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Impact of Uncertainty on Central Bank Digital Currency (CBDC) Development at Different Country Income Levels[1]

Abstract. The drawbacks of cryptocurrencies have prompted central banks to explore central bank digital currencies (CBDCs) as a new means of payment. However, various uncertainties may hinder the optimal design and implementation of CBDCs. This study examines the impact of uncertainty on CBDC development across countries with different income levels. Using data from 92 countries spanning 2014 to 2021, the research employs Ordered Logit and Probit models to analyse categorized dependent variables reflecting CBDC development, followed by an Ordinary Least Squares (OLS) with fixed effects model as a robustness check. Subsample estimations are applied to assess the effects within high, middle, and low-income countries. The study finds that uncertainty significantly and negatively impacts CBDC development, with the effect being more pronounced in middle and low-income countries. This suggests that the underdeveloped interoperability of the financial system, along with insufficient infrastructure and digital literacy, are key factors delaying CBDC progress in these regions, particularly when uncertainty is high. Collaboration and information-sharing among central banks are crucial to reduce global uncertainty and share best practices. Central banks should also prioritize the development of transparent regulatory frameworks, enhance digital literacy, and implement targeted infrastructure development incentives. Future research should focus on identifying optimal CBDC designs tailored to each income level to overcome these obstacles and foster a more inclusive and resilient financial ecosystem.

Keywords: CBDC, Uncertainty, Central bank, Country income, Ordered Logit, Ordered Tobit

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ВЛИЯНИЕ НЕОПРЕДЕЛЕННОСТИ НА РАЗВИТИЕ ЦИФРОВОЙ ВАЛЮТЫ ЦЕНТРАЛЬНОГО БАНКА (CBDC) В СТРАНАХ С РАЗЛИЧНЫМ УРОВНЕМ ДОХОДОВ

Аннотация. В связи с выявлением существенных недостатков использования криптовалют центральные банки в качестве нового платежного средства рассматривают цифровую валюту центрального банка (CBDC). Однако препятствием для оптимального проектирования и внедрения CBDC могут стать различные факторы неопределенности. В данной статье рассматривается влияние неопределенности на развитие CBDC в странах с разным уровнем дохода. На основе данных из 92 стран за период с 2014 по 2021 г. в исследовании сначала используются упорядоченные логит- и пробит-модели для анализа категоризированных зависимых переменных, отражающих развитие CBDC, а затем — обычная модель наименьших квадратов (МНК) с фиксированными эффектами для проверки робастности. Оценка подвыборки применяется для изучения последствий развития CBDC в странах с высоким, средним и низким уровнем дохода. Показано, что неопределенность имеет существенное негативное влияние на развитие CBDC, причем эффект более выражен в странах со средним и низким уровнем дохода. Это говорит о том, что основными факторами, замедляющими развитие CBDC в этих регионах в условиях высокой неопределенности, являются недостаточно развитая функциональная совместимость финансовой системы, инфраструктура и цифровая грамотность. Исследование показало, что для решения этих проблем и обеспечения успешного внедрения CBDC при различных уровнях дохода необходима разработка индивидуальной политики. Сотрудничество и обмен информацией между центральными банками имеют решающее значение для снижения глобальной неопределенности и обмена передовым опытом. Центральным банкам также рекомендуется разработать прозрачную нормативно-правовую базу, повышать цифровую грамотность населения и внедрять целевые стимулы для развития инфраструктуры. Дальнейшие исследования в этой области должны быть направлены на определение оптимальных схем CBDC для каждого уровня дохода, чтобы преодолеть указанные препятствия и создать более инклюзивную и устойчивую финансовую экосистему.

Ключевые слова: CBDC, неопределенность, центральный банк, доход страны, упорядоченная логит-модель, упорядоченная пробит-модель

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Introduction

The use of cryptocurrency, also referred to as digital currency, has grown significantly since its creation by private companies, such as Bitcoin. However, cryptocurrency markets are often viewed as purely speculative. Some argue that the rapid price increases and extreme fluctuations of cryptocurrencies result from speculators' arbitrage practices and a lack of adequate supervision (Tong et al., 2022). Additionally, media hype further fuels speculative behaviour (Coulter, 2022). As the result, cryptocurrencies are highly volatile, risky, and unreliable.

Unlike traditional money, cryptocurrencies are unregulated, exist only in digital form, and are not backed by any government or central bank. Despite these concerns, the Covid-19 pandemic accelerated the adoption of digital, contactless, and alternative payment methods, reducing reliance on physical cash 1. In response to both the challenges posed by the cryptocurrency market and the shift toward digital payments, central

[1] Bank for International Settlements. (2021). Covid-19 accelerated the digitalisation of payments. Report. https://www.bis.org/statistics/payment_stats/commentary2112.htm (Date of access: 09.04.2024).

banks are moving toward issuing central bank digital currencies (CBDCs). Designed as a safer and more regulated alternative, CBDCs offer greater stability and reliability compared to privately issued digital currencies.

