A digital journey towards an empty wallet

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Abstract

Digital money is growing more popular and physical money is not being used as much as it once was. But what happens if we have a cashless society and what would it mean? The purpose of this essay is to investigate if increased technological innovation lead to a decrease in the currency in circulation and if there is a short or long term effect of innovation on currency in circulation. To answer the questions a fixed effects regression model is applied, based on panel data for 4 countries Sweden, Norway, Denmark and Finland for the time period 2007-2020. The regression's findings provide credibility to the hypothesis that increasing innovation has had a negative effect on currency in circulations. With the help of a Vector Error Correction Model with time series data for Sweden from 2007 to 2020, the second part of the question is answered. The result find evidence that increased innovation has a long-run decreasing effect on currency in circulation.

Keywords: Cashless economy, cashless, CBDC, innovation, currency in circulation, digital payments, physical money

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1. Introduction

Digitalized money is becoming more popular; we can see a trend that physical money isn't used as much as before. But what will happen if we get a cash free economy, what would it mean? It should come as no surprise that money and a stable payment market are essential societal functions. Both private and state finances rely on a working and efficient mechanism to carry out payments, i.e. a payment system (SOU, 2014:61). As a result, it's important to understand what might happen when the payment industry changes. Riksbanken argues that continuing transformation is accompanied with hazards such as society being entirely shut out of the picture by private entities. According to Riksbanken, this can result in private monopolies and a loss of public trust in the payment system (Julin, Erlandsson & Segendorf, 2017).

Riksbanken has a legislative mission to create a safe and efficient payment system and has been providing money to the people for 350 years. Nevertheless, as technology advances, currency is being utilized less and less. With the present trend, we will be in a scenario when cash is no longer widely recognized as a form of payment within a few years. The technological innovation has brought into question the Riksbankens public mandate. Riksbanken has two options: ignore payment market trends and hand over complete responsibility for payment methods to the private sector, or continue to supply payment methods to the population in a new technical format (Riksbanken, 2018a).

The main purpose of this essay is to examine whether or not increased innovation has a negative effect on currency in circulation. Additionally, the essay will attempt to distinguish long-term and short-term effects. Thus, the essay question are as follows:

- *Does the increased technological innovation lead to a decrease in currency in circulation? And is there a short or long term effect of innovation on currency in circulation?*

The sample selection for this study will include countries that have had limited coverage about the relationship between currency in circulation and innovation despite being rated within the top 10 countries regarding innovation. The countries included in this study is Sweden, Finland, Norway and Denmark and will henceforth be referred to as the Nordic countries

To answer the first part of the question, a fixed effects regression based on panel data for 4 countries in the period 2007-2020 is used. The results show that there is a negative effect of increased innovation on currency in circulation. Using time series data for Sweden throughout the same time period, a Vector error correcting model is used to provide an answer to the second part of the question. The result shows support for an error correction towards the long run equilibrium and a positive short term effect of increased inflation and household consumption on currency in circulation.

1.1 Disposition

The remainder of this essay is structured as follows. Section two will go over background of money and a literary review and previous studies. Section three reviews theories that are used in this paper. Section four describes the research methodology and data measurements and the collection of data. Section five present the essays models that were run to address the essay's questions. Section six discusses the main findings and projections and section seven concludes with a discussion and closing remarks.

1.2 Contribution

The purpose of this thesis is to contribute to the current literature and existing knowledge of cashless economy by conducting a thorough review of the literature on innovation and currency in circulation, with the goal of investigating a possible relationship amongst these two factors. The research aims to shed light on whether there is a potential relationship between innovation and currency in circulation, as well as to contribute to the literature and research on cashless transactions and digitalization. It may also serve as a foundation for coming researchers to conceptualize, distinguish and understand the underlying behavioral models and theories that may influence the previous, current, and future applications of a cashless economy and societal innovation.

2. Background

2.1 Money: definition and functions

Money serves an important purpose in the economy. However, it is impossible to explain exactly what money is. Money is becoming even more abstract to many people in an age when technology advancements have resulted in it increasingly being in digital form. If you put it concrete, for the general public, there are two primary types of money. First you have money in accounts which is a digital form of money and second you have cash which is a physical form of money (Riksbanken, 2018b).

Money serves three essential and complementary functions. medium of exchange, store of value and unit of account. First, an item must be able to enable the sale of goods and services in order to act as a medium of exchange. The seller in a trade must accept the item as payment with the expectation that the seller will be able to use the instrument as payment in subsequent transactions (Band for International Settlements [BIS], 2018a). So medium of exchange allows people to buy and sell from one another (International Monetary Fund [IMF], 2012). Second, the item must function as a store of value, conserving purchasing power over time. An item that is sensitive to depreciation or fails to retain its value should not be considered as sound money (BIS, 2018a). So store of value implies that individuals can save it and spend it later, meaning that individuals are smoothing their purchases over time (IMF, 2012). Third, in order to serve as a unit of account, the instrument must work as a standard for measuring and comparing value across commodities and services, informing the economic choices of its users (BIS, 2018a). So unit of account serves as a common foundation for prices (IMF, 2012).

To enable trade and consumption, mankind has utilized numerous things as money throughout history. Our bank account funds have increasingly been utilized for payments, i.e. money, in recent years. We utilized checks and bills in the beginning, but technological advancement has contributed to the fact that we now use digital money via numerous online services and mobile apps (Riksbanken, 2020a).

2.2 Central bank money vs private bank money

Currently, central banks issue physical cash and electronic central bank deposits. Central banks also support private money or deposits given by banks established under the fractional reserve banking system. In general, central banks assist commercial banks in many different ways. One, by allowing them to settle interbank payments with central bank deposits. Two, allowing commercial and central bank money to be converted through banknote provision and third providing a lender of last resort function to provide contingent liquidity. One of the most crucial points to remember is that only cash and reserves are regarded liabilities in central bank balance sheets, whereas private bank deposits are not (Bank of Canada, European Central Bank, Bank of Japan, Sveriges Riksbank, Swiss National Bank, Bank of England, Board of Governors Federal Reserve System, BIS, 2020).

The role of central banks is to guarantee that citizens have access to the safest form of money (Bank of England, 2021). In terms of money, central banks bear the primary duty for ensuring that the basic operations of money are maintained. If the politicians in charge were held accountable, they might be tempted to grant exaggerated money production to fund public expenditure, thereby undermining the value of money. There are also several examples in contemporary times of nations that have failed to administer the monetary system, resulting in hyperinflation. Many countries have passed legislation requiring the central bank to be politically independent in order to boost trust in the currency (Riksbanken, 2018b).

However, it is not just Central banks that produces new money in the form of electronic money. When Private banks make new loans, they also inject fresh money to the system. For example, if you get a new house loan from a bank you will have a debt in your bank account. Simultaneously, the money you borrowed is sent to the home's seller, who puts it in his bank account. Fresh loans generate new money in the system in this way. Similarly, when the consumer repays the bank loan, the quantity of bank money is lowered. Private banks, on the other hand, cannot produce infinite money (credits) since they cannot lend out an unlimited amount of money. Lending is constrained by rules and regulations that control how banks may operate. Private banks must have a specific amount of money in liquid funds in order to avoid a liquidity crisis and a scarcity of cash. They also have capital adequacy rules, which require them to keep a specified quantity of capital for each krona granted (Riksbanken, 2020a).

Price stability is a goal that Riksbanken as well as other central banks have set for themselves in order to protect the value of money throughout time. Maintaining confidence in both central bank and private bank money is critical. The crucial distinction is who we have a hold on. We have a claim on a private owner as a client of a private bank, but we have a claim on the state as holders of central bank money. This is critical for the credit and liquidity risk of the money. Because a private bank, apart from a central bank, might go bankrupt. Putting assets in a bank account with a private bank carries some risk. However, central banks can always meet their obligations in the national currency since they have unrestricted ability to generate new money. As a result, central bank money is both a risk-free asset and a source of payment (Riksbanken, 2018a).

