The determinants of issuing central bank digital currencies

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Abstract

Central Bank Digital Currencies (CBDC) are considered 'digital fiat currencies' that do not have a physical form, which is a key distinction from conventional fiat money. This study aims to identify factors that influence central banks' decisions in taking advanced actions to issue CBDC, namely, the economic, market, demographic and technical factors. Data is collected from the CBDC Tracker and the WB database for the period 2013-2021. We applied the Pooled OLS estimations to examine the impact of the key factors on being in an advanced stage for issuing CBDC; moreover, probit and logistic regression are employed to robust our results and overcome the limitations of Pooled OLS. The findings demonstrate that underdeveloped economies are more engaged in issuing CBDC. Besides, better regulations, FDI inflow, young populations, and more urban societies would increase the probability of CBDC issuance. Nevertheless, results show the impact of technical factors is heterogeneous across countries.

Keywords

Money supply, central banks and their policies, financial system, Central Bank Digital Currencies

JEL Classification

E51, E58, G28

1. Introduction

For centuries, central banks have been trusted to provide money in the form of cash to the public as part of their public policy objectives. However, as cash use declined, faster and more convenient digital payments have emerged and grown in volume and scope all over the world. The Covid-19 pandemic arguably accelerated the trend of replacing cash with private digital money and alternative payment methods (BIS, 2020). It has also been argued that, in the digital age, the growth of cashless payments and the rise of cryptocurrencies are not only

challenging central banks' monetary prerogatives but also posing new threats to the stability and integrity of the financial system (Perret, 2019). It is against this background of significant changes and challenges that has motivated the central banks to look at the potential further evolution of issuing a new form of money: CBDC (Barontini and Holden, 2019).

Alongside cash and bank reserves, CBDC would represent a third form of central bank money. The arguments put forward on the issuance of CBDC cover broad issues, such as the possible impact of CBDC on payment efficiency, banks' fund intermediation, liquidity crises, and the transmission mechanism of monetary policy (Yanagawa and Yamaoka, 2019). The adoption of CBDC seems offer several benefits to the economy as a society welfare (Kwon et al., 2020; Lee et al., 2021; Barrdear and Kumhof, 2021; Williamson, 2021; Chuen and Teo, 2021; Garratt et al., 2022). However, the introduction of CBDC might also pose potential risks to consumers, the financial sector and the wider economy (Alonso et al., 2020; Kumhof and Noone, 2021; Lee et al., 2021; Davoodalhosseini, 2021). Albeit the issuance of CBDC is gathering significant attention worldwide, there is a lack of empirical studies on CBDC as this concept is relatively novel (Ozili, 2022). Moreover, most previous studies have only concentrated on the important determinants of CBDC adoption while ignoring the potential determinants of taking an advanced action to issue the CBDC.

Therefore, this study attempts to fill this gap by specifically investigating the factors affecting the probability of a central bank taking an advanced action to issue CBDC. In this study, the advanced stage, defined as the outcome variable, reveals whether a country has reached the Proof-of-Concept stage, Pilot stage, or the Launching stage. The possible determinants are categorised into four different groups including demographic factors, economic factors, technical factors, and market factors.

To achieve the objectives of this study, we employed three approaches: a linear regression model, probit models and logistic regression. In doing so, this study contributes to

the literature in the following ways. *First*, as one of the novel studies in this area, we contribute to building an econometric model for the determinants of CBDC for central banks to examine before launching CBDC. *Second*, to the best of our knowledge, this study filling the gap in the literature to consider various factors that determine the probability of being in an advanced stage in issuing a CBDC. In addition, the findings of this study can highlight the long-term desirable demographic factors that increase the probability for banks of issuing a CBDC. This helps policymakers to consider the predicted economic aspects that are likely to increase or reduce this possibility. This study also demonstrates how infrastructure is crucial for effectively issuing CBDC. Finally, we clarify the circumstances in which market variables might influence the issuing of CBDC.

The remainder of the paper is structured whereby the second section presents the literature review on the background of CBDC and the determinants of CBDC. The third section details the methodology and descriptive statistics for the data used in the study. Section four reports the empirical findings and section five offers a brief discussion of the results. Finally, the sixth section concludes this study and suggests policy implications.

2. Literature review

Digital currency is an innovative financial instrument as a medium of exchange using the internet to facilitate and increase online transactions leading to a revolution to the economy (Saif Almuraqab, 2020). CBDC is one of the newest digital currencies introduced to the general public which are authorised by an issuing central bank. The introduction of CBDC has been broadly discussed by several modern researchers in various sectors. However, the literature is very much still in the initial stages (Bhaskar et al., 2022). Moreover, most of the research studies in this subject are in terms of review of literature and discussion on the literature, such as the studies of Bhaskar et al. (2022) and Ozili (2022). In addition, there is a lack of empirical studies on CBDC as this concept is relatively novel (Ozili, 2022). For clarity, we divide the

literature review into *two* sections. *Firstly*, we review the background of CBDC. *Secondly*, we discuss the literature on the determinants of CBDC.

2.1 The background of CBDC

There is no doubt that financial innovation has rapidly grown in the last decade after the emergence of financial technology (Fintech). This intensive development has also significantly changed human behaviour in several aspects such as conducting financial transactions (Ashworth and Goodhart, 2020) and the improvement of financial inclusion (Allen et al., 2022). Cryptocurrency, known as a digital currency, which was launched by private initiatives such as Bitcoins, Dogecoin, Ethereum and Litecoin, has become increasingly popular from 2017 to 2021 (Ozili, 2022). However, the supply of cryptocurrency is relatively lower compared to its demand, which leads to inflated pricing of cryptocurrency and crypto-backed securities (Katsiampa et al., 2019). This results in high volatility, high risks and high levels of unreliability of cryptocurrencies (Ozili, 2022). Central banks, therefore, aim to issue CBDC as an alternative digital currency with lower risks and increased reliability when compared to other digital currencies in order to respond to the challenges of the cryptocurrency market.

