2017, p. 28). In fact, many households surveyed give importance to the value of payment in choosing the payment instrument. Moreover, it is pointed out that some EU households use cash as an additional investment instrument (in Slovakia as much as 40% of households hold money as "precautionary investment"). The most striking fact in the paper, however, is that many households receive their income (or part of it) in cash. In Greece, 57% of survey respondents declared they received at least a quarter of their income in cash, whilst in Slovakia and Cyprus the share lowered to 30%. Not surprisingly, the same countries have high shares of cash transactions with respect to the other EU member economies (Esselink & Hernández, 2017, pp. 28-ff.).

Table 2.3 Selected EU Countries share of transactions and value/GDP of transactions made by cash *(Esselink & Hernández, 2017, p. 20).*

Country	Name	Cash Transaction No. divided by Tot. ransaction No. (%)	Cash Trans.Value divided by Tot. GDP value (%)
IE	Ireland	79	49
NL	Netherlands	45	27
BE	Belgium	63	32
LU	Luxemburg	64	30
DE	Germany	80	55
FR	France	68	28
PT	Portugal	81	52
ES	Spain	87	68
IT	Italy	86	68
MT	Malta	92	74
SI	Slovenia	80	68
AT	Austria	85	67
SK	Slovakia	78	66
GR	Greece	88	75
CY	Cyprus	88	72
FI	Finland	54	33
EE	Estonia	48	31
LV	Latvia	71	54
LT	Lithuania	75	62

2.3 Cash and the Shadow Economy

In this section we will attempt to ascertain whether cash and the shadow economy have indeed a link: the first subsection is devoted to demonstrating correlation, whilst the second subsection will demonstrate a causality relation between the two.

2.3.1 Use of cash and size of the shadow economy: correlation

We will begin by analysing the data from *Table 2.3*, reported in the 3rd column of *Table 2.4* for ease of analysis, plus data on the shadow economy. The source for such data is Esselink & Hernández, 2017, p. 20 (for the concluded year 2016). The value (in percentage) represents transactions made in cash over total number of transactions. Data was available for the (absolute) number of transactions made in cash as well, but since non-cash transactions are usually lower in value and larger in number, results could have been distorted. Also, to follow macroeconomic analysis, ($M_0 \cdot V_c$) represents value of transactions. Nevertheless, rankings would remain almost unchanged.
Shadow economy levels have been taken from IMF, 2018. Estimates are for the year 2017. The IMF paper from which the data have been taken presented two series of data. Series 1 and Series 2. The one used is Series 2, which has been adjusted, removing from the computation activities which are not *per se* illegal, such as housework, self-production, etc. For the purposes of this experiment, though, we are considering the shadow economy as illegal activities and, as such, we are considering Series 2.
The source for fiscal pressure is a paper from Rogers & Philippe, 2018, p.14. Data is for the year 2018 (fiscal year 2017), figures have been divided by a factor of 100.
Finally, the opportunity cost of cash is the result of the sum of inflation (average 2017) and the interest rate on overnight deposits (average 2017). Additional information both for the sources and the full set of data are available in the appendix to this thesis.

Let us apply the correlation formula to determine co-movement between *Cval* and *Shad*. Let x_i and y_i represent the set of values of the variables we are considering, $\bar{x}$ and $\bar{y}$ their arithmetic mean, and S_X, S_Y their sample standard deviations. Then the correlation coefficient r is:

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{(n-1)S_X S_Y} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}} \qquad (2.9)$$

Correlation between *Cval* and *Shad* is therefore:

$$= corr(Cval, Shad) \qquad Excel\ command$$

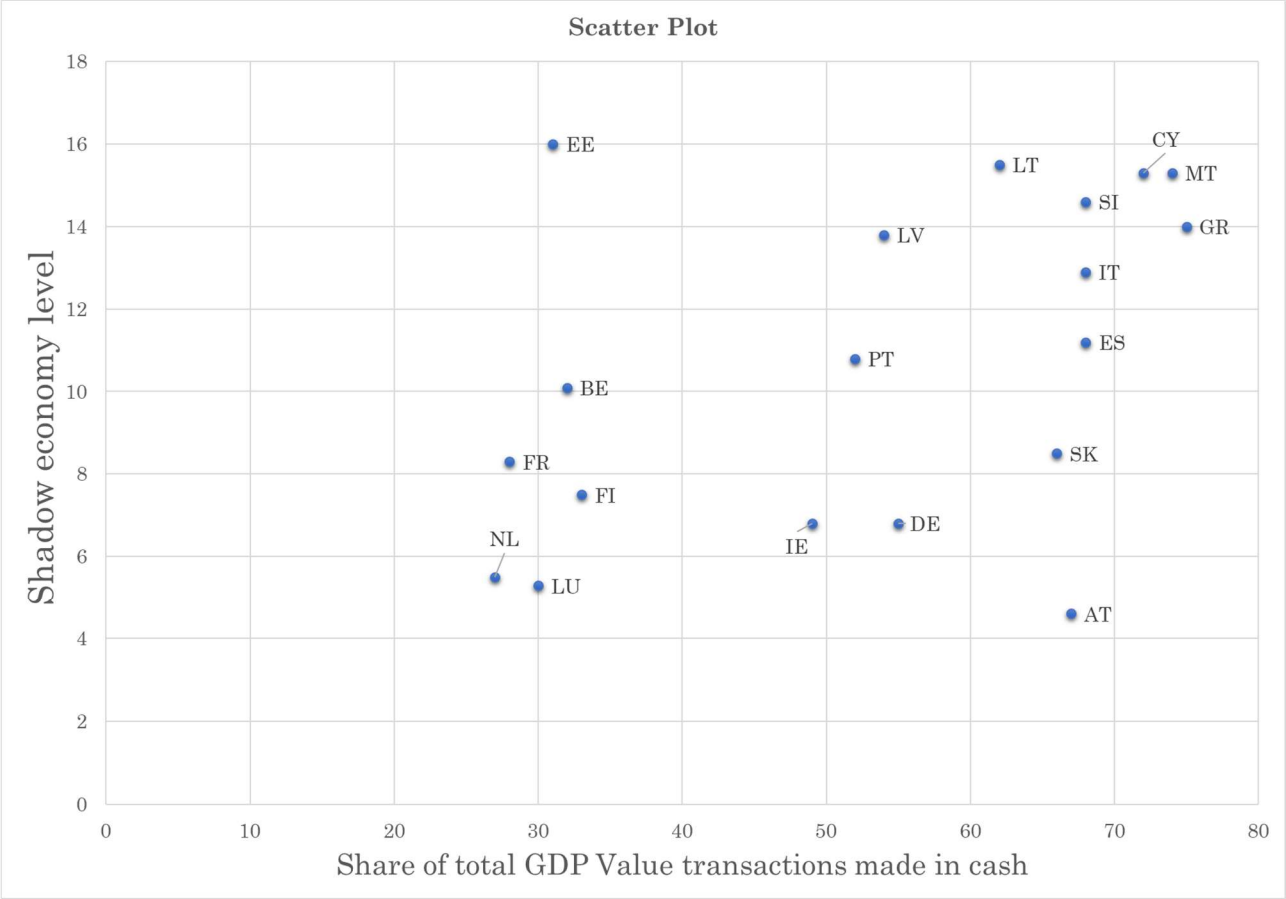
$$r_{Cval,\ Shad} = 0{,}460563932 \cong 0.46 = 46\%$$

which is a medium-high correlation.

Table 2.4 Data on selected EU countries.

Country Code	Country Name	Cash Trans.Value / Tot. GDP %*Cval*	Shadow Economy % *Shad*	Tax Burden *Fis*	Opportunity cost of cash *cst*
IE	Ireland	49	6.8	12.435	0.39
NL	Netherlands	27	5.5	28.459	1.378333333
BE	Belgium	32	10.1	31.159	2.22
LU	Luxemburg	30	5.3	26.521	2.2275
DE	Germany	55	6.8	29.745	1.7425
FR	France	28	8.3	32.233	1.2325
PT	Portugal	52	10.8	9.642	1.618333333
ES	Spain	68	11.2	15.077	2.044166667
IT	Italy	68	12.9	20.512	1.365
MT	Malta	74	15.3	5.824	1.2625
SI	Slovenia	68	14.6	9.321	1.6125
AT	Austria	67	4.6	31.443	2.308333333
SK	Slovakia	66	8.5	6.925	1.435833333
GR	Greece	75	14.0	13.077	1.191666667
CY	Cyprus	72	15.3	5.875	0.805833333
FI	Finland	33	7.5	24.884	0.91
EE	Estonia	31	16.0	7.902	3.62
LV	Latvia	54	13.8	5.711	2.924166667
LT	Lithuania	62	15.5	5.724	3.7

Figure 2.2 A scatter plot representing the correlation in the first two columns of data in Table 2.4.



As a side note, from figure 2.1 Estonia (EE) and Austria seem to be outliers. Estonia had, in 2018, the highest degree of shadow economy (peaking at 16%) whilst maintaining a relatively low level of cash transactions. Estonia is the Baltic country with the highest growth rate of shadow economy. This may be due to a low "tax morale" widespread in the country, together with inadequate control by the relevant authorities (Williams & Horodnic, 2015). Removing Estonia alone from the measurement, r' would spike up to 0.62303993. Austria (AT), on the other hand, seems to have the exact opposite characteristic: a high level of cash circulating and a relatively low level of shadow economy. This may be due to customs, in particular, *"[…] the partially low acceptance of payment cards, the size of cash balances, and consumer preferences. Notably 55% of respondents stated that they preferred to use cash in shops (even if card use is possible); 30% choose to pay by card"* (Rusu & Stix, 2017, p. 1). If removed from the computation as well as EE, r" would yield 0.758946985.

It is necessary to note that correlation does only tell us that for an increase in one variable, the other moves in the same direction and by what magnitude. It does not say anything about whether there is a causal link (and if so, which one causes the other) or if the result of the correlation is chance alone; to show causality, further analysis is needed. Indeed, as Randall Munroe[22] said: "correlation doesn't imply causation, but it does waggle its eyebrows suggestively and gesture furtively while mouthing 'look over there'".

2.2.1 Use of cash and size of the shadow economy: study of causation

Framework for the analysis

To determine if the observed correlation of *Shad* and *Cval* is the result of a causality link and, if so, what is the direction of such link, Instrumental Variable (IV) analysis will be used. IV analysis is widely used in economic analysis when controlled experiments are not feasible. A simple IV regression analysis is composed of two stages: the first stage uses an exogenous instrument (the so-called instrumental variable) to get an estimate of the treatment variable. The second stage of the analysis uses the estimated value for the treatment variable to estimate, in turn, the outcome variable.