2.3 Different kinds of payments systems

There are different kinds of payment systems and some are more common than others. For example, credit cards provide you with a line of credit that can be utilized for purchases, debt transfers or cash advances with the condition that you repay the loan amount in the future. With debit card you may conveniently withdraw money from your checking account. In this case there is no interest rate and the money is not a loan. So there are no minimum monthly payments are required from you compared to credit cards (USbank, 2019). Bankgiro is a bank-owned clearing company that serves as the country's primary intermediary for bulk payments. Bankgiro accepts a variety of payments and transfers, including transfers, direct debit payments, supplier and salary payments, account-to-account transfers, automated clearing of card payments and cash withdrawals. The first service to implement the real-time payment settlement system of Bankgiro was the mobile payment platform Swish, which was released in 2012 in Sweden. Real-time payment access is made available to private persons through Swish. The time it takes for the payee to obtain the final money is typically one to two seconds after the payment is initiated (Boel, 2019).

2.4 Central Bank Digital Currency (CBDC)

A CBDC aims to broaden access to central bank reserves further than the small scope of commercial banks to the general public. As a result, cash would no longer be the solitary form of central bank money that the public could use to transact and save. The same could be said for reserves held at the central bank (Ferrari, Mehl & Stracca, 2020). Our monetary system is founded on the cooperation of private and public money, the latter of which is accessible for retail payments in the shape of banknotes and coins. Our trust in private payment methods is based on our capacity to turn private funds into secure public funds. This is because money from the central bank is guaranteed by the government and is risk-free. If banknotes and coins lose their role as a reference value in payments, it means that it will jeopardizing the monetary system's integrity. Therefore, as the world becomes more digitalized, central banks must think about how to ensure that their currency can still be used as a payment anchor. The coexistence of sovereign and private money would be guaranteed by a CBDC (Panetta, 2022).

	Conventional forms of money			New forms of money	
	Cash	Bank deposits	Master account balances	Privately issued cryptocurrency	Central bank digital currency
Digital	×	✔	✔	✔	✔
Central bank-issued	✔	×	✔	×	✔
Universally accessible	✔	✔	×	✔	(✔)
✔ = existing or likely feature, (✔) = possible feature, × = not typical or possible feature					

Source: Bank for International Settlement, 2018.

2.4.1 The impact of the CBDC on monetary policy

CBDC has the potential to broaden the Central banks toolbox for managing monetary policy in two ways. Firstly, substituting cash with an interest-bearing digital currency could provide the Central banks with a powerful new tool for implementing negative interest rates. that is, the consumers pay the central bank to store its currency, which is a policy meant to prevent users from stashing money and stimulate economic spending. Since cash has no interest rate, a central bank's capacity to cut interest rates is limited when it gets closer negative interest rate territory, because individuals can convert their banking system assets into cash. Secondly, account-based CBDC could allow Central banks to send funds into people’s accounts as an alternative way to boost spending (Rogoff, 2017).

2.4.2 Seigniorage

Seigniorage has long been a lucrative source of revenue for Central Banks. The use of currency in Sweden has decreased dramatically in recent years and a future cashless society could have significant implications for the Riksbank's economic freedom. In practice, seigniorage is the portion of the Central Banks interest revenue that is financed by the issuing of cash. Because equity has remained relatively stable while cash demand has decreased, the central bank now has less interest-free funding than before, which leads to a lower seigniorage. Cash presently makes up a relatively small component of the Riksbank's balance sheet and seigniorage accounts for a small portion of the bank's annual income, according to recent annual reports. This can be explained in part by the Riksbank's recent acquisitions of government bonds for monetary policy purposes. The balance sheet has grown rapidly as a result of these bond purchases and the proportionate significance of cash in financing the Riksbank's assets has reduced as the bond portfolio has been supported by central bank reserves. If the trend of diminishing cash demand proceeds and demand falls to zero, the Riksbank's financial independence will be jeopardized. So another possible source of revenue emerges if the Riksbank chooses to introduce an e-krona (Gustafsson & Lagerwall, 2020).

2.5 Literary review

Payment systems are crucial to the economy, but for a long time they have simply been viewed as the boring and necessary plumbing of the economy. Money has, on the other hand lately received more attention as a result of significant technology improvements in the world and related policy issues. Physical money like banknotes and coins are diminishing and has become a hot topic al around the world and especially in Sweden since currency in circulation is decreasing at a faster rate than other countries. It’s hardly surprising that the academic world has followed shortly after to explore and analyze how this would affect us. However, despite a large coverage of reports especially from Band for International Settlements (BIS) and Sweden’s Riksbank on the subject there are some areas that leaves us with questions.

Payment systems are currently undergoing significant changes, primarily as a result of advancements in technology. Cash's role is diminishing, while fast payment solutions are gaining prominence. In the article *Payment systems - history and challenges* by Boel (2019), the author discusses these advancements as well as the challenges they pose to central banks. In most of the Western world in the late nineteenth and early twentieth century, a political choice was made that resulted in the banknote monopoly, which gave central banks the exclusive authority to produce cash. When sovereignty is endangered, a monopoly upon seigniorage is a tool for political power and a valued help. Theoretically, central banks might have a competitive edge in two main payment system operations. The first is the maintenance of participant accounts, which are used to settle transactions. Due to their credibility and public policy mandate, central banks are well-suited for this function. The second is the provision of very short-term credit to mediators in order to speed up settlement or the resolving of disruptions in settlement.

Julin et al. (2017) say that the introduction of a CBDC, might have implications for monetary policy, partially because forecasting demand for CBDC may be more challenging than forecasting demand for cash today. They claim that a CBDC might have displacement effects on the banking system, but that these are dependent on the system's architecture. They also contend that introducing a CBDC may pose concerns, such as money laundering and terrorist funding issues. A CBDC is being examined at this early stage for modest payments that should not return any interest.

It is not given that just central banks could print money, although private banks have the ability to create money, the money is produced by private banks and has a claim on the issuing bank. The claim on central banks money is however the on the government. In most countries in the 19th and early 20th centuries, the decision was made that only the central bank of a country would be permitted to print cash, a so-called banknote monopoly. The situation is changing and particular in Sweden where cash isn't used as much as before. This raises the question of the Central banks function as a payment system issuer and its connection with private banks. Over a century after the establishment of the banknote monopoly, the question of who produces and is responsible for the nations means of payment is resurfacing. In correlation with this, the Swedish central bank, Riksbanken, has begun to look into options such as releasing their own money in digital form, the so-called e-krona (Söderberg, 2018).

In Sweden, card payments or payments made using the Swish app are becoming more popular than physical cash payments. The market for payments is becoming digitalized at a rapid pace in Sweden. This is due, among other things, to the fact that more and more payment options are appearing like Swish, Apple pay and Google pay. But also because the Swedish government are working on promoting innovation. In case of technical issues with electricity or Internet problem, most individuals can keep cash in their pockets as a solid backup option. These issues can result in more significant effects when there are fewer people with cash on hand. More banks are also ceasing to offer cash services as the demand for them declines. In Sweden, four of the top five banks today only provide manual cash services at the desk at two or fewer locations nationwide. This is why the Swedish central bank has started to look at a E-krona pilot (Riksbanken, 2020b).

2.6 Previous studies

The Swedish Bankers' Association (2012) conduct a study on card payments in Sweden to cast light on the importance of card payments in the development of a modern, productive and secure payment infrastructure, as well as the contribution this has meant for the progress of technology. The purpose of this report is to explain the growth and function of card payments, as well as their significance for society and card payment users. The goal is also to lay the groundwork for highlighting benefits and costs in comparison to alternatives, as well as to define a possible future progress of card payments. They use numbers of transactions of debit and credit cards from year 1998 to 2012 in Sweden and banknotes and coins in circulation as a percentage of GDP. They also have data from different surveys about customer’s preferable method of paying and the cost of the different kind of transactions. The study conducts a two forecasts about the future of card payments. The study shows that payments with cards benefit society significantly by improving the environment, lowering risks and reducing the black market. In comparison to other countries, Sweden has a highly developed card payment sector with high efficiency and strong competition. Besides that, payments with cards have evolved from a niche product to become the dominant payment method in Sweden.

Vukoszavlyev (2019) investigate the relationship between innovation and various well-being indicators in 126 countries and whether there are variances in the innovation index score across geographical regions. The study view and define innovation in accordance with the Global Innovation Index (GII). The variables used in this study are GDP per capita measured at purchasing power parity, unemployment rate, life expectancy, crude mortality rate and human development index (HDI). The study employs non-parametric hypothesis testing, post-hoc tests, and linear regression. According to their findings, there are variances between continents depending on GII. Regions that lag behind will be of lower standard variations, indicating that they are more homogeneous and thus there are no significant differences between countries in the region. According to the regression analysis, GDP per capita, life expectancy and the human development index are all important explanatory variables. HDI was the only explanatory variable in the multivariable regression analyses' final model. It is due to high multicollinearity among the explanatory variables, as well as the fact that the HDI aggregates a number of non-economic indicators such as GII.