CBDC is defined by the International Monetary Fund (IMF) as a widely accessible digital form of a country's fiat currency that could be a legal claim on the central bank. In other words, CBDC is known as a digital money supported and allocated by a central bank or a liability of issuing central banks (Atlantic Council, 2022; Chorzempa, 2021; Kiff et al., 2020). Moreover, a central bank can design a CBDC with the same characteristics with like-cash, bank deposits, and interest-bearing assets (Agur et al., 2022). Recently, CBDC has gained interest around the world, however, introducing CBDC is challenging in terms of the legal, technological, and political considerations (Chen and Siklos, 2022). Around 2016, several central banks started to research CBDC (Chorzempa, 2021). According to recent information

on CBDC issuances in December 2021 from the Atlantic Council (2022), eighty-seven countries, or over nighty percent, of global GDP are investigating in a CBDC. In addition, there are nine countries who have fully issued a CBDC, the last country to this being Nigeria with their e-Naira digital currency. Furthermore, fourteen countries, including China and South Korea, are in the pilot stage of preparing for fully issuing their CBDC. This indicates that CBDC has significantly developed and has become more concrete in its conception.

Comparing a CBDC against other (non-centralised) digital currencies, Nejad (2016) highlighted the difference between CBDC and traditional cryptocurrency. While cryptocurrency is stored in a decentralised control system on a blockchain network, CBDC is stored in a centralised control. This indicates that cryptocurrency cannot be controlled by a single authority, but a central bank who issues a CBDC asset can control CBDC, in line with legal regulations. Moreover, cryptocurrency relies on anonymous systems, which cannot be controlled by monetary policies and fiscal policies from government. In contrast, CBDC is a fiat liability of a central bank, and thus it can be used to settle payments or kept as a value asset (Söilen and Benhayoun, 2022).

Issuing CBDC could offer several benefits to the economy. Barrdear and Kumhof (2021) found that issuing CBDC in a proportion of around 30% of GDP, compared to government bonds, would lead to an increase of GDP by 3% because of a low level in real interest rates, distortionary taxes, and monetary transaction costs., CBDC can be considered as a second monetary policy instrument to support the stabilisation of the business cycle. In addition, the level of the bank's risk can be mitigated by specific arrangements of CBDC issuance. Williamson (2021) developed a new model to consider the level of panic arising within banks following the emergence of CBDC. The author found that even if a CBDC leads to an increased level of panic within banks, the benefits in financial transactions of CBDC are significant and potentially higher than physical currency. Therefore, this evidence can reduce

the harm felt within the financial industry resulting from a banking panic and also provide economic advantages for the wider society. Kwon et al., (2020) also built a dual currency model and argued that the issuing of an interested-bearing CBDC can mitigate an inefficiency of tax evasion in cash transactions and enhance social welfare, especially for tax payments. In addition, Lee et al. (2021) concluded that the adoption of CBDC provides several benefits, including increased financial integration, an improvement of efficiency and security in financial transactions, a reduction of the cost for cross-border payments, and an enhancement of financial inclusion. Furthermore, a CBDC can be managed anonymously, which results in ease of accessibility for the public and also allows it to be tracked and used in both online and offline transactions (Chuen and Teo, 2021). The interest-bearing feature of CBDC allows monetary policy to flow more rapidly (Garratt et al., 2022). In addition, Ding et al. (2022) found that low uncertainty on CBDC can increase the strength of the performance for manufacturing firms. Thus, it is quite clear that the issuance of CBDC offers several advantages to the economy.

On the other hand, the introduction of CBDC ameliorates the risks to financial systems and the economy. For instance, Kumhof and Noone (2021) constructed the core principles of a CBDC system. The authors claimed that if a CBDC is issued under these core principles and is appropriately introduced, the adverse effects on the size of the bank balance sheet or on the total individual credit, or total liquidity provision to the economy, dissipate. However, the residual risks still persist. For example, the required interest rate for CBDC may fall below zero during a crisis period, which is theoretical unacceptable. Moreover, the risks from having no eligible assets to convert into CBDC in the markets is likely to remain. Lee et al. (2021) claimed that the adoption of CBDC raises homogenous challenges and risks from a technological, economic, systematic, ethical and legal perspective, resulting in financial instability, inconsistency in technological standards and technical scalability problems, as well

as revealing gaps in legislation. Davoodalhosseini (2021) investigated the economic impact of introducing a CBDC and found that using a CBDC gains more benefit only the case that the cost of CBDC usage is inexpensive because of high costs of CBDC. Thus, if a CBDC issuer cannot facilitate these costs, issuing CBDC may negatively impact the economy. In addition, Alonso et al. (2020) posited that CBDC can lead to an increase in cybercrime and financial instability. Therefore, CBDC can damage the economy if CDBD is poorly introduced and unrigid in its systemic design.

It is also worth noting that while central banks are curious about CBDC, they remain apprehensive about how to adopt these digital assets. As argued in Allen et al. (2020), most CBDC projects envisioned over the last few years have tended to make use of governance frameworks that are authoritarian in nature. Such systems are typically highly centralised i.e., owned and controlled by one central authority. Nonetheless, there is little incentive for consumers to adopt CBDC as it requires a high level of public trust in governments and banking institutions. In addition, it is not easy to coordinate and achieve good performance in a huge system operated only by a single body. Therefore, while centralised ledgers might be desirable from a management perspective, they are not in demand from the perspective of robustness or public trust. On the other hand, there are blockchain ecosystems that allow CBDC to function in a totally decentralised and transparent manner. Such platforms can protect the privacy of its CBDC users, prevent monetary controls as well as transaction censorship, and demonstrate unprecedented robustness. However, decentralisation also implies a scenario whereby transaction mistakes or operator misbehaviour can occur since there is no central control over the system. Thus, technical, legal and regulatory questions must be answered before central banks are able decide how they would operate the distributed system.