There may be several advantages to the economy from issuing CBDC. The ability of CBDC to offer a safe digital payment and remittance method is one of their main advantages (Lee et al., 2021). CBDC can be incorporated into current payment systems and used for online and offline transactions[1]. Additionally, CBDC can ease cross-border payments[2], which can be extremely difficult with conventional fiat money. Most central banks worldwide have already begun experimenting with CBDCs and their economic potential (Morales-Resendiz et al., 2021). The ability to provide financial inclusion for those who are presently unbanked or underbanked is another benefit of CBDC (Prodan et al., 2024). It could facilitate people's access to financial services and participation in the digital economy by offering a digital substitute for cash. People in developing countries who have limited access to traditional banking services may benefit the most from this.

The development of technological innovations, such as CBDCs, can be influenced by various factors. Innovators cannot accurately assess the risks and opportunities associated with investing in new technologies without economic certainty (Marcus, 1981). This applies to CBDCs as well, as their issuance naturally raises legal questions (Bossu et al., 2020), which are closely tied to the stability of government policies.

While economic uncertainty can have negative consequences, it may also create opportunities for technological advancement (Subramaniam & Loganathan, 2022). Previous studies suggest that technological innovation can help reduce uncertainty across countries. However, whether uncertainty itself can drive innovation remains unclear. Overall, uncertainty appears to have a bidirectional effect on technological innovation, and CBDCs are no exception.

Despite the fact that the issuance of CBDC is receiving considerable attention on a global scale, there are few empirical studies due to the novelty of its concept. Additionally, the majority of earlier studies only focused on the simulated impact on economy (Assenmacher et al., 2023; Barrdear & Kumhof, 2022; Izzulhaq et al., 2024), lesson learned (Morales-Resendiz et al., 2021; Sarmiento, 2022), and design concept (Agur et al., 2021; Koziuk & Ivashuk, 2022; Prayudya & Al-Ayubi, 2023; Zams et al., 2020), but omitting the potential factors that influence the CBDC issuance. To the best of our knowledge, few studies have analysed the determinants of CBDC issuance, such as Maryaningsih et al. (2022) and Alfar et al. (2023). Nevertheless, the uncertainty component of the model has not yet been applied by them.

Given these gaps, this study examines the impact of uncertainty and other influencing factors on CBDC development. To enhance understanding, the analysis is conducted across several subsamples based on the World Bank's country income classifications. This approach helps identify patterns and key insights, contributing to a better understanding of global economic dynamics and supporting informed international policy decisions.

In summary, this study found that uncertainty and other factors influence CBDC development in different ways. For robustness, the results remain consistent across Logit, Probit, and linear regression models. Additionally, compared to high-income countries, uncertainty has a significantly stronger negative impact on CBDC development in middle – and low-income countries.

The remainder of the paper is structured as follows. The second section reviews relevant literature and outlines the hypothesis construction. The third section describes the data and methods used in this study. The fourth section presents the estimation results and discussion. Finally, the fifth section provides the conclusion, followed by policy implications and recommendations.

Theoretical Framework and Literature Review

Uncertainty: Does it Promote or Discourage Innovation?

Uncertainty can have several adverse effects, including a decline in research, development, and investment. In periods of high uncertainty, spending decreases as individuals and businesses anticipate potential instability, leading to reduced demand and production. As a result, both public and private sectors experience significant revenue losses, limiting funding for R&D investments. Additionally, uncertainty can lead to misguided planning decisions, further hindering innovation. To maintain stability, stakeholders often adopt a wait-and-see approach, which also applies to CBDC development (J. Wu et al., 2020). Previous studies show a negative relationship between uncertainty and R&D, with uncertainty reducing

[1] Bank for International Settlements. (2021). BIS Annual Economic Report. https://www.bis.org/publ/arpdf/ar2021e.htm (Date of access: 09.04.2024).

[2] id.

research, development, international trade, corporate confidence, and economic growth (B. Wang et al., 2023). Lin et al. (2021) found that uncertainty significantly affects R&D investment, patent applications, and R&D employment, though the latter was not statistically significant. Bloom (2007) noted that increased uncertainty results in a "caution effect," making R&D less responsive to business conditions.

Conversely, some argue that uncertainty can positively impact R&D. Instead of hindering progress, uncertainty can motivate innovation to address emerging issues (Subramaniam & Loganathan, 2022). In periods of uncertainty, firms may see opportunities to gain a competitive edge while competitors "play safe" (Kulatilaka & Perotti, 1998). Ross et al. (2018) suggest that uncertainty might increase R&D investment as firms seek to build competitive advantages and gather valuable information. He et al. (2020) found a positive correlation between uncertainty and corporate innovation, especially in state-owned firms with limited cash flow and budget constraints. Similarly, C. He et al. (2022) discovered that uncertainty positively impacts innovation in industries with lower budget constraints. Feng & Zheng (2022) found that uncertainty boosts innovation in renewable energy, with faster growth in OECD members and right-wing countries compared to non-OECD and left-wing nations.

Ultimately, the impact of uncertainty on R&D depends on a nation's approach. Optimistic nations foster innovation as a means of navigating uncertainty, whereas risk-averse nations tend to delay investment until economic stability is achieved.