Tee and Ong (2016) use a panel cointegration test and a panel unit test to investigate the association between cashless payments and economic growth in five European countries (Austria, Belgium, France, Germany, and Portugal) from 2000 to 2012. The Pedroni residual cointegration and Panel Vector Error Correction Model (VECM) are used to analyze the different effects of adopting cheque payments, telegraphic transfers, card payment and electronic money on the economies of the chosen EU countries. According to the data, the deployment of cashless payment has a substantial influence on economic growth. The effect, on the other hand, may be observed over time rather than instantly.

Green (1999) investigates whether participation in the payment system by a central bank is necessary for efficiency using a Freeman (1996) model. He concludes that this depends on two factors: first, whether the commercial law framework controls the activities of a private-sector payment mediators is sufficient to support agents' use of credit issued by the mediator as a medium of exchange. Second, whether a central bank can consistently and credibly guarantee to fully absorb money granted to facilitate payments. The legitimacy of a central bank's reabsorption commitment is dependent on the system of governance. In addition, Green (1999) adds that it is plausible that the institutions of central bank governance required for legitimate involvement in the payment system are almost equivalent to those required for the successful execution of monetary policy in a restricted sense. Therefore, the argument for establishing a politically independent central bank is strengthened to the extent that a central bank is necessary to take part directly in the payment system. Furthermore, the necessity for political independence argues that the central bank, rather than the Government or other government-controlled institutions, would be a more appropriate public-sector player in the payment system.

Ong and Chong (2022) examines the impact of cashless transactions on internet and mobile banking service usage in two different ways via a time series analysis. To determine the short-run causal effect of the transition from cash to cashless payments made through internet and mobile banking, they first do a Wald test. Secondly, they do an autoregressive distributed lag (ARDL) bounds test to assess the long-term impact of cashless payments for internet and mobile banking. In their study they use data of real payments made by consumers and total amount of cashless transactions per month. In the short term, charge cards, credit transfers and direct debit transactions will have a substantial impact on the use of mobile banking applications, according to the report. In the near future, credit card and credit transfer payments have a major impact on the value of online banking transactions every month. However, with the exception of direct debit, the transition from cash to cashless payment did not result in the adoption of internet and mobile banking services in the long run.

3. Theoretical framework

3.1 Diffusion of innovations (DOI)

The theory of diffusion of innovation (DOI) works at both individual and aggregate levels. First at individual level, it concentrates on the adoption process, which includes the following: One, the innovation itself. Two, an individual who has already embraced the innovation. Three, another individual who hasn't yet adopt the innovation and four, some sort of communication channel through which these two individuals can exchange information (Rogers, 1995; Eerkens & Lipo, 2014). To begin with, the theory explains the series of steps that an individual who has yet to adopt the innovation will go through before coming to a conclusion to adopt or not adopt (Rogers, 1995; Blackburn, 2011). Second, the theory explains why communication can have a variety of effects on this individual process. Communication between individuals, such as through word-of-mouth processes, observation of individuals who adopt and then use the innovation and thus inspire other individuals to replicate that behavior, and communication transmitting information about the innovation via mass media all play specific role in the personal process of adoption.

According to Rogers (2003, p. 12), an innovation is "an idea, practice, or object that is perceived as new by an individual or other unit of adoption". Early adopters and innovators are the first participants of the population to obtain the innovation. Individuals in these groups share characteristics such as curiosity seeking behavior and price aversion, which encourage them to embrace a new product or service before others. More importantly, they play an important role in sharing information or convincing the rest of the population about the perks of the innovation and its applications. Early identification of innovators and early adopters is thus critical for companies developing new products "since it assists in the process of tailoring each element of the marketing mix to the requirements and behaviors of those buyers who initiate markets and without whom the social comparison that leads to diffusion would often not occur" (Foxall & Goldsmith, 1994, pp. 35–36).

According to Paul and Friday (2012), a cashless transaction is one in which goods and services are exchanged without the use of cash, whether it be through electronic transfer or cheque payment. DOI can be used to examine the impact of cashless payments on an economy. The idea was first presented by Rogers (1995) in 1962, who explained how innovation gradually spreads to people inside a social system. The connection between people via interpersonal networks, according to DOI, explains why a new idea or invention is adopted. Diffusion in this sense refers to the spread of cashless payment where customers look for better, more convenient transactions and businesses pursue new revenue streams. The effects of adopting cashless payment vary depending on the society since the proliferation of cashless payment depends on how rapidly the community is prepared to accept it via various phases of the innovation process.

3.2 Rational Choice Theory

The rational choice theory, which has its roots in law and economics, has been widely used to explain "rational" social and economic behavior (Allingham, 2002). The theory encompasses a number of models, the most important of which is concerned with forecasting the outcome and patterns of choices. Individual rational choice is explained in terms of three fundamental elements: personal preferences, beliefs and restrictions (Acheson, 2002). Individuals' preferences refer to their positive or negative assessments of the prospective results of their actions or alternative choices. Beliefs are an individual's perceptions of cause-and-effect relationships between their actions and many possible outcomes that have a probability connected with them. Constraints indicate the collection of actions' financial, time, effort and other personal capabilities and so aid in assessing their viability. According to the rational choice theory, a rational person will consider all available information while evaluating the costs and benefits of an action, as well as the probability of those possible outcomes and limitations in order to select preferences (McGee & Warms, 2013).

The core assumption of rational choice theory is that people would attempt to get the most out of what they have through rational maximize, which is derived from law and economics. In other words, people want to maximize advantages while minimizing expenses (Coleman, 1990). Another important premise of this theory is that subjective values are self-interested, meaning that an individual behaves in a way that balances costs and rewards to construct an alternative with the highest personal benefit.

Following the receipt of a payment card, an individual must choose between two basic options whenever they want to make a payment. One is using cash or two, using their own payment cards with accompanying services given by the issuing banks. Using cash or a payment card may have different expenses and benefits.

3.3 Endogenous Growth Theory

The notion of endogenous growth is a key theory that links to this study. Endogenous growth theory claims that endogenous rather than external forces drive economic growth. Endogenous growth theory holds that variables including innovation, knowledge, new technology development, efficient and effective production methods and human capital investment are critical contributors to economic growth (Romer, 1994).

The main argument of the endogenous growth theory is that with a knowledge based economy, the ripple effects that comes from investment in technology is that people can generate social, economic and other benefits. Proponents of endogenous growth think that increased productivity is directly connected to increased innovation and human capital investments. As a result, proponents of endogenous growth theory argue that the government and private sector should foster and invest in innovation initiatives and also provide incentive programs and offer schemes for companies and individuals to boost innovation and creativity, which can lead to enabling development of new products and services and intellectual property (Howitt, 2010).

4. Methodology and data

In this chapter the research methodology, data measurements and the collection of data is presented. It includes a description and explanation of the variables used in this essay, as well as descriptive statistics and material flaws. The essay is based on panel data and time series generated from secondary data collected from several databases. This paper conducts quantitative research to investigate the potential relationship between innovation and cash in circulation as a percentage of GDP. One reason for conducting quantitative research is that the variables studied can be easily quantified: first, cash in circulation as a percentage of GDP and second, innovation as Global Innovation Index score from Global Innovation Index editions for each country in the sample.

The second reason for performing quantitative research is to reduce author biases that could influence the outcome of a study. To answer the essays hypothesis, the relationship between currency in circulation, innovation and other control variables is examined. This thesis will concentrate on the Nordic countries apart from Iceland from year 2007 to 2020. Due to the fact that GII didn't begin until 2007, the data's timeframe has been restricted to 2007 to 2020. One reason for this focus is the lack of empirical studies conducted regarding the relationship between currency in circulation and innovation in these countries. Another reason for this focus is that Sweden, Denmark and Finland has been ranked within the top 10 on Global Innovation index during the last decade but Norway hasn't. Norway however have a low currency in circulation just like Sweden.

