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Uncertainty, Central Bank Digital Currency, and the Future of the Transatlantic Economic Order

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Abstract

CBDCs represent a paradigmatic shift in the historical development of money with potentially profound ramifications for monetary policy, financial stability, and the international monetary system. The present paper takes a closer look at CBDCs in the context of uncertainty, establishing a conceptual distinction between quantifiable risks and broader epistemic/aleatory uncertainties associated with technological change, institutional design, and market forces. It is argued that CBDCs do not eliminate uncertainty, but rather transform it, introducing new risks related to financial intermediation, technology, and international spillovers. In the process, the development of CBDCs can be seen within the framework of geoeconomics, contrasting the U.S. approach, characterized by fragmentation and plurality of private digital monies, with the unified vision advanced by the European Union as part of the initiative to introduce the digital euro, representing monetary sovereignty in the new technological reality.

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1. Introduction

In the increasing digitalization era, the emergence of Central Bank Digital Currencies (CBDCs) is one of the most transformative moments in redesigning[1] the monetary system and the state's role in money production. A CBDC is a digital version of a national fiat currency issued by the central bank. Several countries, such as China, the European Union, and the United

[1] The term 'redesigning' is used to capture the magnitude of institutional and functional changes associated with CBDCs. Unlike ordinary developments (e.g., payment upgrades), CBDCs can alter settlement finality and state–market relationships in the process of money creation. The term thus reflects a systemic rather than incremental shift.

Kingdom, have begun exploring or piloting CBDC initiatives, while others, such as the Bahamas, Nigeria, and the Eastern Caribbean, have launched their CBDCs. Cross-border CBDC projects are also underway,[2] hinting at the future potential for a nascent international financial landscape and the emergence of a novel CBDC network.[3]

CBDCs have the potential to transform the financial system. They are a versatile instrument with a wide range of social and economic benefits that central banks can pursue to realize the mandates and public policy goals. These benefits encompass financial inclusion by granting access to digital money for underprivileged communities, modernizing domestic and cross-border payment systems to achieve increased efficiency, lower transaction costs, and the effective delivery of monetary policy, such as direct stimulus delivery, real-time interest rate setting, and financial oversight.

[2] These initiatives include Project Rialto, Project mBridge, Project Jura, and Project Jasper-Ubin, initiated by the Bank for International Settlements (BIS).
[3] See, e.g., Wang and Gao (2024), pp. 288-306.

However, CBDCs also introduce novel layers of complexity and uncertainty, distinct from the challenges of traditional monetary and financial systems. Given the design of CBDCs and a nation's monetary control policy, the central bank's ability to regulate the flow of money independently via CBDCs may be constrained. Disputes can stem from the technological and regulatory complexity of CBDCs. From a social perspective, all stakeholders, including governments, financial institutions, and consumers, hold different views with respect to the policy objectives a CBDC should achieve, revolving around technological infrastructure, data privacy, and cybersecurity. However, disputes may evolve as CBDC implementation progresses.[4]

The task that central banks face is never easy since they navigate political uncertainties, recessions, geoeconomic shifts, and unexpected financial shocks. Additionally, unpredictable events, known as "black swan" events, complicate market perturbations. Popularized by Nassim Taleb, "black swan" is an event that takes everyone by surprise and upsets markets. The

[4] Wang (2025a), pp. 35–73.

concept generally has three characteristics: an element of surprise that could not be predicted from past data; an extreme impact on the existing financial environment; and the tendency for people to rationalize them as expected afterwards.[5] Taleb offers the 2008 global financial crisis as a typical "black swan" event.