The hypotheses for the model are as follows:

$$H_0: The\ test\ is\ not\ a\ good\ fit\ for\ the\ data$$
$$H_1: The\ test\ is\ a\ good\ fit\ for\ the\ data$$

and hypotheses for the coefficients β_i:

$$H_0: \beta_i = 0$$
$$H_1: \beta_i \neq 0$$

We will be able to reject H_0 iff the p-value for the coefficients (or F-value for the model) is lower than the desired significance level.

The limits of the analysis are the used estimates for the cash usage level (available only for the year 2016) as well as the total number of observations for this analysis which are relatively few (19) and may allow for not extremely relevant results.

[22] Randall Munroe is an American cartoonist and the creator of the "webcomic *xkcd*", who worked as a contract programmer and roboticist for NASA at the Langley Research Center.

Setting up the model

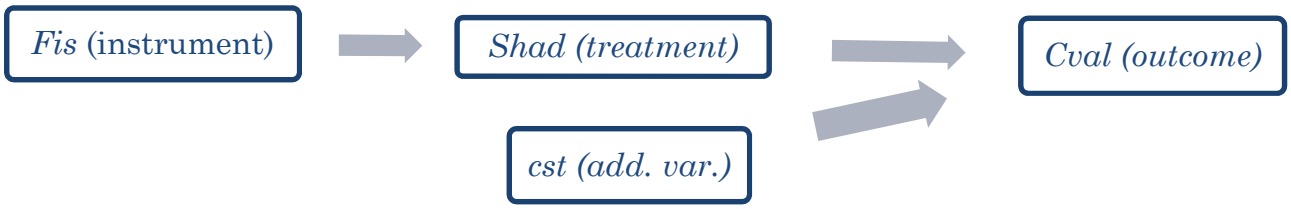


Figure 2.3 A conceptual graph showing the relations to be proved. The variable *Fis* (the instrumental variable) influences the level of cash transactions only through a change in the treatment variable (the shadow economy, *Shad*); in addition, the opportunity cost of holding cash causes changes in the final level of cash transactions (*cst*).

The analysis follows these steps:

1. Define the instrumental variable: a variable that is correlated with the outcome variable only through the treatment variable, i.e. the instrument does not have a direct causal effect on the outcome (exclusion restriction).
2. Assume that the instrument *does* have a causal effect on the treatment (relevance assumption).
3. Assume that the instrument does not share common causes with the outcome (exogeneity assumption).
4. Fit other variables (if any) in the regression analysis. More variables can reduce the error term and yield a better model.

The outcome variable is the share of cash transactions in a given economy (*Cval*). The treatment variable (also referred to as instrumented variable) that will be used is the level of shadow economy *(shad)*, whereas the instrumental variable will be the tax burden imposed by the government (fis). An additional variable will be fitted in the analysis: the opportunity cost of holding cash (rather than deposits or other liquid assets, *cst)*. The cost of holding cash is inflation (π) *plus* the interest rate paid on overnight deposits.[23]

[23] Inflation is the cost of holding cash or any liquid asset within M_1. However, cash has the additional cost of the interest rate lost while holding cash rather than a deposit: overnight rates are the rates paid on *checkable* deposits, with no binding on the depositor as to when the cash may be withdrawn. Other examples of opportunity costs for other payment instruments are: the cost of paying with card is inflation alone; the (real) cost of paying with a mortgage is the (nominal) interest rate of the mortgage *minus* inflation *minus* the overnight interest rate (computed compounded, if cash is held in deposits).

Proceeding with our analysis, we follow the steps defined above on the chosen variables:

1. We evaluate the correlation between the instrument variable *fis, and cval* and observe a positive correlation between *fis* and *Cval* that we will assume is only dependent on the effect of *Shad*. Indeed, we do not expect tax burden to change consumer preferences on payment instruments.
2. We assume that the instrument has a causal effect on the treatment, that is, the level of fiscal pressure has an effect on the level of shadow economy, which is indeed the case because of the Law of Demand: a higher tax burden is reflected in a higher cost and a higher incentive for undertaking illicit (shadow economy) activities. It can be shown that the cost of evading government taxes or control is:

$$\gamma_u = p \cdot S \tag{2.10}$$

where γ is the cost, p is the probability of getting caught, S the sanction to be paid in case of getting caught, whilst the cost of abiding the law is:

$$\gamma_l = Y \cdot t \tag{2.11}$$

where Y is the income and t the tax rate. When tax burden rises, everything else equal,

$$\gamma_u{}^t < \gamma_u{}^{t+1} \tag{2.12}$$

and, eventually,

$$\gamma_u < \gamma_l \tag{2.13}$$

which incentivize not to report transactions and evade government control.

Note that, fortunately, it is not this simple. Ethics and moral principles help refrain individuals from switch to illegal activities as soon as they become advantageous with respect to legal ones. Measurements for ethics could be added, however, the economic point is that when costs of complying with the law rise, more and more people may decide to evade taxes.