4.1 Variable of interest

4.1.1 Currency in circulation

The dependent variable in the regression model is cic and stands for currency in circulation. It is presented as percent of GDP per country and year, which is the most common way to present how much currency in circulation a country has (Band for International Settlements, 2018b). It's gathered from Riksbanken (2022) for Sweden, Statistisk Sentralbyrå (2022) for Norway, Danmarks Nationalbank (2022) for Denmark and last European Central Bank (2022a) for Finland.

4.1.2 Innovation

The independent variable innovation is gathered from World Intellectual Property Organization (2021) and is a Global Innovation Index based on score from 0-100. It ranks world economies based on their capacity for innovation. The higher a country scores on the index, the better potential they have to innovate. The variable is presented as percent of total score.

4.1.3 Real GDP

The variable rgdp stands for Real GDP and is gathered from Federal Reserve Bank of St. Louis (2022) for each country and measures the size of an economy, it is measured in growth rates compared to previous year. It provides information about an economy's size and state of operation. Real GDP growth is frequently used as a measure for the economy's overall health. When the GDP growth rate indicates growing economic productivity, the value of currency in circulation rises. This is due to the fact that each unit of currency can later be exchanged for more valuable goods and services. So real GDP should have a positive correlation to currency in circulation.

4.1.4 Inflation

The variable inflation is also gathered from Federal Reserve Bank of St. Louis (2022) for each country. Inflation is quantified by the consumer price index, which measures the yearly percentage change in the cost to the average individual of obtaining a basket of goods and services that could be fixed or changed at specified intervals. It measures inflation compared to previous year. Inflation should have a positive correlation with currency in circulation because if inflation goes up, money is worth less and then there is a demand for more money and more cash will be printed.

4.1.5 Household consumption

The variable hconsumption stands for household consumption and is gathered from The World Bank (2022) and is measured in percentage of total household income. This variable is included because the demand for money is one of the factors that can determine the amount of currency in circulation. So household consumption is presumed to have a positive correlation with currency in circulation, if consumption goes up, then currency in circulation goes up as well.

4.1.6 Card payments

Variable card_payment stands for share of card payments in number of total payment transactions and is gathered from European Central Bank (2022b). In theory, this relationship takes off based on if a country's banking system is technically advanced and highly established. With a better connection of bank cards, card payments will have a negative impact on the amount of cash in circulation.

4.1.7 Broadband and Broadband fibre

Variable broadband and broadband_fibre is gathered from OECD (2022) and stands for the percentage of people in a country that has access to broadband and broadband fibre. It is divided by the number of people living in the country each year. These variables are included in this study to try to catch the demand for people who have access to internet and faster transactions and is assumed to have a negative correlation with currency in circulation. If people have access to more and faster internet the demand for currency in circulation will decrease.

Table 1. Variable Description

Variable	Name	Description
cic	Currency in circulation	Currency in circulation as a procentage of GDP
innovation	Innovation	Innovation based on scores from GII, higher score means higher innovation within a country
rgdp	Real GDP	Measure of the size of an economy as percentage from previous year
inflation	Inflation	Percentage per year
hconsumtions	Household consumtion	Percentage of total household income
card_payments	Share of cardpayments	Percentage of total transactions
broadband	Broadband	Number of people who have broadband in a cuntry as percentage of total population
broadband_fibre	Broandband Fibre/LAN	Number of people who have fibre broadband in a cuntry as percentage of total population

4.2 Global Innovation Index

The Global Innovation Index (GII) ranks countries based on specific indicators such as their success and capacity for innovation. GII has influenced the innovation measurement agenda and has become a foundation of economic policymaking since its debut in 2007, with a growing number of countries carefully examining their yearly GII results and implementing policy responses to enhance their performance (World Intellectual Property Organization, 2021). The GII considers technological innovation and knowledge in particular when defining innovation (Vukoszavlyev, 2019). The GII measures the performance of 126 nations throughout the world in terms of innovation, using 80 indicators to create a complete picture of national innovation in terms of education, politics, corporate infrastructure and technology. Cornell University, INSEAD Graduate Business School and the World Intellectual Property Organization collaborated to create this innovation index. 96.3 percent of global GDP and 90.8 percent of the world's population are represented in the index (Dutta, Lanvin & Wunsch-Vincent, 2018).

When it comes to how a country's global innovation score is determined, there are 80 indicators that determine the level of innovation. The factors of innovation are composed of five input sections with sub-sections that cover national economy indicators and two output sections with sub-sections that provide evidence of innovation performance. Infrastructure, Institutions, Human Capital and Research, Market sophistication and Business sophistication are the five input sections. Furthermore, two output sections are identified: Creative Outputs and Knowledge and Technology Outputs. The sections are rated as the weighted average of sub-sections, which are calculated as the weighted average of indicators, totaling 80 in the most recent index edition (Dutta, Lanvin & Wunsch-Vincent, 2018). See all indicators specifically in appendix.

4.2.1 Limitations associated with Global innovation index

Cornell University, INSEAD Graduate Business School and the World Intellectual Property Organization (WIPO) collaborated to develop the GII, meaning it takes into account a variety of indicators to provide an overview of a country's innovation performance. However, there is a risk that some of the indicators are overlooked or should be excluded when assessing national innovation performance. Moreover, some of the indicators may have been left out because they are difficult to quantify despite being relevant for innovation evaluation. For example, in 2020 according to the Bloomberg ranking, Germany is the most innovative country (The CEO Magazine, 2020) as opposed to Switzerland, which is the most innovative country according to the GII (World Intellectual Property Organization, 2020). This inconsistency demonstrates how differently innovation can be evaluated. There is no universally recognized way of determining which countries are the most technologically advanced on the planet. As a result, the rankings of each individual source are likely to vary at least a bit from one another. However, when taken as a whole, certain patterns emerge (World Population Review, 2021).

4.3 Descriptive Statistics

Table 2. Descriptive Statistics

Variables	Mean	Min	Max	Std. Dev.
cic	3.132	1.140	7.000	1.649
innovation	57.82	49.30	64.80	3.559
rgdp	1.005	-8.070	5.950	2.427
inflation	1.347	-9.170	4.060	1.813
hconsumptions	47.00	38.38	54.52	4.104
card_payments	63.81	47.00	81.00	7.109
broadband_fibre	12.23	3.00	30.00	7.398
broadband	36.88	29.00	45.00	4.724

Table 2 shows a sample of summary statistics of the variables for all countries included in the panel data. The level of innovation varies across countries and years. One of the highest scores of innovation is found in Sweden year 2012 where they placed second of all rated countries and the lowest score is found 2020 in Norway. There are also interesting observations in the variable cic, minimum is 1,1% and max is 7%. This is both year 2020 but the 1,1% is currency in circulation in Sweden and 7% is currency in circulation for Finland.

Table 3. Correlation Matrix for Model 2

Variables	cic	innovation	rgdp	infaltion	hconsumtions	card_payments	broadband_fibre	broadband
cic	1							
innovation	-0.37	1						
rgdp	-0.15	-0.06	1					
inflation	-0.09	-0.00	0.47	1				
hconsumtions	0.62	-0.20	-0.17	-0.15	1			
card_payments	-0.40	0.10	0.24	0.01	-0.57	1		
broadband_fibre	-0.12	0.60	0.08	-0.11	-0.14	0.15	1	
broadband	-0.48	0.04	0.05	0.05	-0.34	0.26	-0.18	1

A correlation analysis is generated for model 2 to see if the variables are correlated. The correlation coefficient is a statistical measure of how strong a link exists between two variables' relative movements. A positive link is shown by a linear correlation coefficient larger than zero. A negative association is indicated by a value smaller than zero. Finally, a value of 0 implies that there is no correlation between variables. Table 3 above confirms that there are no issues with multicollinearity.

5. Empirical Models

The first model in this study is the OLS regression model and it will allow us to see if innovation has a negative impact on currency in circulation. Model 1 and model 2 in the OLS regression model is based on panel data and includes 4 countries and 42 observations. The second model, the Vector Error Correcting Model is based on time series for Sweden and will help to see if there is any short or long term effect by the increased innovation on currency in circulation.