CBDC Overview

CBDCs are digital currencies issued by central banks. Replacing cash with CBDCs affects various aspects of the economy and society. Functioning like digital money and bank deposits, CBDCs can potentially offer interest (Agur et al., 2021), allowing central banks to exercise more precise control over the money supply and potentially enhancing economic stability. Additionally, CBDCs can incorporate managed anonymity, where transactions remain private unless they exceed a certain threshold, striking a balance between privacy and anti-money laundering and counter-terrorism measures (Soana & de Arruda, 2024)and within the new reality of digital finance, a fully digitised public currency seems to be a natural step. To this end, central banks have been testing the possibility to issue a digital form of the traditional fiat currency (so-called Central Bank Digital Currency-CBDC. Society also benefits from CBDCs through increased financial inclusion, as they expand access to financial services for unbanked and underbanked populations by making transactions more accessible, affordable, and user-friendly (Banerjee & Sinha, 2023).

However, CBDCs also pose several risks. They cannot implement negative interest rates during crises and may lack sufficient marketable assets for conversion (Alfar et al., 2023). Furthermore, technological, economic, ethical, and legal challenges include financial instability, inconsistent regulatory standards, scalability issues, and legislative gaps (Lee et al., 2021). High implementation costs could strain economies, increase cybercrime risks, and, if mismanaged, contribute to financial instability. In extreme cases, disintermediation may occur if individuals shift their deposits from commercial banks to CBDCs, reducing banks' lending capacity and potentially disrupting their business models (Wenker, 2022).

Examples of CBDC projects across different countries highlight diverse motivations and objectives. For instance, Switzerland's Project Jura explores the direct transfer of euro – and Swiss franc-denominated wholesale central bank digital currencies (wCBDCs) between French and Swiss commercial banks using a distributed ledger technology (DLT) platform. This initiative aims to facilitate the efficient and secure settlement of tokenized asset and foreign exchange trades[1]. Jura addresses policy issues related to wCBDC issuance on third-party platforms and aims to complement G20 efforts to improve cross-border payments. Similarly, the People's Bank of China (PBOC) launched the e-CNY to diversify cash forms available to the public, enhancing transaction convenience and efficiency, and supporting financial inclusion by providing a state-backed digital payment option[2]. In Ghana, the eCedi project aims to digitize the economy, foster financial inclusion, enhance digital payment adoption, and position the Bank of Ghana as a progressive regulator[3]. The eCedi seeks to create a secure, efficient, and resilient payment

[1] Swiss National Bank. (2021). Project Jura: Cross-border settlement using wholesale CBDC. Collaboration with BIS and Banque de France. https://www.bis.org/publ/othp44.pdf (Date of access: 02.07.2024).

[2] People's Bank of China. (2021). Progress of Research and Development of e-CNY in China. http://www.pbc.gov.cn/en/3688110/3688172/4157443/4293696/2021071614584691871.pdf (Date of access: 02.07.2024).

[3] Bank of Ghana. (2022). Design paper of the digital Cedi (eCedi). Report. https://www.bog.gov.gh/wp-content/uploads/2022/03/eCedi-Design-Paper.pdf (Date of access: 02.07.2024)

system capable of operating offline, reducing cash reliance, and improving cashless transactions. It also aims to mitigate risks posed by unregulated privately issued digital currencies by offering a stable, central bank-backed digital currency.

Nevertheless, despite these pros and cons, as well as varying national objectives, CBDC adoption should align with each country's capabilities and needs. It must ensure interoperability, support rather than undermine monetary policy, and remain reliable and resilient[1].

Determinants of CBDC Issuance

Although central banks agree on the future potential of CBDCs, different nations have adopted them in varying ways. This discrepancy raises the question of what factors influence global CBDC adoption. Key drivers of CBDC issuance include demographic, macroeconomic, infrastructure, and innovation-related variables.

Since different demographics have varying perspectives on financial inclusion, demographic factors may play a key role in determining whether a nation takes early action to issue a CBDC. Populations with a younger demographic may find it easier to adopt CBDCs due to their greater exposure to new technologies, social media, and gadgets, which can help overcome access barriers to financial services (Mason et al., 2022). The same goes with urban population, they have a better chance of technology adaptation due to the accessibility of technology in the urban area. Moreover, rapid urbanization also contributes to the larger future transaction volume, which motivates the central bank to issue CBDC (Xu, 2022).

Turning to economic conditions, such as macroeconomics and financial development, several studies have shown how they influence CBDC issuance. Financial development fosters capital accumulation and technological progress by increasing the savings rate, mobilizing and pooling savings, providing investment information, encouraging foreign capital inflows, and optimizing capital allocation (Abbas et al., 2022). These conditions create a suitable environment for innovation, thus driving CBDC issuance. Similarly, economic growth and accumulating foreign direct investment (FDI) also enable infrastructure to develop and drive innovation further (Ali et al., 2023).

The role of infrastructure is also critical. Unlike physical cash, which is reliable for almost every situation, CBDC may be constrained by the availability of electricity coverage (Inder, 2024). Feasible CBDC also requires adequate internet coverage and cellular phone usage to fully unleash its potential (Islam et al., 2019) Even though there is a possibility to build offline CBDC, several limitations could impair the ability to combat money laundering and terrorism financing (Soana & de Arruda, 2024).

Last but not least, R&D plays a crucial role in technology development. It involves the accumulation of scientific knowledge that drives the development of concepts, typologies, frameworks, methods, techniques, or data, enabling the discovery of new phenomena (Bird, 2007). Given these arguments, research and development are essential for innovation, and CBDC is no exception. Furthermore, CBDC initiatives are more likely to occur in nations with strong innovation capabilities.