The concept of systemic uncertainty within financial systems has been traced even beyond the work of Taleb. Hyman Minsky, in his "financial instability hypothesis," theorized that contemporary financial systems are innately unstable since they maintain a sustained capacity to generate debts. For Minsky, the nature of capitalism is characterized by periods of prolonged prosperity, associated with lower rates of interest, which eventually sow the seeds of crises.[6] When the period of euphoria sets in, the markets lend money to meet liquidity needs; however, as confidence begins to erode, people prefer to keep their funds in central bank money, government bonds, and bank deposits. Building on the theoretical

[5] The theory was formulated by Nassim Taleb. For a reference, see Taleb (2007).
[6] Minsky (1986), at chap. 9.

framework Minsky formulated, researchers such as Foster, Palley, and Akyüz have studied the profound cracks in today's financial system, which they described as financialized or excessively finance-led capitalism.[7] The over-reliance on financial mechanisms perpetuates the credit creation cycle, thereby increasing dependence on monetary impulses in the economic growth model rather than on production activities.

In fact, with the emergence of new technologies, there is an increasing connection between the financial system's inherent susceptibility to instability and technology itself. Indeed, concerns about mistrust in information technologies, technological breakdowns, and technological obsolescence contribute to additional instability.

The CBDC pursuit in terms of design, research, and policy objectives varies across the world. In this regard, it should be stressed that both the United States and the European Union have divergent approaches to digital currencies. While the United States pursues a fragmented approach driven

[7] See Foster (2008), Palley (2007), and Akyüz (2012).

by overlapping mandates and a heavy focus on innovation in the stablecoins industry, the European Union has embarked on a very different journey. In this regard, it can be observed that the ECB introduced the digital euro as a concept of strategic independence.

This divergence is not merely institutional; it reflects distinct regulatory philosophies for managing uncertainty. While the United States relies on market-driven innovations and regulatory adaptations *ex post*, it is quite open-minded about experiments in times of epistemic uncertainty. By contrast, the European Union applies an *ex ante* design of law and regulation, as seen in its efforts to harmonize crypto-assets and develop the digital euro. Overall, both alternative approaches offer an interesting perspective on how monetary authorities handle uncertainty regarding CBDCs.

2. Theoretical Framework: Uncertainty, unpredictability, and risks

Uncertainty, unpredictability, and risk constitute the very essence of decision-making in disciplines such as economics, finance, and

management. Even though these concepts are often used interchangeably, an analysis reveals both their similarities and differences.

2.1 Risks, unpredictability, and uncertainty: A primer

Frank Knight (1921) distinguished between risk and uncertainty. Knight posited that risk refers to situations in which the potential outcomes are known, and probabilities can be assigned to each outcome.[8] Fernández-Villaverde (2015) defines risk as the 'objective uncertainty'—a phenomenon arising from future events yet to be determined.[9]

> The practical difference between the two categories, risk and uncertainty, is that in the former the distribution of the outcome in a group of instances is known (either through calculation *a priori* or from statistics of past experience), while in the case of uncertainty this is not true, the reason being in general that it is impossible to form a group of instances, because the situation dealt with is in a high degree unique.[10]

There are different kinds of risks, which may lead to uncertainty. Legal risks provide a prime example. In the context of financial market infrastructures on which CBDCs rely, legal risk refers to "the risk of the unexpected

[8] Frank Knight (1921), p. 233.
[9] Fernández-Villaverde et al.(2015), p. 3353.
[10] Knight (n 9), p. 233.

application of a law or regulation, usually resulting in a loss," and may also "arise if the application of relevant laws and regulations is uncertain."[11] Legal risk may create uncertainty because it is not always clear how existing rules apply to CBDCs, a new form of currency.

In the Knightian framework, unpredictability is a non-probabilistic form of uncertainty.[12] Some future events are unpredictable, not because data or better models are lacking, but simply because there is no probability distribution for these events. This is because these future events are structurally new, meaning they arise from a single political, legal, technological, or institutional change rather than repeated instances of something familiar. Therefore, these future events cannot be insured, and modeled using conventional statistical techniques.[13]

By contrast, uncertainty is characterized by a lack of knowledge regarding the probabilities of potential outcomes, rendering outcomes inherently

[11] CPSS and IOSCO (2012), p. 18.
[12] Knight (n 9), pp. 217-221.
[13] id.