5.1 OLS regression model

A pooled ordinary least squares (OLS) regression will be conducted in order to estimate the effect of innovation on currency in circulation. To determine if the OLS regression model should be run with a fixed effect model or random effects model a Hausman test will be applied. When the entities in the sample effectively constitute the entire population, a fixed effects model is more appropriate. Whereas a random effects model is more suitable when the entities in the sample can be considered of as having been randomly selected from the population (Brooks, 2008). To solve the problem of heteroscedasticity, which can occur in panel data, the regression will include robust standard errors. If any omitted variables are constant over time but vary across countries, while others are constant across countries but vary over time, then both country and time effects should be included (Stock & Watson, 2015). The original model is shown below. Another model will be estimated that includes the interaction term of broadband and broadband fibre to test the effect of innovation on currency in circulation in the present of regular broadband and broadband fibre. This will be called model 2.

Model 1.

$$cic_{it} = \beta_0 + \beta_1 innovation_{it} + \beta_2 rgdp_{it} + \beta_3 inflation_{it} + \beta_4 hconsumtion_{it} + \beta_5 card\_payments_{it} + e_{it}$$

Model 2.

$$cic_{it} = \beta_0 + \beta_1 innovation_{it} + \beta_2 rgdp_{it} + \beta_3 inflation_{it} + \beta_4 hconsumtion_{it} + \beta_5 card\_payments_{it} + \beta_6 broadband_{it} + \beta_7 broadband\_fibre_{it} + e_{it}$$

Where subscripts i = 1 ,…, N represents country, and t = 1 ,…, T represents time period and e_{it} is the error term.

The parameter α_i, which represents the different intercept for each entity, will be included if the Hausman test suggests that the model should be a fixed effects model. Furthermore, dummies for each year will be added if the test indicates a fixed effect model. If, however the Hausman test indicates that the model should be run with random effects, the α_i parameter will be used, as well as the parameter ω_{it}, which is the total value of the error term and the random deviation of each entity's intercept term from the overall intercept term α_{it}.

The prediction from model 1 and model 2 is that innovation will have a negative effect on currency in circulation. Meaning that if innovation increases, the currency in circulation will decrease.

5.2 Vector Error Correcting Model

The VECM model has the advantage of accounting for both short and long term effects. Because it is critical that the model is based on cointegrated variables, a two-step Engle-Granger augmented Dickey-Fuller (EG-ADF) test will be performed prior to the VECM. This model will be used to answer the second part of the question of this essay.

5.2.1 Engle-Granger Augmented Dickey-Fuller Test

Cointegration occurs when two or more variables of the same order are integrated and their combination is stationary. Time series that share a stochastic trend will be co-integrated and may have long-term relationship (Stock & Watson, 2015). A two-step EG-ADF test, will be used in this essay to determine if there is cointegration. The EG-test is applied to a model with non-stationary variables to determine whether the error term, e_t, is stationary or not. If all variables are non-stationary as well as integrated of order one I(1), and e_t is stationary and integrated of order zero I(0), the variables are cointegrated (Brooks 2008). The cointegrated coefficient θ is unknown in this case, so it must be estimated. This is accomplished through an OLS estimation of Model 3.

Model 3.

$$cic_t = \alpha + \theta_1 innovation_t + \theta_2 rgdp_t + \theta_3 inflation_t + \theta_4 hconsumtion_t + \theta_5 card\_payments_t + \theta_6 broadband_t + \theta_7 broadband\_fibre_t + e_t$$

If cointegration between the variables exist, e_t should be I(0); otherwise, $e_t$will remain non-stationary. To test the residual, e_t, a Dickey-Fuller test will be performed, with an intercept with no time trend (Stock & Watson, 2015). The test's hypothesis will be as follows:

$$H_0: \hat{e}_t \sim I(1)$$
$$H_A: \hat{e}_t \sim I(0)$$

If the null hypothesis is correct, a stationary linear combination of non-stationary variables has not been discovered which implies that cointegration doesn’t exist. If, however the other hypothesis is correct, the residuals are stationary and a stationary linear integration of the non-stationary variables has been discovered. This indicates that variables are cointegrated and there is a long-term relationship (Brooks, 2008). To determine if the variables are cointegrated, the null hypothesis must be rejected in this test.

5.2.2 VECM

The first differences of each variable may be modelled if the dependent and independent variables are cointegrated. If they are cointegrated an additional regressor $Y_{t-1} - \theta X_{t-1}$, known as the error correction term, is added. The dependent variable varies between $t-1$ and t due to changes in the values of the independent variable $t-1$ and t, but also to compensate for any volatility that existed during the prior period. If two or more variables are cointegrated, the error correction term can assist in forecasting these variables as well as possibly other related variables. Cointegration, on the other hand, requires that the variables have same stochastic trends (Stock & Watson, 2015). The entire VECM model can be found in appendix but since this study is interested in innovation only the first section of the model will be used, shown below as model 4.

Model 4

$$\Delta cic_t = \beta_{10} + \sum_{i=1}^{p} \eta_{1i}\, \Delta cic_{t-i} + \sum_{i=1}^{p} \beta_{1i}\, \Delta innovation_{t-i} + \sum_{i=1}^{p} \gamma_{1i}\, \Delta rgdp_{t-i} + \sum_{i=1}^{p} \omega_{1i}\, \Delta inflation_{t-i} + \sum_{i=1}^{p} \tau_{1i}\, \Delta hconsumtion_{t-i} + \sum_{i=1}^{p} \sigma_{1i}\, \Delta broadband_{t-i} + \sum_{i=1}^{p} \mu_{1i}\, \Delta broadband\_fibre_{t-i} + \alpha_1(cic_{t-1} - \theta_1 innovation_{t-1} + \theta_2 rgdp_{t-1} + \theta_3 inflation_{t-1} + \theta_4 hconsumtion_{t-1} + \theta_5 card\_payments_{t-1} + \theta_6 broadband_{t-1} + \theta_7 broadband\_fibre_{t-1}) + u_{1t}$$

Where Δ is the first difference, β_{j0} is the constant term, $\theta_k$is the cointegrated coefficient and is the long-run coefficient, $\eta_{ji}, \beta_{ji}, \gamma_{ji}, \omega_{ji}, \tau_{ji}, \sigma_{ji}, \mu_{ji}$ is coefficient for short-run relationship, $\alpha_j$is the speed of adjustment, $(cic_{t-1} - \theta_1 innovation_{t-1} + \theta_2 rgdp_{t-1} + \theta_3 inflation_{t-1} + \theta_4 hconsumtion_{t-1} + \theta_5 card\_payments_{t-1} + \theta_6 broadband_{t-1} + \theta_7 broadband\_fibre_{t-1})$ is the error correction term and u_{jt} is the error term.

Model 4 investigates whether innovation has a long-term impact on currency in circulation or not. The relevant parameters for this part is $\alpha_j, \beta_{ji}, \theta_k$. If there is a long-term adjustment toward long-term equilibrium, it is examined by the parameter α_j. In the event of an error correction, this parameter will receive a substantial negative value. The parameter β_{ji} is projected to have the same effect on currency in circulation as the coefficient innovation in model 2.

6. Results and Analysis

6.1 Result OLS Regression

The result from the OLS regression is presented in table 4 below and shows that innovation leads to less currency in circulation as well as the fact that the effect is statistically significant at the 5% level. In model 1 if innovation would increase with one percentage point, then currency in circulation would decrease with 0.190 percentage points, with other conditions remaining the same. If we however look at model 2 in table 4 where the variables broadband and broadband fibre is included, we can see that if innovation would increase with one percentage point, then currency in circulation would decrease with 0.226 percentage points, with other conditions remaining the same. In model 2 innovation is no longer statistically significant at the 5% level but at a 10% level instead. Both model is however consistent with the essay's expectations and the findings of previous studies. The adjusted R-square increases from 91.8 percent in model 1 to 94.2 percent in model 2.

Three of the control variables in model 1 were found to be statistically significant. The coefficient for Real GDP (rgdp) indicates that currency in circulation will decrease if Real GDP goes up. This is not in line with the previous assumptions, it was assumed to have a positive correlation to currency in circulation because with growing economic productivity the value of currency in circulation would rise, however the variable is not significant since it fails to reject the null hypothesis. An increase on inflation on the other hand indicates that currency in circulation will be raised. So if inflation would increase with one percentage point, then we will have more currency in circulation. The variable for household consumptions indicate that the more a household consumes the more currency is in circulation and is in line with previous literature. The coefficient for card payments also indicates that an increase would lead to more currency in circulation. This is interesting because the assumption was that an increase in card payments should lower currency in circulation but the result in this study shows a positive correlation.