Data and Methods

To investigate the factors influencing CBDC issuance, this study analyses data from 92 countries worldwide between 2014 and 2021. The variables used are an extension of those explored in previous literature (Alfar et al., 2023; Maryaningsih et al., 2022) by incorporating uncertainty factors. These nations are filtered due to the existence of their CBDC development. CBDC development information is collected from Atlatis Council, particularly https://cbdctracker.org/, and converted into dummy variables. These variables, which are 0, 1, 2, 3, and 4, represent cancelled, research, proof of concept, pilot, and launching stages, respectively. Since this study focuses on how uncertainty affects CBDC issuance, this sample did not distinguish between retail and wholesale CBDC. As a reminder, numerous studies found that innovation will be influenced by uncertainty regardless of its form (Bloom, 2007; Lin et al., 2021; B. Wang et al., 2023; Y. Wu, 2020).

This study performs several subsample estimations by analysing high, middle, and low-income country subsamples. This approach allows for the identification of patterns within each income group, providing deeper insights into the influencing factors. Additionally, the subsample analysis serves as a robustness check across different income levels. The low-income subsample includes both low-income and lower-middle-income countries due to limited data

[1] Bank for International Settlements. (2020). Central bank digital currencies: foundational principles and core features. Joint report by The Bank of Canada, European Central Bank, Bank of Japan, Sveriges Riksbank, Swiss National Bank, Bank of England, Board of Governors of the Federal Reserve and Bank for International Settlements. https://www.bis.org/publ/othp33.htm (Date of access: 15.06.2024).

Table 1

Variable Descriptions

Variable	Description	Data Origin	Expected Sign
Dependent Variable:			
CBDC development	A dummy variable that illustrates CBDC development. None/ cancelled, research, proof of concept, and launching stage are described by 0, 1, 2, 3, 4, respectively	CBDC Tracker by Atlantic Council	
Independent Variable:			
ln WUI	Natural logarithm of World Uncertainty Index (WUI)	Ahir et al. (2022)	Negative
Country Control:			
ln GDP per Capita	Natural logarithm of GDP per capita	World Bank	Positive
FDI inflow	Foreign direct investment equity inflows in current USD	World Bank	Positive
Infrastructure Control:			
Electricity access	Percentage of population with access to electricity	World Bank	Positive
Internet coverage	Fixed subscriptions to high-speed access to the public Internet (a TCP/IP connection), at downstream speeds equal to, or greater than, 256 kbit/s	World Bank	Positive
Cellphone usage	Subscription to a public mobile telephone service that provide access to the PSTN using cellular technology	World Bank	Positive
Demographic Control:			
Urban population	People living in urban areas as a percentage of the total population	World Bank	Positive
Young population	Population between the ages 0 to 14 as a percentage of the total population	World Bank	Positive

availability. Despite this combination, their economic structures are generally similar[1].

For the baseline model, the dependent variable, Y_{it}, is a categorized variable representing CBDC development of each nation i in the given time t. The remainder is an intercept, independent variables affecting CBDC issuance, and error term. Each of them is denoted in $\propto$, βX and ε, respectively.

$$Y_{it} = \propto + \beta X_{it} + \varepsilon_t \qquad (3.1)$$

This study uses a linear regression approach, followed by logistic regression, to capture what factors influence central banks to issue CBDC. Since the linear regression approach creates negative probabilities, logistic regression is used subsequently (Alfar et al., 2023). Instead of the best-fitting line, observed data are connected by a logistic curve (Klieštik et al., 2015). The formula can be written as follows[2]:

$$\rho = \frac{e^{\alpha+\beta X}}{1+e^{\alpha+\beta X}} \qquad (3.2)$$

[1] Dabla-Norris et al. (2015). Causes and Consequences of Income Inequality: A Global Perspective. IMF Staff Discussion Note. https://www.imf.org/external/pubs/ft/sdn/2015/sdn1513.pdf (Date of access: 02.07. 2024).

[2] Brannick, M. (2020). Logistic Regression. University of South Florida. http://faculty.cas.usf.edu/mbrannick/regression/Logistic.html (Date of access: 09.04.2024).

The probability is denoted in ρ, while *e* represents the base natural logarithm. The value of ∝ yields ρ when *X* is zero.β adjusts how quickly the probability changes with changing *X* a single unit. Due to the nonlinear relation between *X* and ρ, β does not have a straightforward interpertation in this model as it does in linear regression.

However, since CBDC development involves more than two stages, an ordered regression model, also known as an ordinal regression model, will be used. This model extends the logistic regression framework,whichistypicallyappliedtodichotomous dependent variables, by allowing for more than two ordered response categories (McCullagh, 1980). The method begins with tabulating the dependent variables where i=1 denoted as the minimum value, *i*=2 for the next value, and so on for determined *k* categories. Meanwhile, k_0 and k_k denote–∞ and +∞, respectively[1].