unpredictable. Knight uses the term 'uncertainty' to describe a condition under which it is impossible to measure the probability of events yet to occur, and hence, rational probabilistic judgment becomes problematic.[14]

Although uncertainty *per se* does not necessarily carry a negative connotation, risk inherently entails the possibility of undesirable outcomes.[15] Knight distinguishes measurable risk (where probabilities exist and can, at least hypothetically, be insured) from "true uncertainty", where probabilities are not capable of measurement and therefore the future is fundamentally unpredictable in a probabilistic sense. Risk analysis, therefore, is a critical tool for *a priori* reduction of undesirable uncertainties. A case in point is the use of derivative contracts, which enable parties to hedge or transfer uncertain future outcomes in advance—converting unpredictable exposures into pre-specified contractual risks.

[14] Knight (n 9), p. 233.
[15] id.

The Knightian perspective further studies perceived environmental uncertainty as a potential metric for measuring improbabilities. Tosi et al. (1973) define environmental uncertainty as "the degree of accuracy with which one can predict the future". [16] Such predictions by firms or individuals are based on information derived from their unique experiences, cognitive schemata, and past knowledge. [17] Their perspectives on the uncertainties may differ despite the same conditions, and this would shape how they react to the situation. One can appreciate the relationship between uncertainty and unpredictability; uncertainty impacts predictions of future events. As a result, the perception of uncertainty regarding CBDCs by stakeholders, including central banks, commercial banks, technology firms, and users, will shape their predictions about future prospects. Such discernment is subject to, among other factors, the stakeholders' capacity and constraints of their knowledge base.[18] The perception of uncertainty may encompass geoeconomic dynamics.

[16] Tosi et al. (1973), p. 30.
[17] For a reference, see Milliken (1987).
[18] Wang (2024), pp. 657, 659.

Uncertainty is often related to unpredictability—characterized by being unforeseen, unknown, or random. Uncertainty often manifests as a "surprise" where expectations clash with actual outcomes.[19] Chaos theory also explains the phenomenon of uncertainty. The theory contextualizes the random and unpredictable behavior arising from deterministic yet large complex systems. The underlying notion, as Berliner argues, is that in a complex system, uncertainty "leads to the use of random or probabilistic methods."[20] Such effects arise from nonlinear interactions among variables, in which small initial disturbances can be amplified, thereby breaking predictable patterns based on earlier historical data. It is often known as "butterfly effects"—a small alteration in the status quo can bring unpredictable changes in the system.[21] Kuhlmann argues that the butterfly effects in a complex financial system create "[a] remarkable insensitivity to variations on the micro level . . .[that] can give rise to macro effects."[22]

[19] Shackles (1949), p. 11.
[20] Berliner (1992), p. 76.
[21] Bishop (2011), p. 105-136.
[22] Kuhlmann (2014) pp. 1117, 1118.

Packard et al. (2017) note that unpredictability is not just a consequence of a system's inherent complexity but also the emergence of new conditions and the dynamic nature of human cognition. The outcome of a decision, when unknown, requires "human imagination, intuition, and estimation" in the process.[23] That is, uncertainty is not a fixed condition embedded in the system; rather, it emerges dynamically from the interaction between structural complexity and the limits of understanding at any given moment. The enduring interplay between an intrinsic complex system and the perpetual emergence of new information reveals a fundamental challenge, if not an impossibility, of obtaining exact predictions in complex economic and financial environments.

The economics of uncertainty and unpredictability relate to the discourse of invention and innovation. The development of new technologies or innovative ideas inevitably leads to new instances of information asymmetry, forcing people and institutions to make decisions with

[23] Packard, Clark, and Klein (2017), p. 14.

incomplete information about future events.[24] Although situations of this kind induce a high degree of uncertainty, it should, according to Arrow (1962), not be mixed up with pure unpredictability and cannot be regarded as being wholly irresolvable. On the contrary, he argues, the inherent uncertainty of novel projects can and ought to be accommodated within a broader risk management framework.[25] Within it, measures of a diversified nature, such as insurance and contractual arrangements, collaborate to ward off undesirable events and foster efficient resource allocation despite severe informational deficits.