3. The instrument is exogenous. Tax burden is determined outside the model by social, political and budget choices by governments both at EU and national level.
4. We fit in the regression the variable *cst,* correlated with the outcome, that is, with the level of cash transactions. We observe no relation between *cst* and the treatment variable (correlation is -0.0014).[24]

[24] It has been suggested that the shadow economy causes inflation, as the higher the level of shadow economy, the more governments will be incentivized to use inflation rather than ordinary taxation which

Having set the assumptions, we then use IV two-stage least squares (2SLS) model to try to capture the causality relation to be demonstrated. The first stage least squares will estimate $\widehat{Shad}$ (the predicted value of *Shad* based on the IV *fis*) as follows:

$$\widehat{Shad} = \alpha_0 + \beta_0 fis + \varepsilon \qquad 1SLS$$

and use such estimate to get the estimated shadow economy level, and adding the additional variable *cst*:

$$\widehat{Cval} = \alpha_1 + \beta_1 \widehat{Shad} + \beta_2 cst + \varepsilon \qquad 2SLS$$

Running the IV regression in STATA with the following command:

$$ivreg\ cval\ cst\ (shad = fis) \qquad STATA\ command$$

yields an instrumental variable regression (2SLS) with *cval* as outcome variable, *shad* as instrumented treatment variable, *fis* as instrumental variable, and *cst* as an additional variable in the regression, with the results shown in Table 2.4.

Table 2.4 Results from STATA running the IV regression.

Instrumental variables (2SLS) regression

Source	SS	df	MS
Model	1377.62796	2	688.813981
Residual	4205.52993	16	262.845621
Total	5583.15789	18	310.175439

Number of obs	19
F(2, 16)	3.56
Prob > F	0.0525
R-squared	0.2467
Adj R-squared	0.1526
Root MSE	16.213

cval	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
shad	3.499233	1.349118	2.59	0.020	.6392295	6.359236
cst	-7.380085	4.66453	-1.58	0.133	-17.26845	2.508277
_cons	29.06308	14.08266	2.06	0.056	-.7908181	58.91698

Instrumented: shad
Instruments: cst fis

shadow activities evade (Mazhar & Méon, 2017). In our case, however, the goal of the ECB clearly states that it is to maintain inflation throughout the EU constant and under the threshold of 2% and the level of shadow economy does not influence it. Moreover, the instrumental variable in use is not inflation alone, but rather the opportunity cost of holding money, which is also composed by inflation.

We now turn to the result of our experiment. The first result we look at is the adjusted r-squared which suggests that 15.26% of the movement of the outcome variable is explained by this regression.

Since for the F-test the value is smaller than the significance level of 0.1

$$0.0525 < 0.1$$

we can conclude that the result is worth working with. As for the variable *shad*:

$$p - value < 0.1$$

we thus reject the null hypothesis for the variable coefficient with a 10% significance level. However, we get a very high p-value for the variable *cst,* therefore we accept the null hypothesis for the *cst* coefficient.

Keeping in mind all the limitations that pertain to the analysis, our model suggests that there is a causal relationship from the level of shadow economy to the cash transactions (as proxy for overall cash circulation) and that such causality relationship has a coefficient of 3.49. That is, for every +1% change in the shadow economy level of a given country, the cash transactions in value rise by 3.49%.

Also, for rising costs of holding money, our model would suggest a negative relationship between the cost of holding money and the demand for money holdings in cash (as economic analysis would predict). However, the results are not statistically significant, as the p-values are quite high and the adjusted r-squared is very low.

This analysis would be more significant if it were possible to repeat the experiment on a panel data and on a bigger number of countries. Indeed, a mismeasurement or deviation from the average would have a huge impact with a small number of observations. Moreover, the problems expressed in 2.3.1 with respect to Austria and Estonia are mainly related to customs which are not easy to predict and assign a variable to.

Conclusions on the economic literature and ethics of a cashless society

Many of the problems that a cashless society would pose could be easily (some more, some less easily) resolved, but one in particular: cash is the only means of payment the unbanked have to pay for goods and services. Governments would need to aid those people, providing the services they cannot do for themselves. Providing such a service would, however, have a significant cost. On the other hand, requiring everyone to have a bank account or a similar instrument would entail greater national and international security, as people need to identify themselves in subscribing to bank accounts. Still, people that are not security threats but have no documents would find themselves incapable of buying goods.

Since there is still demand for cash and governments do not have the organizational means and capabilities to provide for the need of people that use mainly cash, society is not ready to do without cash yet. As Yves Mersch (member of the Executive Board of the ECB) said at the 4th *Bargeldsymposium* of the Deutsche Bundesbank, on 14 February 2018, printed euro banknotes will retain their place and their role in society as legal tender for a very long time to come. However, Mersch pointed out that if there will be public demand for digital central bank money, this might be a technical variant of cash: alternative payment methods cannot replace euro cash, they can only complement it (European Central Bank, 2018).

As for the relationship of cash and the shadow economy, the model analyzed in the previous section with the Instrumental Variable approach suggests that rising shadow economy levels cause a rise in cash transactions (as a proxy for the level of cash). The conclusion seems legitimate, thinking about the logics behind the *Cash Demand Approach (CDA).* However, there may be more than meets the eye. If rising shadow economy levels cause more cash to be demanded, what would happen if cash is withdrawn from circulation? Would that prevent such growth in the shadow economy level to begin with? Is cash needed in shadow economy transactions such that a cashless society would (at least) limit shadow economy activity, as suggested by Dybka et al. (2016)? That is, even if the decision of undertaking an illicit transaction is done, is the absence of cash enough to prevent it to be concluded and if so, in which cases?