For ordered Logit, the probability is captured with:

$$p_{ij} = \Pr\left(y_j = i\right) = \Pr\left(k_{i-1} < x_j\beta + u \le k_i\right) = \\ = \frac{1}{1+\exp\left(-k_i + x_j\beta\right)} - \frac{1}{1+\exp\left(-k_{i-1} + x_j\beta\right)} \quad (3.3)$$

meanwhile, for ordered Probit:

$$p_{ij} = \Pr\left(y_j = i\right) = \Pr\left(k_{i-1} < x_j\beta + u \le k_i\right) = \\ = \phi\left(k_i - x_j\beta\right) - \phi\left(k_{i-1} - x_j\beta\right) \quad (3.4)$$

where ϕ denotes the distribution function of normal cumulative. Log-likelihood in this model will be obtained from this model where w_j is an optional weight:

$$lnL = \sum_{j=1}^{N} w_j \sum_{i=1}^{k} I_i\left(y_j\right)$$

$$I_i\left(y_j\right) = \begin{cases} 1, if\ y_j = i \\ 0, otherwise \end{cases} \quad (3.5)$$

Results and Discussion

As a preliminary step, given the focus on probability, Logit and Probit models are presented first. Additionally, an OLS fixed effects (FE) estimation is conducted to assess the consistency of the results. The analysis begins with full-sample estimations.

From Table 2 above, our result shows a negative relationship between uncertainty and CBDC issuance probability. Central banks are typically risk-averse institutions (van der Ploeg, 2009) and are cautious when introducing new forms of currency. Uncertainty can heighten perceived risks, making central banks more hesitant to implement CBDCs due to concerns about potential negative impacts on financial stability and the broader economy. As a result, central banks may prioritize other policy areas over CBDC development. Limited resources for experimental "trial-and-error" further challenge the feasibility of CBDC implementation. Additionally, introducing a new digital currency could disrupt existing financial systems, adding to central banks' reluctance (Y. Wang et al., 2022).

Macroeconomic conditions influence CBDC development. The negative relationship between GDP per capita and CBDC development suggests that less developed economies are more inclined to pursue CBDC initiatives than developed ones. These economies often struggle with financial inclusion and high transaction costs within their financial systems. A significant portion of the unbanked population is also concentrated in less developed countries. By reducing intermediaries and enhancing transparency and security through blockchain technology, CBDCs can help lower transaction costs. Additionally, technologies such as near-field communication (NFC), quick response (QR) codes, and Bluetooth enable offline CBDC transactions, making them a viable solution for countries with less developed communication infrastructure (Chu et al., 2022). In this context, the introduction of CBDCs presents an opportunity to address financial challenges in less developed countries. Similarly, Alfar et al. (2023) found that countries with lower GDP per capita are more likely to develop CBDCs.

Although small in magnitude, an increase in FDI is associated with greater CBDC development. This finding aligns with Alfar et al. (2023) who suggest that countries with more regulated and organized markets attracting foreign direct investment are more likely to issue CBDCs. FDI inflows can enhance overall economic activity and provide the necessary funding to support CBDC development and its associated infrastructure. However, both have distinct objectives as CBDC focuses on the financial system (Luu et al., 2023), while FDI is driven by the prospect of the host country such as investment opportunities and profit (Islam & Beloucif, 2023). To that end, the effects provided by FDI are not felt directly, which explains why it has a small magnitude.

[1] Long, J., & Freese, J. (2014). Regression Models for Categorical Dependent Variables Using Stata (3rd ed.). STATA Press. https://www.stata-press.com/books/regression-models-categorical-dependent-variables/ (Date of access: 15.06.2024).

Table 2

Full Sample Estimation

	Logit	Probit	OLS FE
ln WUI	−0.828***	−0.468***	−0.146**
	(0.282)	(0.159)	(0.06)
ln GDP per capita	−4.058***	−2.022***	−1.087***
	(1.115)	(0.597)	(0.319)
FDI inflows	$9.84 \cdot 10^{-13}$	$5.88 \cdot 10^{-13}$	$6.05 \cdot 10^{-13}$
	$(2.95 \cdot 10^{-12})$	$(1.65 \cdot 10^{-12})$	$(7.17 \cdot 10^{-13})$
Electricity access	0.1***	0.05***	−0.005
	(0.033)	(0.018)	(0.007)
Internet coverage	0.361***	0.178***	0.09***
	(0.073)	(0.039)	(0.01)
Cellphone usage	0.001	0.001	−0.001
	(0.007)	(0.004)	(0.002)
Urban population	0.048	0.025	0.124***
	(0.029)	(0.015)	(0.027)
Young population	0.049	0.022	−0.154***
	(0.084)	(0.043)	(0.031)
Constant			7.787**
			(3.483)
/cut1	−24.52027	−12.7033	
/cut2	−22.14142	−11.3889	
/cut3	−20.81351	−10.6755	
/cut4	−17.79807	−9.24075	
Log-likelihood	−498.37745	−499.38912	
R-Squared			0.309
McFadden R-squared	0.086	0.081	
Obs	728	728	728
Using *z*-statistic (*t*-statistic for OLS), *, **, and *** represent significance at 10, 5, and 1 percent level, respectively. Standard errors are presented in parentheses. For Logit and Probit, /cut 1 is the estimated cut point of latent variable used to differentiate cancelled CBDC development from research, proof of concept, pilot, and deployed CBDC development. The same goes with /cut 2, it differentiates research CBDC development from proof of concept, pilot, and deployed CBDC development. /cut 3 differentiates proof of concept CBDC development from pilot and deployed CBDC. Lastly, /cut 4 differentiates pilot from deployed CBDC development.			