It is clear that a CBDC can provide both benefits and drawbacks depending on the arrangement of several conditions and that appropriate answers are lacking, especially in

context of the effects of CBDC on financial, economic, and environmental stabilities (Elsayed and Nasir, 2022). Thus, it is remains inconclusive as to whether the introduction of CBDC is likely to be successfully adopted by the public as an alternative digital currency. While there is much interest in the adoption of CBDC around the world, including by central banks, commercial banks, private and state institutions and other related stakeholders, there are few empirical studies since this topic is comparably new (Ozili, 2022). In the study of Bhaskar et al. (2022), the authors provided a list of previous literature related to CBDC. The authors concluded that there are six out of eight reviews on the context of fintech, blockchain, and digital currency, while there are only two out of eight studies focused on the adoption, primary function, and comparative position of CBDC (Chu et al., 2022; Ozili, 2022). This indicates that there is still little evidence in previous literature on the adoption of CBDC. It is, therefore, advantageous to provide a further empirical study to shed light on the key determinants of CBDC.

2.2 The determinants for issuing CBDC

The key determinants for issuing CBDC to achieve optimum levels of adoption from the public is important to consider. Regarding the previous literature, there are few studies on this subject since it remains at the very early stages of development. In the context of Netherlands, van der Cruijsen, et al. (2021) used a representative panel of Dutch customers to examine the determinants of CBDC. The authors found that the customer's knowledge about CBDC, their trust in central banks, price incentives, privacy and security, and clear communication are the potential factors to enhance the customer acceptance of CBDC. Lee et al. (2021) considered the key factors for CBDC adoption using China's Digital Currency Electronic Payment (DCEP) as a case study due to the considerable success of its implementation. The authors concluded that there are three main categories and ten factors to achieve optimum adoption of CBDC. The three main categories are cited as an integrated and

supporting infrastructure, global cooperative standards, compliance and accessibility, and finally, inclusivity of storage and exchange. The ten enabling factors of integrated and supporting infrastructure include digital identification, data privacy protection and interoperable value transfer gateway. The main enabling factors of global cooperative standards, compliance and accessibility include ease of compliance, comprehensive data, and oracle ecosystem and open-source and trust distribution governance. The key enabling factors of accessibility, and inclusivity of storage and exchange, are digital literacy and user experience, strong security framework and fast and stable network. In addition to this, Tronnier (2021) claimed that an increase of privacy in payment for users is a main requirement for a central bank in order for it to successfully develop and install a CBDC.

Davoodalhosseini (2021) scrutinised the monetary policy in introducing a CDBC for the United States (US) and Canada via three scenarios where the currency is accessible to agents; only cash; only CBDC; and both cash and CBDC. The authors concluded that a key factor in successfully introducing a CBDC is the cost of using the CBDC. If a CBDC is not costly, then the implementation of CBDC has more potential than using psychical cash. However, the if using both cash and a CBDC, there is a lower likelihood for successfully issuing the CBDC. Garratt and Zhu (2021) claimed that the size of the bank is significant. A large bank offers a higher convenience to a customer and leads to an increase of their market power. Thus, the different size of banks can be a potential determinant of CBDC issuance. Söilen and Benhayoun (2022) investigated the key determinants related to the adoption of CBDC. Using 282 survey questionnaires, the results from their partial least squares structural equation modelling (PLS-SEM) and importance performance map analysis (IPMA) revealed that the key determinants for acceptance of CBDC by households is high performance expectancy, social recommendations and the presence of facilitating conditions. However, the confidence in the respective institution is a crucial moderator influencing CBDC household

adoption and above three determinants to build a flexible and understandable currency in the currency's system. Recently, Allen et al. (2022) reviewed the literature in the context of fintech, cryptocurrencies, stablecoins, and CBDC using China as a case study. The authors concluded that a key success factor of digital currency launch is widespread use of the virtual currencies by the public. Moreover, effectively designed cryptocurrency regulation works to enhance public trust in digital currencies.

As previously indicated, there are few studies investigating the determinants of CBDC, especially in terms of empirical studies. Some studies used only instances of successful issuance of CDBC or scenarios or modelling as case studies. For example, Bhaskar et al. (2022) used the bibliometric data of articles published on CBDC from the Scopus database over the period of 2018 to 2022. The authors received 174 final articles, which is relatively few compared to other topics. However, the authors found that there is an upward trend for article publication related to CBDC and this has been increasing from 2018, with 4 articles, to 2022, with 36 articles, and peaked in 2021 with 81 articles. To date, the potential determinants of taking an advance action to issue CBDC has been ignored and these issues represent significant gaps in the context of CBDC. This study aims to fill these gaps by investigating the determinants of taking advance action to issue a CBDC. The possible determinants employed in this study consist of demographic factors, economic factors, technical factors, and market factors.

2.3 Discussion on CBDC vs crypto vs fiat currencies

2.3.1 Debate on CBDC Vs crypto

In reality, central banks were spurred on to establish digital currencies with government support by the market's hasty maturation for cryptocurrencies. Additionally, Bitcoin, which is often brought up in discussions about digital currencies issued by central banks vs cryptocurrencies, has progressed well past its reputation as a bubble pump and dump strategy.

Since it invented cryptocurrencies, Bitcoin is being used in a wide variety of retail use cases. The most significant of all is that Bitcoin has found uses as an institutional hedge, demonstrating its importance in the contemporary financial environment.

Despite the fact that the maturity of cryptocurrencies is continuing to advance, central banks have seen a significant danger in Facebook's launch of Libra, their own cryptocurrency. Even with barely 5% global acceptance, central banks undoubtedly saw Bitcoin as a danger, despite the fact that there were no significant problems.

Therefore, comparing cryptocurrencies to digital currencies issued by central banks seems like a sensible idea for such institutions. The general public could also attempt to distinguish between the two recent innovations in a global financial ecosystem. The conceptual distinction between cryptocurrencies and CBDCs is what stands out the most in this analysis. The fundamental elements of CBDC essentially go counter to the principles of cryptocurrency. It's crucial to remember that Bitcoin was created to circumvent traditional central bank oversight. In reaction to the 2008 global financial crisis, Bitcoin demonstrated how cryptocurrencies may debase Federal Reserve monetary policy.