Unfortunately, there is not enough data at this time to provide clear answers for such questions. In fact, data on shadow economy level is difficult to obtain as it is an unobserved variable and at the same time, determining a causality link with absolute certainty is not easy. Indeed, the ECB itself is trying to determine whether this is actually the case. Withdrawing the 500€ note from circulation would suggest that there is at least suspicion of such a causality.

Although "there is no viable alternative for euro cash" yet, countries like Sweden already have a very limited amount of cash in circulation. The possibility that cash is influenced positively by shadow economy level and that may serve in some ways its scope, plus the disadvantages of cash itself and the threat-benefit of anonymity that it poses may well be seen as catalysts to the abandonment of cash. There will be no cashless societies in the short run, for sure, but encouraging cashless transactions where possible could have benefits for the whole society and incentivize to adopt such payments even more (Dybka, et al., 2016).

Rogoff (2014) concludes his paper suggesting the evaluation of costs and benefits of a more proactive strategy in phasing out cash, especially in relation to the role high denomination notes have in the economy. As the withdrawal of the 500€ note show, cashless economies' benefits (and problems) are now more and more central in the economic discussion. As central banks reason on the possible issue of a central bank virtual currency (such as the e-krona), Rogoff's conclusion that we may live in the twilight era of cash anyway seems an even more realistic possibility.

Appendix: Data tables

The following data has been used to find the appropriate instrumental variable in the analysis of section 2.2.1. Also, here here we explicit calculations made to compute the variable *cst*.

Variable Name	Description	Source
Ctot	Total number of cash transactions %	Henk Esselink & Hernández, L. H. (2017)
Cval	Total value of cash transactions %	Henk Esselink & Hernández, L. H. (2017)
Shadow1	Shadow economy estimates, series 1	Medina, L., Schneider, F. (2018)
Shad	Shadow economy estimates, series 2, adj.	Medina, L., Schneider, F. (2018)
over	Interst for overnight deposits (overnight rate)	Euro Area Statistics
π	Inflation	EUROSTAT (2019)
cst	Inflation + over (opportunity cost of holding cash)	N.A.
fis	Tax burden on workers (figures divided by factor of 100)	Rogers, J., & Philippe, C. (2018)

Country	Name	Ctot	Cval	Shadow1	Shad
IE	Ireland	79	49	10.4	6.8
NL	Netherlands	45	27	8.4	5.5
BE	Belgium	63	32	15.6	10.1
LU	Luxemburg	64	30	8.2	5.3
DE	Germany	80	55	10.4	6.8
FR	France	68	28	12.8	8.3
PT	Portugal	81	52	16.6	10.8
ES	Spain	87	68	17.2	11.2
IT	Italy	86	68	19.8	12.9
MT	Malta	92	74	23.6	15.3
SI	Slovenia	80	68	22.4	14.6
AT	Austria	85	67	7.1	4.6
SK	Slovakia	78	66	13	8.5
GR	Greece	88	75	21.5	14
CY	Cyprus	88	72	23.6	15.3
FI	Finland	54	33	11.5	7.5
EE	Estonia	48	31	24.6	16
LV	Latvia	71	54	21.3	13.8
LT	Lithuania	75	62	23.8	15.5

Country	Name	fis	over	π	cst
IE	Ireland	12.435	0.09	0.3	0.39
NL	Netherlands	28.459	0.078333333	1.3	1.378333333
BE	Belgium	31.159	0.02	2.2	2.22
LU	Luxemburg	26.521	0.1275	2.1	2.2275
DE	Germany	29.745	0.0425	1.7	1.7425
FR	France	32.233	0.0325	1.2	1.2325
PT	Portugal	9.642	0.018333333	1.6	1.618333333
ES	Spain	15.077	0.044166667	2	2.044166667
IT	Italy	20.512	0.065	1.3	1.365
MT	Malta	5.824	0.0625	1.2	1.2625
SI	Slovenia	9.321	0.0125	1.6	1.6125
AT	Austria	31.443	0.108333333	2.2	2.308333333
SK	Slovakia	6.925	0.035833333	1.4	1.435833333
GR	Greece	13.077	0.091666667	1.1	1.191666667
CY	Cyprus	5.875	0.105833333	0.7	0.805833333
FI	Finland	24.884	0.11	0.8	0.91
EE	Estonia	7.902	0.02	3.6	3.62
LV	Latvia	5.711	0.024166667	2.9	2.924166667
LT	Lithuania	5.724	0	3.7	3.7

Bibliography

Access to Cash Review, (2018, December) "Is Britain Ready to go Cashless?"

Arcelli, M., Dongili, P. (1977), Economia Monetaria, CEDAM, Padova.

Crosby M. et al., (2016, June) "BlockChain Technology: Beyond Bitcoin", in *AIR* (Issue 02), Berkeley.

Bellamy, E. (1888). *"Looking Backward"*, Cambridge, Riverside Press.

Birch, D. G. W. (2014). *"Identity is the new money"*, London Publishing Partnership.