Source: Authors' calculations

The significant positive relationship with electricity indicates that a reliable and widespread electrical infrastructure is essential for the successful implementation of CBDC. Access to electricity ensures the functionality of digital devices and financial services, which is crucial for individuals and businesses to adopt CBDC. Investments in digital infrastructure—such as broadband connectivity, mobile network coverage, and electrical systems—would further support CBDC accessibility, particularly in underserved areas (Lannquist & Tan, 2023). Increased adoption of CBDC can be attributed to increased accessibility and use of digital currency services by many individuals and businesses with

high internet coverage. Thus, broader internet coverage motivates central bank to develop CBDC. Although insignificant, these arguments also explain the positive effect of internet coverage on the CBDC development probability.

Regarding cellphone usage, user adoption plays a crucial role, as evidenced by the positive relationship between cellphone usage and CBDC development in our estimation. Mobile devices provide users with convenient access to their CBDC accounts, increasing familiarity and encouraging adoption. Widespread cellphone usage ensures that a large segment of the population can access CBDC, promoting participation in digital finance.

To analyse the impact of demographics on CBDC development, this study distinguishes between urban and young populations, both of which show a positive relationship with CBDC adoption. Urban areas tend to have larger populations and higher economic activity than rural regions, making them key drivers of digital currency adoption. Additionally, urban residents typically possess higher levels of technological and digital literacy, facilitating the transition to digital financial services. Similarly, younger populations are generally more tech-savvy, enabling them to adapt more easily to new technologies, including CBDC (Mason et al., 2022). This demographic is more open to innovations and can readily adopt CBDC.

The subsequent estimation, presented in Table 3, focuses on high-income countries. Compared to the full sample, the results for high-income countries show different outcomes for certain variables.

Despite the same outcome that uncertainty is associated with reducing CBDC issuance probability, higher-income countries have lower magnitude. The political and economic landscapes of high-income countries are frequently more stable (Dalgaard & Olsson, 2013), which supports

Table 3

High-Income Countries Estimation

	Logit	Probit	OLS FE
ln WUI	–0.685*	–0.409*	–0.077
	(0.424)	(0.244)	(0.118)
ln GDP per capita	–5.104**	–3.43***	–0.84
	(2.002)	(1.274)	(0.501)
FDI inflows	$-1.38 \cdot 10^{-13}$	$-7.28 \cdot 10^{-15}$	$8.4 \cdot 10^{-14}$
	$(3.11 \cdot 10^{-12})$	$1.82 \cdot 10^{-12}$	$8.9 \cdot 10^{-13}$
Electricity access	5.98	2.731	1.61
	(4.934)	(3.002)	(1.169)
Internet coverage	0.3***	0.186***	0.057
	(0.1)	(0.06)	(0.016)
Cellphone usage	–0.011	–0.008	0.002
	(0.01)	(0.006)	(0.003)
Urban population	0.176**	0.117**	0.425
	(0.083)	(0.056)	(0.083)
Young population	–0.267	–0.265	–0.51
	(0.324)	(0.242)	(0.065)
Constant			–178.567
			(117.548)
/cut1	555.263	242.912	
/cut2	557.73	244.381	
/cut3	558.732	244.958	
/cut4	561.759	246.542	
Log-likelihood	–224.115	–223.926	
R-Squared			0.423
McFadden R-squared	0.096	0.096	
Obs	264	264	264

Using *z*-statistic (t-statistic for OLS), *, **, and *** represent significance at 10, 5, and 1 percent level, respectively. Standard errors are presented in parentheses. For Logit and Probit, /cut 1 is the estimated cut point of latent variable used to differentiate cancelled CBDC development from research, proof of concept, pilot, and deployed CBDC development. The same goes with /cut 2, it differentiates research CBDC development from proof of concept, pilot, and deployed CBDC development. /cut 3 differentiates proof of concept CBDC development from pilot and deployed CBDC. Lastly, /cut 4 differentiates pilot from deployed CBDC development.

Source: Authors' calculations

the smooth operation of the financial system. This stability may lessen the perceived risks connected to the development of CBDC. Furthermore, these nations usually possess greater financial and human resources (Corral et al., 2021), which can be used to address the difficulties and uncertainties associated with implementing the CBDC.

GDP per capita in high-income countries shows the same result as in the full sample, reinforcing the argument that the features offered by CBDC provide greater motivation for underdeveloped countries. However, a negative relationship was found for FDI, as high-income countries often have well-established and sophisticated financial systems. This explains why high-income countries might have higher saturation levels (Qiu & Tao, 2001), which would reduce room for new investment growth, with no exception to CBDC development. On the other hand, countries with lesser income might have unexplored markets and industries with greater room for expansion, drawing in investors with the promise of larger profits.