Thus, we can argue that cryptocurrencies concentrate on democratising financial institutions, CBDC strives to maintain the oligopoly of the international banking system.

2.3.2 Debate on CBDC Vs fiat

Any type of money that is not backed by a precious metal like silver or gold is referred to as a fiat currency. Currently, almost all kinds of money are fiat currencies like the US dollar, British pound, Japanese yen, etc. These "fiat" currencies may be printed or physically kept, such as in the form of coins or banknotes.

Moreover, CBDC is considered a ‘digital fiat currency’ that does not have a physical form, which is a key distinction between them and conventional types of fiat money. The

government, which is in charge of controlling the currency's regulation, creates fiat currencies as means of payment in both the physical and digital realms. However, digital fiat money offers a digital token or electronic record of the money of the nation that issued it.

3. Hypothesis development

We have developed hypotheses to consider the key factors driving the successful issuance of CBDC, including demographic factors, economic factors, technical factors, and market factors.

3.1 Demographic factors

Demographic factors may be a potential determinant of taking an advance action to issue CBDCs as different demographics reflect differently on financial inclusion. It is possible that demographics with high levels of financial exclusion, such as rural populations and younger age groups, may find it difficult to adopt new CBDC due to difficulties in accessing new technologies and financial services (Alonso et al., 2020). Ozili (2022) found that by improving levels of digital literacy in a demographically younger and older population, especially in rural areas, increased their ability to use the e-Naira, which is the CBDC issued in Nigeria. Thus, in relation to demographics, we hypothesise that:

H1.1: Rural population share has a negative impact on taking an advance action to issue the CBDCs.

H1.2: Young population share has a negative impact on taking an advance action to issue the CBDCs.

3.2 Economic factors

The previous literature has shown that CBDC can provide both advantages and disadvantages to the economy (i.e., Chuen and Teo (2021); Davoodalhosseini (2021); Lee et al. (2021); Garratt et al. (2022). This indicates that there is a relationship between CBDC and economy, and thus, it is likely that economic factors are key factors on taking an advance action

to launch the CBDC. In addition, Auer et al. (2020) found that the progress of CBDC projects, in terms of preparing to issue CBDC, is higher when the informal economy is larger. Lee et al. (2021) also found that an integrated and enabling infrastructure is the most important factor to ensure large-scale adoption of CBDC. Thus, we hypothesise that:

H2.1: GDP per capita has a positive impact on taking an advance action to issue CBDC.

H2.2: Gross capital formation has a positive impact on taking an advance action to issue CBDC.

H2.3: Foreign direct investments inflow has a positive impact on taking an advance action to issue CBDC.

H2.4: Money supply has a positive impact on taking an advance action to issue the CBDC.

3.3 Technical factors

CBDC is a digital currency which needs to use technologies to create or access it. Therefore, technological factors are key determinants for taking an advance action to launch CBDC. Allen et al. (2022) claimed that innovation in banking services initially depends on technological advances including a quicker internet, higher computing power and increasing capabilities for utilising big data. Söilen and Benhayoun (2021) suggested that trust and technological acceptance factors support increased adoption of CBDC. Thus, we hypothesise that:

H3.1: Electricity access has a positive impact on taking an advance action to issue the CBDC.

H3.2: Technology exports has a positive impact on taking an advance action to issue CBDC.

3.4 Market factors

Different markets may impact CBDC adoption differently, especially in the design of regulations to support the use of CBDC. Allen et al. (2022) found that effectively designed cryptocurrency regulations is a key success factors of digital currencies including CBDC. Bijlsma et al. (2021) and Tronnier (2021) also found that an increase in privacy and security is

are important determinants for customer acceptance of CBDC. Furthermore, Shen and Hou (2021) claimed that a fundamental success factor for CBDC is the existence of market competition. Thus, it is likely that market factors are related to taking an advance action to issue CBDC and we hypothesise that:

H4.1: Government effectiveness has a positive impact on taking an advance action to issue CBDC.

H4.2: Volume of trade in the service sectors has a positive impact on taking an advance action to issue CBDC.

4. Methodology

This section investigates the determinants of CBDC, in other words, what factors can increase or decrease the probability of a central bank taking an advanced action to issue the CBDC.

4.1 Data collection

In order to investigate the determinants of issuing CBDC, the dependent variable used for this study is a binary variable that takes the value 1 if the country was engaged in one of the advanced stages in issuing the CBDC or the value 0 if it did not. Data on the dependent variable was obtained from CBDC Tracker[1] and covers the period 2014-2021. The data includes information explaining the status of a country at the time of issuing the CBDC. These stages are as follows:

- Cancelled countries: Countries that cancelled or decommissioned a CBDC.
- Research countries: Countries that conducted the first explanatory CBDC research.
- Proof of concept countries: Countries are in an advanced research stage and published a CBDC proof of concept.

[1] Data on CBDC can be found at https://cbdctracker.org/

- Pilot countries: Countries that developed a CBDC that was tested in a real environment either with a limited number of parties or on a wide scale.
- Launched countries: Countries that officially fully launched a CBDC.

The advanced stage, which is defined as the outcome variable in this study, reveals that the country had reached the proof-of-concept stage, pilot stage, or the launching stage.

The selected independent variables were classified into 4 different groups:

4.1.1 Demographic factors:

The demographic characteristics may indicate the probability of issuing a CBDC. This study includes the rural population share of the total population and the share of youth as a percentage of the total population as well. Confidence in CBDC is positively and substantially highly connected with the percentage of the younger generation (Koziuk, 2021). Shree et al. (2021) argued that there is compelling evidence that elderly people are less inclined to use digital payment methods while purchasing online. Moreover, modern area residents are more likely to use online payment than in other areas.