Brown, S. D. (2016, July 25), "Cryptocurrency and criminality: The Bitcoin opportunity", in *The Police Journal: Theory, Practice and Principles,* pp. 327-339. Retrieved April 07, 2019, from https://journals.sagepub.com/doi/abs/10.1177/0032258x16658927

Dybka, P., Karska, M., Olesiński, B., Kowalczuk, M., Opala, P., Rozkrut, M., & Torój, A. (2016) "*Reducing the Shadow Economy through Electronic Payments"*. Retrieved February 24, 2019, from https://www.ey.com/Publication/vwLUAssets/Report_Shadow_Economy/$FILE/REPORT_ShadowEconomy_FINAL_17.pdf

Engert, W., Fung, B. S., & Scott, H. (2018) "*Is a Cashless Society Problematic?",* Bank of Canada.

Esselink H., Hernández L., (2017) "*The use of cash by households in the euro area"* ECB Occasional Paper Series, Retrieved March 16, 2019, from https://www.ecb.europa.eu/pub/pdf/scpops/ecb.op201.en.pdf

European Central Bank (2007) "*Annual Report 2007"*. Retrieved April 06, 2019, from https://www.ecb.europa.eu/pub/pdf/annrep/ar2007en.pdf?e8d45fad08e7d67e5d824ddac2f6db07

European Central Bank (2010) "*The Payment System"*. Retrieved 2019, from https://www.ecb.europa.eu/pub/pdf/other/paymentsystem201009en.pdf

European Central Bank (2012, October) "*Virtual Currency Schemes"*. Retrieved March 24, 2019, from https://www.ecb.europa.eu/pub/pdf/other/virtualcurrencyschemes201210en.pdf

European Central Bank (2018) "The role of euro banknotes as legal tender." Speech by Yves Mersch, Member of the Executive Board of the ECB, at the 4th Bargeldsymposium of the Deutsche Bundesbank, Frankfurt am Main, 14 February 2018. Retrieved March 31, 2019, from https://www.ecb.europa.eu/press/key/date/2018/html/ecb.sp180214.en.html

European Commission (2014, December) "*EU Employment and Social Situation - Quarterly Review - December 2014"*. Retrieved March 07, 2019, from http://ec.europa.eu/social/BlobServlet?docId=13356&langId=en

Eurostat (2019) "Annual inflation down to 1.6% in the euro area". Retrieved June 04, 2019 from https://ec.europa.eu/eurostat/documents/2995521/9499950/217012019-AP-EN.pdf/4ea467c3-8ff2-4723-bc6e-b0c85fb991e4

EUROPOL (2015) *"Why is cash still king? A strategic report"*. Retrieved June 04, 2019, from https://www.europol.europa.eu/publications-documents/why-cash-still-king-strategic-report-use-of-cash-criminal-groups-facilitator-for-money-laundering

Friedman, M. (1987) "Quantity Theory of Money" in The New Palgrave: A Dictionary of Economics, edited by John Eatwell, Murray Milgate, and Peter Newman, vol. 4, pp. 3-20, New York, Stockton Press; and London: Macmillan.

Ghosh, T. P (2017). *"Efficacy of Demonetisation in Eliminating Black Money An Analysis of Indian Demonetisation November 2016"*, Institute of Management Technology, International Academic City, Dubai.

King, C., Walker, C., & Gurulé, J. (2018) "Cash, Crime and Anti-Money Laundering" (M. Riccardi, M. Levi) in *The Palgrave Handbook of Criminal and Terrorism Financing Law* (p. 151), Palgrave Macmillan, Cham.

Kramer, A., Kampf, G., & Schwebke, I. (2006) "How long do nosocomial pathogens persist on inanimate surfaces? A systematic review", *BMC Infectious Diseases*.

Mazhar, U., & Méon, P.-G. (2017) *"Taxing the unobservable: The impact of the shadow economy on inflation and taxation"*, World Developement, Vol. 90, pp. 89-103. Retrieved May 23, 2019, from ScienceDirect: https://www.sciencedirect.com/science/article/abs/pii/S0305750X1630465X

Medina, L., Schneider, F., (2018) "Shadow Economies Around the World: What Did We Learn Over the Last 20 Years?", IMF Working Papers.

Nakamoto, S. (2008, October 31) "*Bitcoin: A Peer-to-Peer Electronic Cash System"*. Retrieved March 27, 2019, from https://bitcoin.org/bitcoin.pdf

Nanda, K. and Kaur, M., (2016, September 20), "Financial Inclusion and Human Development: A Cross-country Evidence", Journal Indexing Metrics, Volume: 41 issue: 2, page(s): 127-153, Issue published: May 1, 2016.

OECD (2017) "*Shining Light on the Shadow Economy: Opportunities and Threats"*. Retrieved February 25, 2019, from http://www.oecd.org/tax/crime/shining-light-on-the-shadow-economy-opportunities-and-threats.pdf

OECD Economic Surveys (2007, November). "*OECD Economic Surveys: Spain"*. Retrieved March 10, 2019

Prelec, D., & Simester, D. (2001) "*Always Leave Home Without It: A Further Investigation of the Credit-Card Effect on Willingness to Pay"*. Retrieved March 17, 2019, from https://doi.org/10.1023/A:1008196717017

Reserve Bank of India (2018, July) "*Annual Report 2017-2018"*. Retrieved March 03, 2019, from https://rbidocs.rbi.org.in/rdocs/AnnualReport/PDFs/0ANREPORT201718077745EC9A874DB38C991F580ED14242.PDF

Rogers, J., & Philippe, C. (2018) "*The Tax Burden of Typical Workers in the EU"*, Paris: Institut Économique Molinari.