The remaining variables—electricity, internet, and phone usage as infrastructural factors, and demographic aspects (excluding the young population)—show the same signs as in the full sample. However, electricity stands out due to a significantly different magnitude. In high-income countries, electricity has a greater impact on CBDC development compared to the full sample, likely due to the more reliable and advanced electrical grids that support cutting-edge infrastructure. Regarding the young population, research shows that higher-income countries tend to have lower birth rates (Jain & Ross, 2012). In high-income countries, larger families may not always take precedence over personal goals, leisure time, and career advancement. Additionally, the cost of living tends to be higher in wealthier countries. As a result, despite the potential benefits of CBDC adoption, it shows a negative association with CBDC development. However, these results are not statistically significant at any given level.

In middle-income countries (as shown in Table 4), uncertainty consistently reduces the probability of CBDC development. However, the impact is greater than in previous estimations, whether in the full sample or high-income countries. Middle-income economies may be more vulnerable to volatility and external shocks (Meyer, 2020), and economic dynamics such as fluctuations in exchange or inflation rates can significantly affect research and development. In contrast, high-income nations are less susceptible to economic uncertainties due to their more diversified and stable economies. Overall, central banks in middle-income countries are more sensitive to uncertainty in CBDC development than those in high-income countries.

The effects of GDP are consistent with previous estimations, with only a small difference in magnitude for middle-income countries. Regarding FDI, despite small magnitudes, it positively affects CBDC development. Middle-income countries often find themselves in a transitional phase of economic development, seeking foreign expertise and capital to support their economic growth and infrastructure expansion.

The remaining variables, including infrastructure and demographics, share similar signs with the full sample estimation, with only slight differences in magnitude for middle-income countries. Middle-income nations may be actively pursuing digital transformation projects at this stage. Electricity, internet, and mobile coverage collectively enable the adoption of digital technologies, supporting industries like fintech and, in this case, CBDC, which contribute to economic growth. Regarding the demographic aspect, similar rationales apply: urban and young populations are generally more technologically adept and comfortable using digital platforms, which increases the likelihood of CBDC adoption (Mason et al., 2022).

The last subsample estimation, shown in Table 5, focuses on low-income countries. When considering how uncertainty affects CBDC development, we can see that its magnitude is significantly higher than in high-income countries but closer to middle-income countries. This aligns with the fact that low-income countries, being less developed than high-income ones, are more vulnerable to economic shocks (Meyer, 2020).

Similar to the full sample and middle-income countries, GDP per capita and FDI exhibit negative and positive relationships with CBDC development, respectively. Infrastructural and demographic factors also show consistent signs, with slight variations in magnitude. While the significance levels may differ, the significant results are observed within the same variables.

Concluding Remarks

Conclusion

This study investigates the factors influencing the development of Central Bank Digital Currencies (CBDC) by employing Logit, Probit, and linear regression models. These models estimate the determinants of CBDC development at various stages, including cancelled, research, proof of concept, pilot, and launch. Additionally, the study

Table 4

Middle-Income Countries Estimation

	Logit	Probit	OLS FE
ln WUI	–0.912**	–0.541**	–0.175**
	(0.410)	(0.235)	(0.070)
ln GDP per capita	–3.399*	–1.827*	–1.473***
	(1.738)	(1.021)	(0.486)
FDI inflows	$1.45 \cdot 10^{-11}$	$8.02 \cdot 10^{-12}$	$6.2 \cdot 10^{-12}$**
	$(1.2 \cdot 10^{-11})$	$(6.38 \cdot 10^{-12})$	$(2.66 \cdot 10^{-12})$
Electricity access	0.103**	0.057*	0.006
	(0.053)	(0.032)	(0.007)
Internet coverage	0.451***	0.228***	0.072***
	(0.120)	(0.069)	(0.013)
Cellphone usage	0.022	0.013*	0.002
	(0.014)	(0.008)	(0.003)
Urban population	0.038	0.021	0.184***
	(0.038)	(0.021)	(0.029)
Young population	0.308**	0.161**	0.013
	(0.122)	(0.066)	(0.034)
Constant			1.802
			(4.491)
/cut1	–5.802	–3.658	
/cut2	–3.496	–2.401	
/cut3	–0.760	–1.019	
/cut4			
Log-likelihood	–220.964	–222.462	
R-Squared			0.379
McFadden *R*-squared	0.102	0.092	
Obs	376	376	376

Using *z*-statistic (*t*-statistic for OLS), *, **, and *** represent significance at 10, 5, and 1 percent level, respectively. Standard errors are presented in parantheses. For Logit and Probit, /cut 1 is the estimated cut point of latent variable used to differentiate cancelled CBDC development from research, proof of concept, pilot, and deployed CBDC development. The same goes with /cut 2, it differentiates research CBDC development from proof of concept, pilot, and deployed CBDC development. /cut 3 differentiates proof of concept CBDC development from pilot and deployed CBDC. Lastly, /cut 4 differentiates pilot from deployed CBDC development.

Source: Authors' calculations.

conducts separate analyses for countries grouped by income levels—high, middle, and low.

Our findings indicate that higher uncertainty reduces the likelihood of central banks developing CBDCs. However, the impact of country-specific factors varies. GDP per capita has a negative effect on CBDC development, while FDI positively influences it. Infrastructural factors, such as access to electricity, internet, and mobile networks, also contribute positively to CBDC adoption. Similarly, demographic factors—specifically the presence of younger and urban populations—have a positive impact on CBDC development.