4.1.2 Economic factors:

When it comes to those factors that might potentially affect the demand for CBDC, we find that CBDC projects are further along when there is a higher GDP per capita, financial development, and search interest (Auer et al.,2020)

Therefore, this study assumes that economic characteristics have an impact on issuing CBDC. These economic factors include: The GDP per capita is transformed into the logarithmic form in the model, which reflects the country's level of income. The gross capital formation imitates the development of the infrastructure in a country. The Foreign direct investment inflow reflects the health of an economy from an external perspective. In addition to the money supply.

4.1.3 Technical factors:

The technical factors represent the country's ability to develop technologies that serve any required structural changes to engage in CBDC. These factors include access to electricity, share of the population and high-technology exports. Advanced and emerging countries have almost the same access to electricity infrastructure, but the quality of electricity in emerging countries is lower. (Maryaningsih et al., 2022)

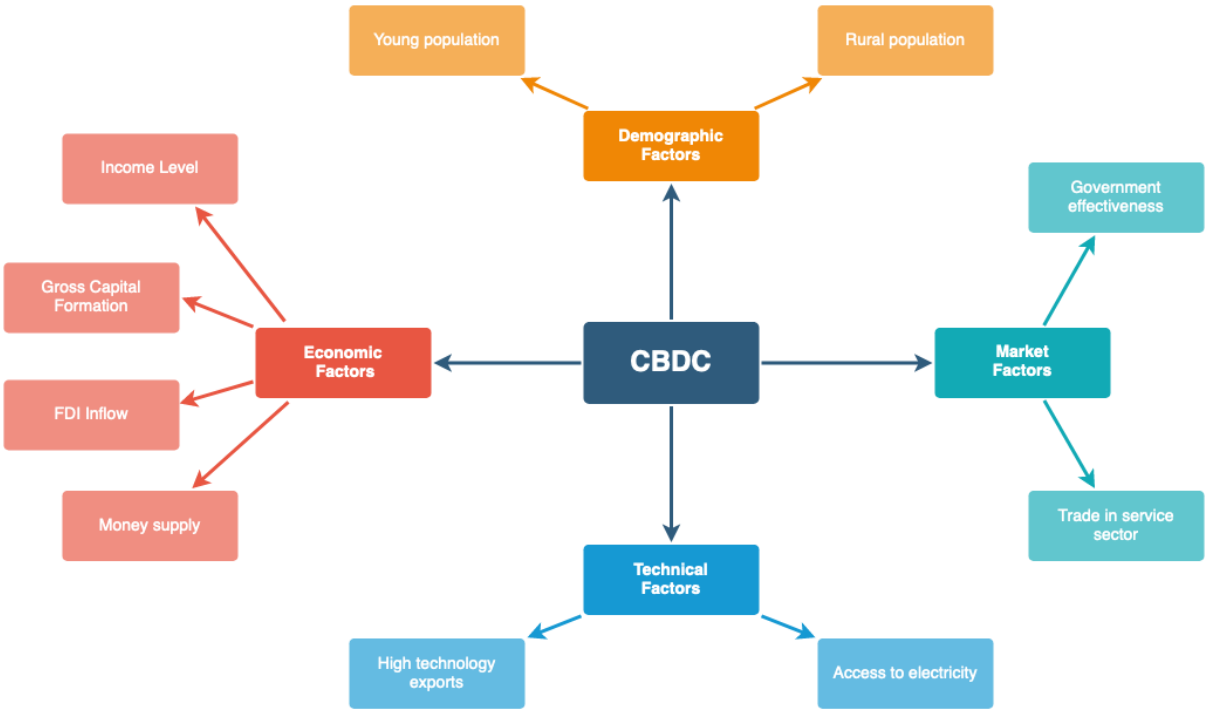
4.1.4 Market factors

Effective issuing of CBDC may require specific market factors. These factors can include government effectiveness and the volume of trade in the services sector. Countries with more effective governments are more likely to launch CBDC projects (Auer et al., 2020).

Data on the determinants of CBDC were obtained from the World Bank database, and cover the period 2013-2020. We intentionally collected data on the independent variables with an additional year prior to 2014 in order to enable models which test the endogeneity to run a regression with a one-year lag for the independent variables.

Based on the above-mentioned justification, the authors set out the following diagram showing the proposed determinants of CBDC.

Figure 1: Key determinants of issuing a CBDC



Source: Authors' work

4.2 The model

To fulfil the aim of the study, this article uses three approaches: linear regression models, probit models and logistic regression. The study starts the analysis by using the linear regression models (LRM) to determine what factors affect the probability of a country engaging in issuing a CBDC.

$$y_{it} = \alpha + \beta X_{it} + \varepsilon_t \quad (1)$$

In this equation, y is the outcome variable which is a binary variable that takes the value 1 if the country was engaged in one of the advanced stages in issuing the CBDC, or the value 0 if it did not, at time t and country i.

α : is the constant term.

X: is a set of determinants, with a coefficient β for each of them.

ε: is the error term.

Using the LRM has some disadvantages, including generating negative probabilities. Therefore, the study is going to use the probit and logit models.

The main purpose of logistic regression is to quantify the dependence of the outcome variable on the independent variable(s), the outcome variable is. However, the logistic regression does not use linear dependence. Observed data are interleaved by a logistic curve instead of the best fitting line (Klieštik et. al, 2015). The following formula describes the use of the logistic regression:

$$\pi = \frac{e^{\alpha+\beta X}}{1+e^{\alpha+\beta X}} = \frac{1}{1+e^{1(\alpha+\beta X)}} \quad (2)$$

Where

π is the probability of a country being engaged in one of the advanced stages (you should remind readers here what the advanced stages are) in issuing the CBDC.

The probit models are alternative to the logit approach. The principal difference is that the probit assumes a normal distribution of the random variables. The difference is summarised in the fact that the logistic function has harder "fat tails". Thus, there are no substantial differences in practice, only in the situation where the sample encompasses numerous observations with extreme values (Lehútová, 2011). The following formula represents the use of the probit regression:

$$\pi = \Theta(\alpha + \beta X)$$

In this formula, Θ is the cumulative density function for the standard normal.