Furthermore, investment decisions made prior to Keynesian thought were always evaluated through the lens of quantifiable risks and fixed expectations, without recourse to the phrase "rational expectation". The methodology employed in making these decisions usually assumes that economic actors operate with some level of certainty and quantifiable probabilities. This can be illustrated by Marshall's assertion that firms

[24] Arrow (1962), pp. 610-612.
[25] id.

invest and produce goods based on their expectations of profits, influenced by market variables such as costs, demand, and interest rates.[26] Here, uncertainty is not viewed as a constraint on decision-making but rather as something that can be managed within the given market environment. Similarly, Fisher (1930) makes intertemporal decisions and investment by evaluating the discounted streams of income relative to the given interest rate.[27]

Keynes criticized deterministic thinking by contending that expectations are not just influenced by objective information and rational reasoning but also by psychological factors, social pressures, and herd behavior.[28] In such situations, cognitive faculties follow no fixed rules, thereby introducing an intrinsic element of unpredictability into economic decision-making. Market psychology and group sentiment can heighten uncertainty and undermine rational thinking. Evidence indicates a significant negative relationship between firm-level capital spending and economic policy

[26] Marshall (1890), p. 348-351.
[27] Fisher (1930), p. 7-10, 213-218.
[28] Shackle (n 18), pp. 24-31.

uncertainty, as measured by news-based indicators, suggesting that higher uncertainty tends to slow firms' spending.[29]

2.2 Epistemic and aleatory uncertainties

To better understand the uncertainty at the heart of this article, we should grapple with distinct forms of uncertainty. The complex system also suffers from 'epistemic uncertainty'—an uncertainty arising from the lack of knowledge,[30] and 'aleatory uncertainty'—the chance of randomness.[31] Both concepts are rooted in Hacking's framework of probability and inductive logic.[32] Walters et al. (2020) elaborate on the distinction between these two forms of uncertainty from a psychological standpoint:

> People tend to communicate degrees of epistemic uncertainty using expressions such as "I'm 90% sure" or "I'm fairly confident" whereas they tend to communicate degrees of aleatory uncertainty using expressions such as "I think there's a 90% chance" or "I'd say there's a high likelihood."[33]

[29] Gulen and Ion. (2016), pp. 523, 531-532.
[30] McClarren (2018), p. 14.
[31] id.
[32] Hacking (2011), pp. 151-210.
[33] Walters et al. (2020), p. 4.

Notably, epistemic uncertainty could also involve skill, since 'epistemic uncertainty is attributed to missing knowledge, information, or skill.'[34] Epistemic uncertainty is affected by the positions, knowledge and skills of different actors.

Now, let us apply these concepts to the financial realm. At the micro-level, an individual's engagement in the market may be prompted by both epistemic and aleatory uncertainty.[35] Some may consider investment as "a game of skill" or "a game of chance."[36] However, financial institutions primarily assess financial risks and implement risk management controls in response to epistemic uncertainty.[37] The significance of individuals' epistemic traits (i.e., the use of cognitive faculties like perception and memory) is therefore crucial for the efficient oversight or regulation of financial activities.[38]

[34] Walters et al. (2023) (n 25).
[35] id, p. 3
[36] id.
[37] de Bruin et al. (2023).
[38] id.

In a highly uncertain financial environment, CBDCs emerge. There will be a paradigm shift in the mechanisms by which money operates at the micro-level, a development that might introduce additional uncertainty. Relatively minor design considerations, such as the choice between interest-bearing and non-interest-bearing accounts, intermediary vs non-intermediary models, and the degree of privacy afforded by the CBDC, might have unexpected macroeconomic consequences, including effects on financial stability, bank disintermediation, and monetary transmission. It will be difficult to predict such consequences since the system will not exhibit a linear response.