Rogoff, K., (2014) *"Costs and benefits to phasing out paper currency"*, Harvard University, Cambridge: NBER Macroeconomics Annual Conference.

Rusu, C., & Stix, H. (2017) "*Cash and card payments – recent results of the Austrian payment diary survey"*. Retrieved from Oesterreichische Nationalbank (OeNB): https://www.oenb.at/dam/jcr:d575fb1b-f59c-4a74-8652-1c6e05cd5ce7/Cash-and-card-payments.pdf

Sands, P. (2016, February) "*Making it Harder for the Bad Guys: The Case for Eliminating High Denomination Notes", M-RCBG Associate Working Paper Series, No. 52*, Harvard-Kennedy School. Retrieved from https://www.hks.harvard.edu/sites/default/files/centers/mrcbg/files/Eliminating%2BHDNfinalXYZ.pdf

Schneider, F., & Williams, C. C. (2013) "*The Shadow Economy"*. Retrieved March 04, 2019, from http://www.iea.org.uk/sites/default/files/publications/files/IEA%20Shadow%20Economy%20web%20rev%207.6.13.pdf

Sharma, S., & Sumbali, G. (2014) "Contaminated money in circulation: a review", *International Journal of Recent Scientific Research*.

Swan, M. (2015) *"Blockchain - Blueprint for a new economy"*, Sebastopol, O'Reilly.
Flying Magazine (1953, June) "The travel card that gave "credit" to the public", *Flying Magazine*, No. 11/1953. Retrieved from https://books.google.it/books?id=aXIHl--RuqkC&lpg=PA1&hl=it&pg=PA2#v=onepage&q&f=true
Yoshitaro Heshiki et al. (2017, April 13), *"Toward a Metagenomic Understanding on the Bacterial Composition and Resistome in Hong Kong Banknotes"*, in Frontiers in Microbiology.
Williams, C. C., & Horodnic, I. A. (2015) *"Explaining and tackling the shadow economy in Estonia, Latvia and Lithuania: a tax morale approach"*, in Baltic Journal of Economics, Vol. 15, Issue 2. Retrieved May 18, 2019, from https://www.tandfonline.com/doi/full/10.1080/1406099X.2015.1114714

Webliography

American Credit Cards Collectors Society (ACCCS), *Card Classifications*. Retrieved March 27, 2019, from http://www.creditcollectibles.com/categories/

Banco de España, *Peseta banknotes in circulation: Breakdown denomination.* Retrieved April 06, 2019, from https://www.bde.es/f/webbde/INF/MenuVertical/BilletesYMonedas/ficheros/be_enero2016_en7_14_bill.pdf

Banco de España, *Peseta banknotes and coins,* Retrieved March 03, 2019, from https://www.bde.es/bde/en/areas/billemone/Publico_general/Billetes_y_moned/

Bank for International Settlements (2017), "*CT2: Banknotes and coins in circulation"*. Retrieved March 20, 2019, from https://stats.bis.org/statx/srs/table/CT2?p=2017&c=

Cadwalladr, C., & Graham-Harrison, E. (2018, March 18). *"Revealed: 50 million Facebook profiles harvested for Cambridge Analytica in major data breach"*, *The Guardian*, Retrieved March 17, 2019, from https://www.theguardian.com/news/2018/mar/17/cambridge-analytica-facebook-influence-us-election

Casciani, D. (2010, May 13) *"500 euro note - why criminals love it so"*, *BBC News*. Retrieved May 06, 2019, from http://news.bbc.co.uk/2/hi/uk_news/magazine/8678979.stm

Gohd, C. and Leary, K., (2017, October 11) *"Sweden could stop using cash by 2023"*, *World Economic Forum,* Retrieved September 14, 2019, from https://www.weforum.org/agenda/2017/10/sweden-could-stop-using-cash-by-2023/

Encyclopaedia Britannica (2005, April 28) "*Peseta"*. Retrieved March 03, 2019, from https://www.britannica.com/topic/peseta

Euro Area Statistics, *"Bank Interest Rates – Deposits"*. Retrieved June 04, 2019 from https://www.euro-area-statistics.org/bank-interest-rates-deposits?cr=eur&lg=en

European Central Bank, *"ECB ends production and issuance of €500 banknote"*. Retrieved from https://www.ecb.europa.eu/press/pr/date/2016/html/pr160504.en.html

European Central Bank, "*Electronic Money"*. Retrieved from https://www.ecb.europa.eu/stats/money_credit_banking/electronic_money/html/index.en.html

European Central Bank (2019, January 15). *"Euro Circulation"*. Retrieved February 20, 2019, from https://www.ecb.europa.eu/stats/policy_and_exchange_rates/banknotes+coins/circulation/html/index.en.html

European Central Bank, "*Banknotes"*. Retrieved April 06, 2019, from https://www.ecb.europa.eu/euro/banknotes/html/index.en.html#500

European Central Bank, *"Security Features"*. Retrieved from https://www.ecb.europa.eu/euro/banknotes/security/html/index.en.html

European Central Bank, *"The Euro*". Retrieved from https://www.ecb.europa.eu/euro/intro/html/index.en.html