5. Results

The analysis starts with the OLS regression; however, the OLS is not an efficient and reliable estimate to predict probabilities. Therefore, interpretation of the results focuses on the probit logit models.

The probit and logit models report similar levels of significance for each determinant. In Table 1, the magnitude is meaningless, nonetheless, the focus is on the direction and the

level of significance. Table 3 shows the CBDC determinants margins, setting out the effect of each determinant on the probability of being in an advanced stage in issuing a CBDC.

This paper starts the analysis without considering any impact for the endogeneity problem as shown in Table 3 models (1), (3), and (5). Results show that there is an inverse impact for the level of income on issuing a CBDC. When a country's GDP per capita increases by 1%, the probability of issuing a CBDC declines by 4.5% according to the probit estimation. Gross capital formation and money supply are other economic indicators that negatively affect the probability of issuing a CBDC. When the gross capital formation or the money supply increased by 1%, the probability of issuing a CBDC declined by less than 1%. Moreover, the structure of an economy can also impact the probability of issuing a CBDC, and it is noted that a service economy reduces the possibility of engaging in issuing the centralised digital currencies.

Results have not shown a significant impact for the development of infrastructure or the level of technological development on issuing the CBDC. Both the access to electricity and the use of the internet are insignificant. Technology exports have a very mild impact on CBDC. Nonetheless, demographic factors can play a significant impact, whereby an increase to the younger population of 1%, increases the probability of issuing a CBDC by less than 1%. Yet, the increase of the rural population decreases this probability by less than 1%.

The fourth dimension that can affect the probability of issuing CBDC is market factors. The model summarises these factors into the openness of the market to attract FDI, and government effectiveness. FDI increases the probability by less than 1%; however, when the government effectiveness index increases by 1 unit, the probability increases by 5%.

Table 1: Key determinants of issuing a CBDC

Variables	(1) Pooled OLS	(2) Pooled OLS with lags	(3) Probit	(4) Probit with lags	(5) Logit	(6) Logit with lags
Log (GDP capita)	-0.0186		-4.038***		-6.946***	
	(0.0121)		(1.459)		(2.665)	
Government effectiveness	0.00262		4.577**		7.975**	
	(0.0127)		(1.794)		(3.311)	
Rural population	-0.00162***	-0.00225***	-0.218***	-0.0450***	-0.390***	-0.119***
	(0.000406)	(0.000529)	(0.0792)	(0.0167)	(0.145)	(0.0454)
Access to electricity	0.000128		-0.0577		-0.105	
	(0.000355)		(0.0464)		(0.0847)	
Internet use	-0.000502		-0.0548		-0.103	
	(0.000486)		(0.0487)		(0.0918)	
Young population	0.00275**	0.00395**	0.634**	0.144**	1.111**	0.401***
	(0.00135)	(0.00177)	(0.271)	(0.0570)	(0.512)	(0.146)
Technology exports	0***		0***		6.57e-11***	
	(0)		(0)		(0)	
Trade in service sector	-0.000411		-0.138**		-0.248**	
	(0.000319)		(0.0640)		(0.116)	
Gross capital formation	-0.00235***		-0.712***		-1.244***	
	(0.000653)		(0.208)		(0.385)	
FDI inflow	0.000474		0.152**		0.269*	
	(0.000798)		(0.0725)		(0.142)	
M2	-0.000227*		-0.0564**		-0.0973*	
	(0.000135)		(0.0272)		(0.0501)	
Log (GDP capita)$_{t-1}$		-0.0281*		-0.996**		-2.478***
		(0.0158)		(0.434)		(0.948)
Government effectiveness $_{t-1}$		0.00811		1.160**		2.857**
		(0.0166)		(0.573)		(1.230)
Access to electricity $_{t-1}$		0.000132		0.0159		0.0105
		(0.000465)		(0.0288)		(0.0565)
Internet use $_{t-1}$		-0.000803		-0.0131		-0.0377
		(0.000636)		(0.0189)		(0.0390)
Technology exports$_{t-1}$		0***		0***		0***
		(0)		(0)		(0)
Trade in service sector $_{t-1}$		-0.000485		-0.0261**		-0.0698**
		(0.000418)		(0.0129)		(0.0305)
Gross capital formation $_{t-1}$		-0.00342***		-0.204***		-0.499***
		(0.000855)		(0.0489)		(0.118)
FDI inflow$_{t-1}$		3.60e-05		-0.0298		-0.0520
		(0.00104)		(0.0282)		(0.0615)
$M2_{t-1}$		-0.000113		-0.00470		-0.0145
		(0.000176)		(0.00403)		(0.00916)
Constant	0.156	0.231	22.14*	2.694	38.55	7.949
	(0.112)	(0.147)	(13.03)	(4.895)	(23.85)	(10.78)
Observations	630	630	630	630	630	630
R-squared	0.066	0.099				

Table 2: Predicted probabilities

Variables	Obs	Mean	Std.Dev.	Min	Max
Linear	630	.016	.032	-.085	.143
Linear with lags	630	.029	.053	-.145	.344
Probit	630	.015	.096	0	.972
Probit with lags	630	.029	.081	0	.625
Logit	630	.016	.097	0	.955
Logit with lags	630	.029	.096	0	.747