The uncertainties surrounding CBDCs are multifaceted and distinctly tied to the forms of uncertainty discussed. The epistemic uncertainty arises in the "lack of knowledge" about how a CBDC will function in practice. Central banks, policymakers, and market participants simply do not have complete information on how people will adopt and use CBDC; the precise impact on commercial banks' balance sheets and lending capacity; the

efficacy of new monetary policy tools enabled by CBDC; the potential for cyber vulnerabilities or systemic risks; and the geoeconomic implications.

The interdependence of national economies may exacerbate the risk of informational asymmetry and uncertainty. For central banks operating in a state of high financial interconnectedness, it is even more crucial to heed the complex interconnections of global financial systems, including cross-border capital flows, multinational financial institutions, and transnational market linkages. Monetary authorities need to recognize both the domestic state of economic circumstances and also review other countries' policies, setting of interest rates, and other elements of liquidity management, as these external dynamics can exert significant spillover effects on the safety and soundness of the national financial system.

Given the technical capabilities and attributes of CBDCs, they cannot operate independently and will need support from external actors to ensure interoperability and cybersecurity, enabling successful operation. Herd behavior can influence the perception and adoption of CBDCs as much as

economic reasoning can. The introduction of new money in a form that is easily accessible to the public can create new uncertainties due to epistemic problems.

Unlike the former type of uncertainty, which arises from possible risks, including unexpected shifts in customer tastes toward CBDCs, that could lead to disturbances similar to those in bank runs. In fact, the design and implementation of CBDCs are hinged on public trust and their mechanisms to mitigate potential speculative behaviors or sudden shifts in confidence during periods of volatility.[39]

The adoption of CBDCs into an already complex financial system may challenge the existing bank-dominated two-tier financial system. Economists and policymakers have warned about the impact of CBDCs on the disintermediation of commercial banks, liquidity, the profitability of banks' business models, and systemic risks.[40] The market's response to the

[39] Gazi (2023), p. 100, 105-107.
[40] Huifeng et al. (2023), pp. 25, 35 (generally discussing CBDC's risk of disintermediation of banks and reducing their lending power); Kunaratskul et al. (2024), p. 6 (discussing

shift from a bank-based deposit system to a central bank-controlled digital currency infrastructure could trigger new speculative booms and busts. CBDCs' interoperability features may enable the integration of multiple payment systems.[41] Without safeguards, emerging economies may face unprecedented capital outflows, warranting regulators' strict vigilance to ensure the financial system's integrity.[42] Capital inflows may destabilize their national currencies and lead to currency substitution.[43]

Regulatory fragmentation and divergence in governance structures create another channel of uncertainty in the diffusion of new money. In the United States, epistemic uncertainty is amplified by fragmented institutional mandates and ongoing debates over the role of stablecoins versus public digital money. Whereas, in the European Union, regulators aim to reduce such uncertainties through regulatory codification and centralized institutional design, although such efforts do not necessarily eliminate

CBDC's risks of substituting "some degree of cash, bank deposits, or central bank reserves").

[41] Duffie (2020).

[42] Soderberg et al.(2023).

[43] Pistor (2013).

aleatory uncertainty stemming from user beavior, market dynamics, and technological dynamics.

In the following sections, the paper will contribute to this discourse by further analyzing two major factors: (i) the financial system and uncertainty, and (ii) technology and uncertainty. This is because CBDCs are a crucial part of the financial system and rely heavily on rapidly advancing technology.

3. Uncertainty in the financial system and uncertainty

The uncertainty of financial systems includes both internal factors related to the financial system itself and external factors, such as geoeconomic dynamics. For the former, the Asian Financial Crisis (AFC) of 1997 involved policy choices around financial liberalization and arguably concerned premature financial liberalization. For the latter, power relations would affect the financial system, including the response to the financial crises.

3.*1 Structural rift*

The interconnectedness of the global financial system can lead to unintended consequences of financial fragility, as economic or financial shocks are transmitted across channels, affecting multiple economies.