European Commission, "*Cash Controls"* Retrieved February 22, 2019, from https://ec.europa.eu/taxation_customs/individuals/cash-controls_en

European Consumer Centre Germany (ECC) "*Cash Payment Limitations"*, Retrieved March 05, 2019, from https://www.evz.de/en/consumer-topics/buying-goods-and-services/shopping-in-the-eu/cash-payment-limitations/

EUROPOL (2016, May 05) "*Europol welcomes decision of the ECB to stop printing EUR 500 notes"*. Retrieved March 2019, from https://www.europol.europa.eu/newsroom/news/europol-welcomes-decision-of-ecb-to-stop-printing-eur-500-notes

Eurostat (2018, September 28) "*Recorded offences by offence category - police data"*. Retrieved March 07, 2019, from http://appsso.eurostat.ec.europa.eu/nui/show.do

Firstpost (2017, November 8) *Demonetisation anniversary: Full text of Prime Minister Narendra Modi's speech from 8 November, 2016*, *Firstpost,* Retrieved February 19, 2019, from https://www.firstpost.com/business/demonetisation-anniversary-a-year-later-heres-what-prime-minister-narendra-modi-had-said-on-8-november-2016-4198753.html

Indian Government - Ministry of Statistics and Programme Implementation (2018) "Qarterly Growth Rates of GDP Released from First Quarter of the Financial year 2012-13 to Fourth Quarter of Financial year 2017-18". Retrieved from: https://data.gov.in/resources/quarterly-growth-rates-gdp-released-first-quarter-financial-year-2012-13-fourth-quarter

India Today (2016, November 8)*, Here is what PM Modi said about the new Rs 500, Rs 2000 notes and black money*, India Today. Retrieved from https://www.indiatoday.in/india/story/live-pm-narendra-modi-addresses-nation-350943-2016-11-08

Paesani, P. (2018, May 3) *"Bitcoin di Stato? Il caso della moneta digitale di banca centrale"*, Menabò di Etica ed Economia. Retrieved from https://www.eticaeconomia.it/bitcoin-di-stato-il-caso-della-moneta-digitale-di-banca-centrale/ on September 14, 2019.

Robbins, J. (2018, June 29) *"Revealed: 300 cash machines disappearing every month from the UK",* Which?, Retrieved on September 17, 2019, from https://www.which.co.uk/news/2018/06/revealed-300-cash-machines-disappearing-every-month-from-the-uk/

Shaw, G. (2019, April) *"Bank branch closures: is your local bank closing?",* Which?, Retrieved on September 17, 2019, from https://www.which.co.uk/money/banking/switching-your-bank/bank-branch-closures-is-your-local-bank-closing-a28n44c8z0h5

Sheffield, H. (2015, May 25) *"UK moves towards cashless society"*, The Independent. Retrieved from https://www.independent.co.uk/news/business/news/uk-moves-towards-cashless-society-10267215.html

Schneeweiss, Z. (2016, February 02). *ECB Wants Proof That 500-Euro Note Helps Criminals, Mersch Says*, Bloomberg. Retrieved March 2019, 02, from https://www.bloomberg.com/news/articles/2016-02-04/ecb-wants-proof-that-500-euro-note-helps-criminals-mersch-says

Skingsley, C., (2018, November 10) *"Why Sweden's cashless society is no longer a utopia"*, *World Economic Forum,* Retrieved September 14, 2019, from https://www.weforum.org/agenda/2018/11/sweden-cashless-society-is-no-longer-a-utopia/

Sveriges Riksbank (2018, October 18) "*E-krona*". Retrieved March 20, 2019, from https://www.riksbank.se/en-gb/payments--cash/e-krona/

Sveriges Riksbank (2018) "*Payment Patterns"*. Retrieved March 20, 2019, from https://www.riksbank.se/globalassets/media/statistik/betalningsstatistik/2018/numerical-data-payments-patterns-in-sweden-2018.xlsx

Sveriges Riksbank (2018, October 22) "*The Swedish payment market"* Retrieved March 20, 2019, from https://www.riksbank.se/en-gb/payments--cash/the-riksbanks-task-in-relation-to-payments/the-swedish-payment-market/

The Times of India*, "Rs 500 and Rs 1,000 notes pulled out of circulation immediately: PM Narendra Modi"*, The Times of India. Retrieved from https://timesofindia.indiatimes.com/india/Rs-500-and-Rs-1000-notes-pulled-out-of-circulation-immediately-PM-Narendra-Modi/articleshow/55315473.cms?

The World Bank (2019) "*Global Findex Databas*e", The World Bank Report. Retrieved March 04, 2019, from https://globalfindex.worldbank.org/sites/globalfindex/files/databank/Global%20Findex%20Database.xlsx

The World Bank "*Inflation, GDP deflator - annual %"*. Retrieved March 14, 2019, from https://data.worldbank.org/indicator/NY.GDP.DEFL.KD.ZG?end=2017&locations=IN&start=2006&view=chart

TIM, *"L'Italia si Accende con il 5G"*. Retrieved February 26, 2019, from https://www.tim.it/reti-veloci-5g

UK Finance Press Release (2019, June 06). "*Rise in mobile banking and contactless as consumers take pick 'n' mix approach to payments"*. Retrieved September 17, 2019, from https://www.ukfinance.org.uk/press/press-releases/rise-mobile-banking-and-contactless-consumers-take-pick-n-mix-approach-payments