Table 4. OLS Regression with Fixed Effect

Variable	Model 1	Model 2
innovation	-0.190**	-0.226*
	(0.059)	(0.076)
rgdp	-0.088	-0.058
	(0.047)	(0.037)
inflation	0.118*	0.104*
	(0.055)	(0.044)
hconsumtion	0.141*	0.146*
	(0.165)	(0.085)
card_payments	0.098*	0.041*
	(0.028)	(0.016)
broadband		-0.221**
		(0.073)
broadband_fibre		-0.100***
		(0.026)
N	42	42
Adjusted R-squared	0.918	0.942

Note: Robust standard errors in parentheses.
Significance level: * $p \leq 0.1$, ** $p \leq 0.05$, *** $p \leq 0.01$.

In model 2 the variables broadband and broadband fibre is included to see if different kinds of broadband affect currency in circulation. The estimate is raised to 0.226 percentage points when these variables are included and is now significant at a 10% level instead of 5% as in model 1. Regarding the control variables that is included in model 1 there is no big difference between the models. However, both new variables broadband and broadband fibre is significant. Broadband at a 5% level and broadband fibre at a 1% level. Both broadband and broadband fibre has a negative effect on currency in circulation. This means that if broadband would increase with one percentage point, then currency in circulation would decrease with 0.221 percentage points, with other conditions remaining the same. And currency in circulation would decrease with 0.100 percentage point if broadband fibre increases with one percentage point. This is in line with the study.

6.2 Result Vector Error Correcting Model

To answer the second part of the question, whether there is a short or long term effect of innovation on currency in circulation a Vector Error Correcting model will be performed. Before running the VECM, eight independent Dickey-Fuller tests are run to determine whether the variables from model 2 are stationary or not and in what order they are integrated.

Table 5. Dickey Fuller Test

Variables	T-value	Integration Order
cic	-3.91	I(1)
innovation	-6.71	I(1)
rgdp	-10.95	I(1)
inflation	-6.64	I(1)
hconsumtion	-4.61	I(1)
card_payments	-3.61	I(2)
broadband	-4.64	I(1)
broadband_fibre	-4.78	I(1)

The table shows the T-value and integration order of the variable
Critical value is -2.89 at the 5% level

According to Table 5's result, cointegration may exist between the variables of currency in circulation, innovation, real GDP, inflation, household consumption, broadband and broadband fibre because these variables are stationary when are stationary when taking first difference. Card payments are stationary in I(2), which means that it is stationary in the second difference and therefore can't be included in the next test.

An Engle and Granger test is run in addition to the Dickey-Fuller test to see if the residuals are non-stationary, meaning if the variables are cointegrated. The only variable from model 2 that isn't included in this model is card payment because it wasn't integrated in the same order as the other variables.

Table 6. Engle and Grange Test

Variables	T-value	Integration Order
Residuals	-6.15	I(0)

The table shows T-value and the integration order of the residuals of the variable
Critical value is -3.00 at the 5% level

The result from the Engle and Grange test shows that the residuals are stationary and that a stationary linear combination of non-stationary variables has been discovered. The t-value is also greater than the 5 % level at -3.00 which means that we can reject the null hypothesis and there is cointegration and we can continue to do a VECM model.

Table 7. Vector Error Correction Model

Variables	Parameter Estimates
Intercept	0.025
	(0.055)
Error Correction term	-0.235**
	(0.094)
cic	
lag 1	-0.411
	(0.316)
lag 2	-0.246
	(0.296)
innovation	
lag 1	0.024
	(0.028)
lag 2	0.005
	(0.026)
rgdp	
lag 1	0.058
	(0.032)
lag 2	0.036
	(0.024)
inflation	
lag 1	0.045*
	(0.034)
lag 2	0.014
	(0.030)
hconsumtion	
lag 1	0.068
	(0.063)
lag 2	0.108*
	(0.055)
broadband	
lag 1	0.120
	(0.071)
lag 2	-0.058
	(0.070)
broadband_fibre	
lag 1	-0.024
	(0.032)
lag 2	-0.014
	(0.029)

The table shows the coefficient for the variables and the standard error in the parentheses
*Significance level: * $p \leq 0.1$, ** $p \leq 0.05$, *** $p \leq 0.01$.*

From the result we can see that the error correction term is negative, meaning that there is an adjustment against long-term equilibrium. The speed at which the currency in circulation returns to equilibrium following a change in the independent variables is shown by the value, which also reflects the pace of adjustment towards the long-run equilibrium. The error correction term shows an annual adjustment to equilibrium of 23.5%.

The first lag of inflation and the second lag of housing consumption are significant. As we can see from the result, innovation does not have a short term relation to currency in circulation and is expected. The short-term effect of inflation on currency in circulation is positive, therefore if inflation changes by one percentage point one year from now, the change in currency in circulation will change by 0.04 percentage points. Household consumption also has a positive short term effect on currency in circulation which means that if the change in household consumption increases with one percentage point the change in currency in circulation will increase with 0.10 percentage points two years ahead, ceteris paribus.

7. Discussion and Conclusions

The aim of this study was to investigate if increased technological innovation has led to a decrease in currency in circulation and to examine if there is a short or long term effect of innovation on currency in circulation. This was done for the years between 2007 and 2020. The result of this study implies that innovation belongs to one factor that has contributed to a lower currency in circulation, at least in the Nordic countries.

According to the first regression based on model 2, increased innovation has had a negative impact on currency in circulation, which is consistent with prior study findings. This is a reasonable result given that increased technological innovation gives people faster and more efficient way of paying and therefore the currency in circulation will decrease. This is also consistent with The Swedish Bankers' Association (2012) statement that it is likely that payments with cards benefit society significantly by improving the environment, lowering risks and reducing the black market and therefore digital payments a more desirable payment method then physical cash. Why the Nordic countries has these result could depend on that they are early adopters and innovators as the theory of diffusion of innovation says and are more inclined to embrace cashless payment via various stages of innovation processes (Rogers, 1995).

The adoption of different kinds of payments, which can reduce the amount of cash in circulation, is one of the input and output pillars that make up the Global Innovation Index score (Vukoszavlyev, 2019). These pillars can be used to explain the negative correlation. The more payment systems are adopted, the less need for cash circulation in the economy, which is consistent with the correlation analysis result that showed a negative correlation between cash in circulation and innovation.

The outcome of the Vector error correction model indicates that there is support for an adjustment of 24 percent per year toward a long-run equilibrium. This is in line with Tee and Ong (2016) study that the implementation of cashless payment has a significant impact on economic growth and that the effect might be seen over time rather than instantly. Different kinds of technological innovation take time and when more efficient payment method is implemented through innovation it can contribute to economic growth. So the result indicated that innovation has a long run effect on the change in currency in circulation but not in the short run. However, the VECM parameter estimations should be evaluated with some caution since they are not entirely reliable. Due to a shortage of data for the variable innovation, the model is run on a restricted sample of observations.

The development of new payment systems and the desire of people and organizations to find efficient payment methods may act as catalysts for innovation, which is one of the potential explanations for the negative correlation. As a result, businesses may run their daily operations more effectively and save both money and time by allowing businesses to invest more in innovation to gain a competitive advantage. To put it another way, this example demonstrates how reduced cash consumption might spur greater innovation in a country. Another possibility for the negative relationship between the amount of currency in circulation and innovation could be that governments that encourage and subsidize emerging firms understand the value of innovation. Consequently, it is possible that indirectly it's likely that the government have motivated less cash use.

There are benefits with less cash usage like reduced crime rates, less illegal transactions due to that you can trace with digital money and less cost for the government. There are however, also disadvantages of less cash use like we wouldn't have a backup options for money in the event of technological problems or hacker activity. That's why countries have started to investigate a central bank digital currency and especially Sweden since it is one of the countries with the most rapid reduction of cash (Riksbanken, 2020b).