Table 3: CBDC determinants margins

Variables	(1) Pooled OLS	(2) Pooled OLS with lags	(3) Probit model	(4) Probit model with lags	(5) Logit model	(6) Logit model with lags
Log (GDP capita)	-0.0186		-.0458085***		-.0433941***	
	(0.0121)		(.0142936)		(.0144853)	
Government effectiveness	0.00262		.0519244***		.0498222***	
	(0.0127)		(.0180807)		(.0186136)	
Rural population	-0.00162***	-0.00225***	-.0024744***	-.001806**	-.0024355***	-0.002***
	(0.000406)	(0.000529)	(.0008059)	(0.00083)	(.00079)	(0.001)
Access to electricity	0.000128		-.0006549		-.000656	
	(0.000355)		(.0005186)		(.0005198)	
Internet use	-0.000502		-.0006216		-.0006447	
	(0.000486)		(.0005486)		(.0005698)	
Young population	0.00275**	0.00395**	.0071955**	.0057**	.0069413**	0.0074**
	(0.00135)	(0.00177)	(.0028306)	(0.0026)	(.003012)	(0.003)
Technology exports	0***		4.28e-13***		4.10e-13***	
	(0)		(1.05e-13)		(1.02e-13)	
Trade in service sector	-0.000411		-.0015645**		-.0015502**	
	(0.000319)		(.0006767)		(.0006755)	
Gross capital formation	-0.00235***		-.008078***		-.0077713***	
	(0.000653)		(.0018516)		(.001853)	
FDI inflow	0.000474		.0017259**		.0016827**	
	(0.000798)		(.0007638)		(.0008238)	
M2	-0.000227*		-.0006404**		-.0006078**	
	(0.000135)		(.0002867)		(.0002971)	
Log (GDP capita)$_{t-1}$		-0.0281*		-0.04**		-0.046***
		(0.0158)		(0.018)		(0.017)
Government effectiveness $_{t-1}$		0.00811		0.047**		0.053**
		(0.0166)		(0.023)		(0.023)
Access to electricity $_{t-1}$		0.000132		0.001		0.000
		(0.000465)		(0.001)		(0.001)
Internet use $_{t-1}$		-0.000803		-0.001		-0.001
		(0.000636)		(0.001)		(0.001)
Technology exports$_{t-1}$		0***		0***		0.000***
		(0)		(0)		(0.000)
Trade in service sector $_{t-1}$		-0.000485		-0.001**		-0.001**
		(0.000418)		(0.001)		(0.001)
Gross capital formation $_{t-1}$		-0.00342***		-0.008***		-0.009***
		(0.000855)		(0.002)		(0.002)
FDI inflow$_{t-1}$		3.60e-05		-0.001		-0.001
		(0.00104)		(0.001)		(0.001)
$M2_{t-1}$		-0.000113		0		-0.000
		(0.000176)		(0)		(0.000)

It is noted that the stated results above may suffer from endogeneity. Endogeneity bias has the potential to provide inconsistent estimates and inaccurate inferences, which might result in false findings and improper theoretical explanations. Such bias can occasionally even lead to the incorrect direction for coefficients (Ullah et al., 2018).

Endogeneity is said to occur in a multiple regression model if:

$$E(X_j u) \neq 0, for\ j = 1,2, \dots, k$$

A statistical guarantee that an endogeneity issue can be fully handled is impossible. To properly deal with endogeneity, researchers must first identify the causes of the issue and then take appropriate steps to lessen its harmful effects (Ketokivi and McIntosh, 2017). The endogeneity problem can arise from any or all of the omitted variables, measurement error, and/or simultaneity in simultaneous equations models. In this paper, we do believe that simultaneity exists as CBDC may have an effect on the economic and the market factors primarily, and also potentially the technical factors.

To mitigate the endogeneity problem, we propose including the independent variables with one lag year. This enables us to not expect an impact for the outcome variable on the independent variable. On all even models at Table 1 and Table 3, all independent variables are included with one lag year except the demographic factors, as there is no chance to be endogenous. The results of these models are consistent with the no lag models, the odd ones, which means endogeneity has a minimal impact on our results.

6. Discussion

This section analyses the discussion of the overall results. The discussion of our findings is divided into four key factors i.e., economic factors, market factors, demographic factors and technical factors.

6.1 Impact of economic factors

We have considered economic factors which could have a possible impact on CBDC, such as income level, gross capital formation, trade in the service sector and money supply. Our results indicate that the impact of economic factors on issuing a CBDC is negative. This is inconsistent with Auer et al. (2020) and Lee et al. (2021) who found that CBDC projects have significantly advanced when the informal economy is larger or when the integrated and enabling infrastructure is higher. However, this direction of the relationship is not misleading. Countries which have underdeveloped economies are the most engaged in these digital

currencies. Based on macroeconomic stability, Yao (2018) indicated that the growth of CBDC in China and other underdeveloped economies may have the advantage of money to become stable value and control the macroeconomic tools efficiently.

Moreover, the author also highlights that CBDC diminishes crime related to physical currency, and allows payment to flow transparently through the central bank. Kim and Kwon (2019), through a monetary general equilibrium model, also argued that implementation of CBDC brings financial stability.

6.2 Impact of market factors

Market factors have an influence on CBDC. We consider two key elements of market factors i.e., regulatory quality and FDI inflows. Our results indicate that market factors play an important role in issuing CBDC. Countries that have more organised and governed markets, and attract the FDI, have a better probability for successfully issuing CBDC. Didenko and Buckley (2021) highlighted that CBDC can provide a viable solution for financial inclusion issues in the pacific region. However, regulators must focus on developing expertise and knowledge towards CBDC and issue well designed CBDC. Lee et al. (2021) illustrated the importance of regulators for CBDC and argued that after implementing CBDC, there will be a requirement to constantly monitor existing regulations to support CBDC, and act on modifications of CBDC whenever international dynamics alter the CBDC. Allen et al. (2022) also claimed that an effective design in regulation for cryptocurrency is one of the potential determinants of digital currencies including CBDC. Moreover, Bijlsma et al. (2021) and Tronnier (2021) found that the customer's acceptance of CBDC can be increased when privacy and security are also increased. On the other hand, Rennie and Steele (2021) argued that present CBDC models consist of privacy risks that could cause losses such as loss of anonymity, loss of liberty, loss of individual control and loss of regulatory control.