The effects of these factors differ across income levels. In high-income countries, the negative impact of uncertainty on CBDC development is the smallest. However, in middle and low-income countries, uncertainty has a significantly greater effect, approximately one and a half times stronger than in high-income countries. Notably, although not statistically significant, FDI and young populations in high-income countries exhibit a negative relationship with CBDC development. For other variables, the patterns observed in middle and low-income countries align closely with the full sample.

Recommendations

Tailored strategies from central banks are essential to overcoming obstacles and ensuring

Table 5

Low-Income Countries Estimation

	Logit	Probit	OLS FE
ln WUI	–0.882**	–0.523**	–0.131**
	(0.524)	(0.295)	(0.075)
ln GDP per capita	–3.236*	–1.564*	–1.201***
	(1.935)	(1.062)	(0.517)
FDI inflows	$4.43 \cdot 10^{-11}$	$2 \cdot 10^{-11}$	$2.93 \cdot 10^{-11}$**
	$(4.94 \cdot 10^{-11})$	$(2.49 \cdot 10^{-11})$	$(1.46 \cdot 10^{-11})$
Electricity access	0.104**	0.050*	0.012
	(0.058)	(0.033)	(0.007)
Internet coverage	0.358***	0.159***	0.042***
	(0.134)	(0.070)	(0.018)
Cellphone usage	0.012	0.006*	0.003
	(0.017)	(0.009)	(0.003)
Urban population	0.007	0.006	0.116***
	(0.032)	(0.016)	(0.032)
Young population	0.233**	0.106**	–0.007
	(0.137)	(0.071)	(0.042)
Constant			–2.052
			(5.909)
/cut1	–2.314	–2.674	
/cut2	0.464	–1.254	
/cut3	2.816	–0.255	
/cut4			
Log-likelihood	–123.725	–125.429	
R-Squared			0.152
McFadden *R*-squared	0.085	0.071	
Obs	256	256	256

Using *z*-statistic (*t*-statistic for OLS), *, **, and *** represent significance at 10, 5, and 1 percent level, respectively. Standard errors are presented in parentheses. For Logit and Probit, /cut 1 is the estimated cut point of latent variable used to differentiate cancelled CBDC development from research, proof of concept, pilot, and deployed CBDC development. The same goes with /cut 2, it differentiates research CBDC development from proof of concept, pilot, and deployed CBDC development. /cut 3 differentiates proof of concept CBDC development from pilot and deployed CBDC. Lastly, /cut 4 differentiates pilot from deployed CBDC development.

Source: Authors' calculations.

the successful implementation of CBDCs. Given the adverse impact of uncertainty on CBDC development across all income levels, particularly in middle – and low-income countries, collaboration and information-sharing among central banks are crucial. Such collaboration allows central banks to learn from each other's experiences, share best practices, and collectively tackle common challenges, helping to reduce global uncertainty surrounding CBDCs. These collaborative platforms could be particularly effective in regional integrations, such as BRICS, where member countries share close ties. This study suggests that lower-income economies have greater opportunities for CBDC development, particularly in terms of improving financial inclusion. However, these economies face significant challenges, including underdeveloped financial system interoperability, infrastructure limitations, and low levels of digital literacy.

Central banks should develop transparent and favourable regulatory frameworks for CBDC, which clarify regulations and build investor confidence. Governments and central banks must collaborate to create an adequate environment for CBDC, which includes implementing targeted infrastructure development incentives in rural and underserved areas. This could involve tax breaks, subsidies, or other financial incentives to attract private investment in these regions. Additionally, central

banks should focus on enhancing digital literacy through educational programs and initiatives, ensuring that citizens are well-equipped to use digital financial services. By adopting a comprehensive and collaborative approach, central banks can effectively address the challenges associated with CBDC implementation and foster a more inclusive and resilient financial ecosystem.

This study also indicates diverse impacts of population demographics on CBDC development across income levels. In high-income countries, the urban population plays a significant role in driving CBDC adoption, while in middle – and low-income nations, the young population has a greater influence. CBDC initiatives aim to improve financial inclusion, a critical goal in less developed countries where youth demographics can drive faster adoption. To support this, extensive education and awareness campaigns should be implemented to highlight the security features of CBDCs, safe usage practices, and potential risks. These campaigns can be conducted through public service announcements, workshops, and partnerships with fintech companies or central banks. In contrast, high-income countries already have well-established financial inclusion systems, which explains the greater relevance of urban populations in these regions. As a result, retail CBDC implementations should prioritize middle – and low-income countries to enhance daily transactions and increase financial access. Meanwhile, high-income countries can focus on developing wholesale CBDC to strengthen their banking settlement systems.

Future Research Direction

This study acknowledges the limitations of the available data on CBDC development. Specifically, data from low-income countries are scarce, prompting the combination of lower-middle and low-income countries for analysis. Additionally, the proxy used for CBDC development is general and does not differentiate between specific designs, such as retail, wholesale, interest-bearing, or non-interest-bearing models. As more central banks continue to engage in CBDC development over time, more data and insights will become available, addressing these gaps. These limitations highlight potential directions for future research, such as filling the data gaps and exploring the optimal CBDC design based on the magnitudes of influencing factors across different income levels.

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