In summary, this study obtained predicted findings for the main hypothesis. However, additional enhancements are possible. A larger number of observations could be included in the time series data collection, resulting in more credible estimations and, as a result, more representative findings. Another issue that should be addressed is the timeframe on which the study is based on, it is a rather short period of time and it could have had a small effect on the outcome. It would be recommended for future research to include a longer time period. However, on a positive note the descriptive statistics suggest no extreme outliers. Additional technical control factors, such as different kinds of payments, might be added to model 1 to further enhance the study. The findings in this article also highlights a possible advantage of transitioning to a cashless economy, suggesting that higher degree of innovative performance are associated with less currency in circulation. The research does not address which of the forces is stronger, that is if innovation leads to society using less currency to a greater extent than a decline in cash usage encourage innovation. Future study should focus on expanding on the correlation analysis and exploring the causal link and lag structure between these two variables.

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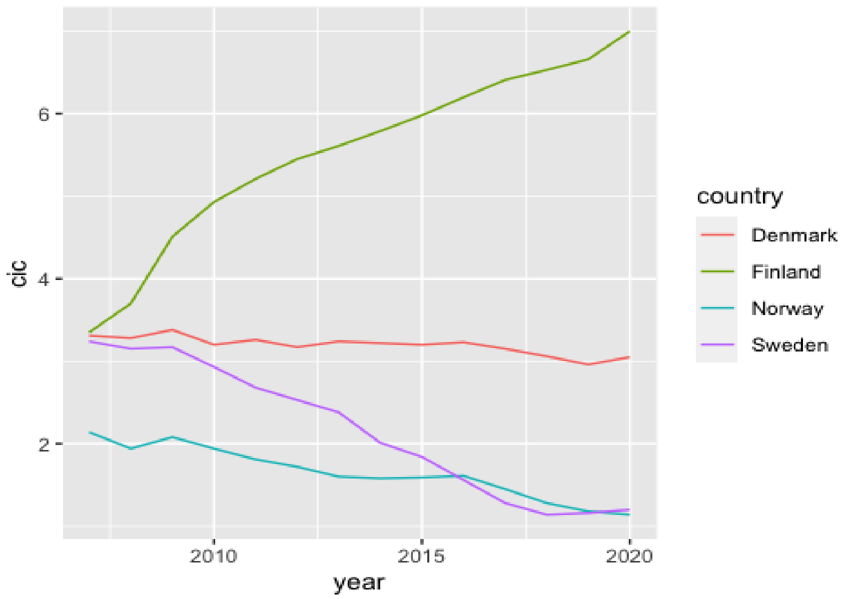
Appendix

Graph 1. Currency in circulation in percent per year and country



Vector Error Correcting Model

$$\Delta cic_t = \beta_{10} + \sum_{i=1}^{p} \eta_{1i}\, \Delta cic_{t-i} + \sum_{i=1}^{p} \beta_{1i}\, \Delta innovation_{t-i} + \sum_{i=1}^{p} \gamma_{1i}\, \Delta rgdp_{t-i}$$
$$+ \sum_{i=1}^{p} \omega_{1i}\, \Delta inflation_{t-i} + \sum_{i=1}^{p} \tau_{1i}\, \Delta hconsumtion_{t-i}$$
$$+ \sum_{i=1}^{p} \rho_{1i}\, \Delta card\_payments_{t-i} + \sum_{i=1}^{p} \sigma_{1i}\, \Delta broadband_{t-i}$$
$$+ \sum_{i=1}^{p} \mu_{1i}\, \Delta broadband\_fibre_{t-i} + \alpha_1 (cic_{t-1} - \theta_1 innovation_{t-1} + \theta_2 rgdp_{t-1}$$
$$+ \theta_3 inflation_{t-1} + \theta_4 hconsumtion_{t-1} + \theta_5 card\_payments_{t-1}$$
$$+ \theta_6 broadband_{t-1} + \theta_7 broadband\_fibre_{t-1}) + u_{1t}$$

$$
\begin{aligned}
\Delta innovation_t = \beta_{20} &+ \sum_{i=1}^{p} \eta_{2i}\, \Delta cic_{t-i} + \sum_{i=1}^{p} \beta_{2i}\, \Delta innovation_{t-i} + \sum_{i=1}^{p} \gamma_{2i}\, \Delta rgdp_{t-i} \\
&+ \sum_{i=1}^{p} \omega_{2i}\, \Delta inflation_{t-i} + \sum_{i=1}^{p} \tau_{2i}\, \Delta hconsumtion_{t-i} \\
&+ \sum_{i=1}^{p} \rho_{2i}\, \Delta card\_payments_{t-i} + \sum_{i=1}^{p} \sigma_{2i}\, \Delta broadband_{t-i} \\
&+ \sum_{i=1}^{p} \mu_{1i}\, \Delta broadband\_fibre_{t-i} + \alpha_2 (cic_{t-1} - \theta_1 innovation_{t-1} + \theta_2 rgdp_{t-1} \\
&+ \theta_3 inflation_{t-1} + \theta_4 hconsumtion_{t-1} + \theta_5 card\_payments_{t-1} \\
&+ \theta_6 broadband_{t-1} + \theta_7 broadband\_fibre_{t-1}) + u_{2t}
\end{aligned}
$$

$$
\begin{aligned}
\Delta rgdp_t = \beta_{30} &+ \sum_{i=1}^{p} \eta_{3i}\, \Delta cic_{t-i} + \sum_{i=1}^{p} \beta_{3i}\, \Delta innovation_{t-i} + \sum_{i=1}^{p} \gamma_{3i}\, \Delta rgdp_{t-i} \\
&+ \sum_{i=1}^{p} \omega_{3i}\, \Delta inflation_{t-i} + \sum_{i=1}^{p} \tau_{3i}\, \Delta hconsumtion_{t-i} \\
&+ \sum_{i=1}^{p} \rho_{3i}\, \Delta card\_payments_{t-i} + \sum_{i=1}^{p} \sigma_{3i}\, \Delta broadband_{t-i} \\
&+ \sum_{i=1}^{p} \mu_{3i}\, \Delta broadband\_fibre_{t-i} + \alpha_3 (cic_{t-1} - \theta_1 innovation_{t-1} + \theta_2 rgdp_{t-1} \\
&+ \theta_3 inflation_{t-1} + \theta_4 hconsumtion_{t-1} + \theta_5 card\_payments_{t-1} \\
&+ \theta_6 broadband_{t-1} + \theta_7 broadband\_fibre_{t-1}) + u_{3t}
\end{aligned}
$$

$$
\begin{aligned}
\Delta inflation_t = \beta_{40} &+ \sum_{i=1}^{p} \eta_{4i}\, \Delta cic_{t-i} + \sum_{i=1}^{p} \beta_{4i}\, \Delta innovation_{t-i} + \sum_{i=1}^{p} \gamma_{4i}\, \Delta rgdp_{t-i} \\
&+ \sum_{i=1}^{p} \omega_{4i}\, \Delta inflation_{t-i} + \sum_{i=1}^{p} \tau_{4i}\, \Delta hconsumtion_{t-i} \\
&+ \sum_{i=1}^{p} \rho_{4i}\, \Delta card\_payments_{t-i} + \sum_{i=1}^{p} \sigma_{4i}\, \Delta broadband_{t-i} \\
&+ \sum_{i=1}^{p} \mu_{4i}\, \Delta broadband\_fibre_{t-i} + \alpha_4 (cic_{t-1} - \theta_1 innovation_{t-1} + \theta_2 rgdp_{t-1} \\
&+ \theta_3 inflation_{t-1} + \theta_4 hconsumtion_{t-1} + \theta_5 card\_payments_{t-1} \\
&+ \theta_6 broadband_{t-1} + \theta_7 broadband\_fibre_{t-1}) + u_{4t}
\end{aligned}
$$

$$
\begin{aligned}
\Delta hconsumtion_t & \\
= \beta_{50} &+ \sum_{i=1}^{p} \eta_{5i}\, \Delta cic_{t-i} + \sum_{i=1}^{p} \beta_{5i}\, \Delta innovation_{t-i} + \sum_{i=1}^{p} \gamma_{5i}\, \Delta rgdp_{t-i} \\
&+ \sum_{i=1}^{p} \omega_{5i}\, \Delta inflation_{t-i} + \sum_{i=1}^{p} \tau_{5i}\, \Delta hconsumtion_{t-i} \\
&+ \sum_{i=1}^{p} \rho_{5i}\, \Delta card\_payments_{t-i} + \sum_{i=1}^{p} \sigma_{5i}\, \Delta broadband_{t-i} \\
&+ \sum_{i=1}^{p} \mu_{5i}\, \Delta broadband\_fibre_{t-i} + \alpha_5 (cic_{t-1} - \theta_1 innovation_{t-1} + \theta_2 rgdp_{t-1} \\
&+ \theta_3 inflation_{t-1} + \theta_4 hconsumtion_{t-1} + \theta_5 card\_payments_{t-1} \\
&+ \theta_6 broadband_{t-1} + \theta_7 broadband\_fibre_{t-1}) + u_{5t}
\end{aligned}
$$