6.3 Impact of demographic factors

Demographic factors have an important influence on CBDC. We have considered the young and rural demographics in our examination. Our results indicate that demographic factors do have an impact on issuing CBDC, and that a young population, as well as more urban societies, have a better chance of successfully issuing CBDC. However, it is essential to promote digital literacy among the older and younger demographic. According to Nanez et al.'s (2020) studies, the segment of population, particularly in the rural areas, do not completely know digital technologies and may find it challenging to recognise and fully understand digital currencies. Therefore, their lack of understanding will restrict them in their use of the digital currency to develop their welfare. In addition to this, the elderly population also may have mobility limitations (for e.g., difficulty in getting physical cash) or knowledge of how to manage digital applications. It is, therefore, important to launch an extensive digital literacy programme in rural areas to provide awareness among all segments of the population. This supports Ozili (2022), who found that improving digital literacy, for the young and older population, especially in rural areas, is required to increase access to CBDC. Another study, from Söilen and Benhayoun (2021), argued that acceptance of digital currency primarily depends on social recommendations. Therefore, peer pressure within demography also plays an important role in CBDC acceptance.

6.4 Impact of technical factors

We considered technical factors that may influence CBDC. Nevertheless, results did not show a significant impact for the technical factors. This is inconsistent with Allen et al. (2022) who stated that innovation in banking services initially depends on technological advances including a quicker internet, higher computing power and a larger capability for utilising big data. Moreover, our results are also different from Söilen and Benhayoun (2021), who argued that trust and technological acceptance factors increase the adoption of CBDC.

However, it is possible that while high technologies are exported by developed countries; basic technologies are accessible in most countries. Therefore, the impact is heterogeneous across countries. In addition, technology is not a measurable tool and high-level use of technology has negative environmental impact due to the higher demand for electricity. Therefore, it is a challenge to accurately measure electricity across different demographics.

7. Conclusion

The execution and investigation of various factors (for instance; economic, demographic, market, and technological factors) are increasingly dependent on CBDC. To fulfil this aim, our paper apply a linear regression model (LRM) to examine the effects of the major key factors on issuing a CBDC at the stage of Proof-of-Concept, Pilot, or Launching. In addition, probit and logistic regression are also employed to robust our results and overcome limitations of LRM. We have also extended our analysis to examine endogeneity issue. The results showed that economic factors negatively affect the probability of a central bank issuing a digital currency. However, urbanisation and a young population, which reflect the demographic factors, positively impact on the probability. The same result was obtained for the market factors. Nonetheless, the study found that the development of technology and infrastructure have no impact on the likelihood of issuing a CBDC.

Our results show a gateway to managers to be learned about CBDC. This provides as a reminder to policymakers that collaborative infrastructure design should be given priority in order to accommodate CBDC when they are implemented. Investigators are working very hard to figure out how CBDC relate to global commerce and other assets, including cryptocurrencies. Theoretical advancement, contextual coverage, and technique improvements are all very desirable. The development of CBDC might lead to the creation of a universal common currency, and they have significant consequences for financial and payment systems.

The CBDC may replace cash in the future. Therefore, we are proposing that future studies may investigate the likely effects of currency digitalization on the dominance of the US dollar and the British pound. The management of the global transaction system and its costs in a diverse ethical, technical, social, legal, economic, and political context should be on the other future plan. The CBDC should also investigate how CBDC will affect other digital currencies, how that will affect monetary policy, and how it will affect the money supply.

Moreover. policymakers should pay more attention in developing technical awareness and knowledge for elderly people; as well as the infrastructure in rural areas, if they are intending to issue CBDC.

Furthermore, countries which intend to issue a CBDC should set long-term plans to develop and stabilise the markets in order to attract investments and reflect a good image of the economy. Despite this, weak economies are likely to have a better probability of issuing digital currency. This leads us to recommend that a detailed review of the economic situation of the developing countries is implemented prior to issuing CBDC. It is not complicated to issue the CBDC; however, it is more challenging to protect and promote the new currency.

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Appendix

Table 4: Descriptive statistics

Variables	Obs.	Mean	Std. Dev.	Min	Max
Advance	1944	.026	.16	0	1
Launched	1728	.002	.042	0	1
Pilot	1728	.012	.11	0	1
Development	1728	.016	.124	0	1
Research	1728	.071	.257	0	1
Cancelled	1728	.015	.122	0	1
Log GDP capita	1632	8.758	1.44	5.601	12.11
Government effectiveness	1616	-.026	.99	-2.475	2.335
Rural population	1704	39.66	23.983	0	88.518
Access to electricity	1505	84.241	26.3	3.609	100
Internet use	2460	55.832	28.451	.99	100
Young population	2688	63.694	6.552	47.2	85.765
Technology exports	1227	1.67e+10	6.49e+10	0	7.58e+11
Trade in service sector	1436	29.094	32.473	2.855	297.158
Gross capital formation	1373	24.607	8.559	-.098	79.401
FDI inflow	1537	8.422	78.601	-1275.19	1709.766
M2	1205	65.801	49.166	11.449	452.548

Table 5: Matrix of correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Advance	1.000											
(2) Log GDP capita	0.032	1.000										
(3) Government effectiveness	0.008	0.871	1.000									
(4) Rural population	-0.116	-0.812	-0.664	1.000								
(5) Access to electricity	0.066	0.692	0.534	-0.591	1.000							
(6) Internet use	0.042	0.904	0.786	-0.795	0.742	1.000						
(7) Young population	0.064	0.651	0.513	-0.515	0.773	0.707	1.000					
(8) Technology exports	0.098	0.217	0.270	-0.137	0.145	0.160	0.207	1.000				
(9) Trade in service sector	-0.069	0.347	0.358	-0.198	0.247	0.314	0.387	-0.011	1.000			
(10) Gross capital formation	-0.104	-0.003	0.012	0.023	0.022	-0.023	0.164	0.191	0.078	1.000		
(11) FDI inflow	-0.016	0.052	0.137	-0.061	0.012	0.039	0.103	0.072	0.376	0.155	1.000	
(12) M2	0.017	0.484	0.538	-0.410	0.389	0.454	0.405	0.495	0.284	0.043	0.306	1.000