$$
\begin{aligned}
\Delta broadband_t = \beta_{60} &+ \sum_{i=1}^{p} \eta_{6i}\, \Delta cic_{t-i} + \sum_{i=1}^{p} \beta_{6i}\, \Delta innovation_{t-i} + \sum_{i=1}^{p} \gamma_{6i}\, \Delta rgdp_{t-i} \\
&+ \sum_{i=1}^{p} \omega_{6i}\, \Delta inflation_{t-i} + \sum_{i=1}^{p} \tau_{6i}\, \Delta hconsumtion_{t-i} \\
&+ \sum_{i=1}^{p} \rho_{6i}\, \Delta card\_payments_{t-i} + \sum_{i=1}^{p} \sigma_{6i}\, \Delta broadband_{t-i} \\
&+ \sum_{i=1}^{p} \mu_{6i}\, \Delta broadband\_fibre_{t-i} + \alpha_6 (cic_{t-1} - \theta_1 innovation_{t-1} + \theta_2 rgdp_{t-1} \\
&+ \theta_3 inflation_{t-1} + \theta_4 hconsumtion_{t-1} + \theta_5 card\_payments_{t-1} \\
&+ \theta_6 broadband_{t-1} + \theta_7 broadband\_fibre_{t-1}) + u_{6t}
\end{aligned}
$$

$$
\begin{aligned}
&\Delta broadband\_fibre_t \\
&= \beta_{70} + \sum_{i=1}^{p} \eta_{7i}\, \Delta cic_{t-i} + \sum_{i=1}^{p} \beta_{7i}\, \Delta innovation_{t-i} + \sum_{i=1}^{p} \gamma_{7i}\, \Delta rgdp_{t-i} \\
&+ \sum_{i=1}^{p} \omega_{7i}\, \Delta inflation_{t-i} + \sum_{i=1}^{p} \tau_{7i}\, \Delta hconsumtion_{t-i} \\
&+ \sum_{i=1}^{p} \rho_{7i}\, \Delta card\_payments_{t-i} + \sum_{i=1}^{p} \sigma_{7i}\, \Delta broadband_{t-i} \\
&+ \sum_{i=1}^{p} \mu_{7i}\, \Delta broadband\_fibre_{t-i} + \alpha_7 (cic_{t-1} - \theta_1 innovation_{t-1} + \theta_2 rgdp_{t-1} \\
&+ \theta_3 inflation_{t-1} + \theta_4 hconsumtion_{t-1} + \theta_5 card\_payments_{t-1} \\
&+ \theta_6 broadband_{t-1} + \theta_7 broadband\_fibre_{t-1}) + u_{7t}
\end{aligned}
$$

Where Δ is the first difference, β_{j0} is the constant term, $\theta_k$is the cointegrated coefficient and is the long-run coefficient, $\eta_{ji}, \beta_{ji}, \gamma_{ji}, \omega_{ji}, \tau_{ji}, \sigma_{ji}, \mu_{ji}$ is coefficient for short-run relationship, $\alpha_j$is the speed of adjustment, $(cic_{t-1} - \theta_1 innovation_{t-1} + \theta_2 rgdp_{t-1} + \theta_3 inflation_{t-1} + \theta_4 hconsumtion_{t-1} + \theta_5 card\_payments_{t-1} + \theta_6 broadband_{t-1} + \theta_7 broadband\_fibre_{t-1})$ is the error correction term and u_{jt} is the error term.

Table 8. Global Innovation Index Score (GII) rank indicators

Index	**Rank Indicators**
1	**Institutions**
1.1	Political environment
1.1.1.	Political stability and absence of violence/terrorism
1.1.2	Government effectiveness
1.2	Regulatory environment
1.2.1	Regulatory quality
1.2.2.	Rule of law
1.2.3.	Cost of redundancy dismissal
1.3.	Business environment
1.3.1.	Ease of starting a business
1.3.2.	Ease of resolving insolvency
1.3.3.	Ease of paying taxes
2	**Human capital and research**
2.1	Education
2.1.1.	Expenditure on education
2.1.2.	Government expenditure on education per pupil, secondary
2.1.3.	School life expectancy
2.1.4.	Assessment in reading, mathematics, and science
2.1.5.	Pupil-teacher ratio, secondary
2.2	Tertiary education
2.2.1	Tertiary enrolment
2.2.2.	Graduates in science and engineering
2.2.3.	Tertiary level inbound mobility
2.3	Research and development (R&D)
2.3.1.	Researchers
2.3.2.	Gross expenditure on R&D (GERD)
2.3.3.	Global R&D companies, average expenditure top 3
2.3.4.	QS university ranking average score top 3 universities
3	**Infrastructure**
3.1.	Information and communication technologies (ICTs)
3.1.1.	ICT access
3.1.2.	ICT use
3.1.3.	Government's online service
3.1.4.	Online e-participation
3.2.	General infrastructure
3.2.1.	Electricity output
3.2.2.	Electricity output
3.2.3.	Gross capital formation
3.3.	Ecological sustainability
3.3.1.	GDP per unit of energy use
3.3.2.	Environmental performance
3.3.3.	ISO 14001 environmental certificates
4.	**Market sophistication**
4.1.	Credit
4.1.1.	Ease of getting credit
4.1.2.	Domestic credit to private sector

4.1.3.	Microfinance institutions' gross loan portfolio
4.2.	Investment
4.2.1.	Ease of protecting minority investors
4.2.2.	Market capitalization
4.2.3.	Venture capital deals
4.3.	Trade, competition, & market scale
4.3.1.	Applied tariff rate, weighted mean
4.3.2.	Intensity of local competition
4.3.3.	Domestic market scale
5	**Business sophistication**
5.1.	Knowledge workers
5.1.1.	Employment in knowledge-intensive services
5.1.3.	Firms offering formal training
5.1.3.	GERD performed by business enterprise
5.1.4.	GERD financed by business enterprise
5.1.5.	Females employed with advanced degrees
5.2.	Innovation linkages
5.2.1.	University/industry research collaboration
5.2.2.	State of cluster development
5.2.3.	GERD financed by abroad
5.2.4.	Joint venture/strategic alliance deals
5.2.5.	Patent families filed in at least two offices
5.3.	Knowledge absorption
5.3.1.	Intellectual property payments
5.3.2.	High-tech imports
5.3.3.	ICT services imports
5.3.4.	Foreign direct investment, net inflows
5.3.5.	Research talent in business enterprise
6.	**Knowledge and technology outputs**
6.1.	Knowledge creation
6.1.1.	Patent applications by origin
6.1.2.	PCT international applications by origin
6.1.3.	Utility model applications by origin
6.1.4.	Scientific and technical publications
6.1.5.	Citable documents H index
6.2.	Knowledge impact
6.2.1.	Growth rate of GDP per person engaged
6.2.2.	New business density
6.2.3.	Total computer software spending
6.2.4.	ISO 9001 quality certificates
6.2.5.	High-tech and medium high-tech output
6.3.	Knowledge diffusion
6.3.1.	Intellectual property receipts
6.3.2.	High-tech exports
6.3.3.	ICT services exports
6.3.4.	Foreign direct investment, net outflows
7	**Creative outputs**
7.1.	Intangible assets

7.1.1.	Trademark application class count by origin
7.1.2.	Industrial designs by origin
7.1.3.	ICTs and business model creation
7.1.4.	ICTs and organizational model creation
7.2.	Creative goods and services
7.2.1.	Cultural and creative services exports
7.2.2.	National feature films produced
7.2.3.	Global entertainment and media market
7.2.4.	Printing and publishing output
7.2.5.	Creative goods exports
7.3.	Online creativity
7.3.1.	Generic top-level domains (gTLDs)
7.3.2.	Country-code top-level domains (ccTLDs)
7.3.3.	Wikipedia yearly edits
7.3.4.	Video uploads on YouTube