The AFC was a major example of global financial fragility and the interconnected nature of the financial system (i.e., financial liberalization). The crisis occurred during the period of financial liberalization, when many financial institutions in Asia were engaged in unrestricted borrowing without hedging.[44] In Thailand, the capital account liberalization started off in the 1990s, creating an uninterrupted and unregulated channel for the influx of foreign capital while pegging the baht to the US dollar. The monetary mechanism attracted foreign investors with money flowing into the financial system, creating a market euphoria, particularly in the real estate market. In hindsight, it led to the accumulation of a massive dollar-denominated debt and exposure to foreign exchange risk.

[44] Lane, (1999).

The crisis peaked when the baht was de-pegged from the U.S. dollar. The unpegging triggered a series of currency devaluations across Asian economies, including Thailand, Indonesia, Malaysia, Japan, and South Korea.[45] As the boom burst, foreign investors began exiting the market, taking their capital with them. Given that there was no control over the capital outflow, Asian economies started losing their capital, materializing the AFC. Although this complex crisis has multifaceted consequences, many view it as the outcome of crony capitalism.[46] The crisis was exacerbated due to national governments' lack of foresight in assessing risks to financial systems.[47] Others argue that it was due to 'premature liberalization' of the credit sector without effective regulatory oversight.[48] Lane argues that the crisis underscored the problem of the IMF's liberalized financial policies, which did not consider the economies' structural rifts and vulnerabilities.[49] This made the crisis systemic and led to spillovers to other Asian economies.

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[45] id.
[46] For example, Lee (1999), p. 163.
[47] For a general discussion, see Verdier (2025), p. 232; Montes (1998).
[48] Akyüz (2000).
[49] Lane (n 38).

In particular, the AFC entailed a high degree of epistemic uncertainty. The crisis had materialized mainly due to a dearth of transparency, partial data, and systemic misconceptions. The failure of data accessibility and market opacity contributed to a precipitous decline in confidence among both external and internal investors, leaving market agents barely able to judge the major indicators of the economy's fundamental nature. [50] Such information asymmetry heightened not only the efforts of private agents but also those of universal institutions to extend financial aid tenfold.[51]

The AFC also suffered significant misjudgments by actors, as investors and banks underestimated macroeconomic and institutional vulnerabilities and risks in emerging markets, only to overreact when market sentiment shifted. [52] Such misperceptions were often caused by larger epistemic uncertainties, given that actors operated under conditions of asymmetric information. Stiglitz (2000) notes that the information-gathering process

[50] IMF (1998).
[51] Hofman (2022).
[52] IMF (n 42).

was flawed due to sudden changes in the structure of emerging economies, coupled with foreign investors' risk-averse perceptions of these markets.[53] Due to the opacity and a degree of unpredictability, at the first signs of economic weakness, bankers and foreign investors swiftly pulled their capital out of the market, jeopardizing the stability of the system.[54]

Financial crises, particularly those driven by capital flight and currency devaluation, often involve elements of herd mentality triggered by a "self-fulfilling prophecy" and panic.[55] Once initial doubts or small events trigger a loss of confidence, investors may withdraw funds *en masse*, following others' actions rather than relying on their individual assessments. However, as euphoria dissipated from the markets, initial underestimations of risks evolved into dramatic overreactions. This particular aspect of human behavior psychology has a strong association with herd behavior, wherein people mimic each other's decisions rather than making independent judgments.[56] Various literature suggests that herd behavior is

[53] Stiglitz (2000), p. 6.
[54] id.
[55] Liang et al. (2012), p. 41.
[56] Banerjee (1992).

the culmination of the investors' subjective perception of the market condition, in which they make the optimal or rational decision based on the information available.[57] The herd effect in the AFC was, in essence, an example of a decision made by investors when not all information was available. The investors' change in attitude further fueled the downward momentum, leading to currency depreciation in emerging markets.[58] The sensitivity of financial systems to such triggers reflects an informational fragility.

The event of panic may be marked by randomness; the precise trigger or timing of the shift in overall attitude can be highly unpredictable due to the influence of numerous variables, such as rumors, media coverage, or even minor incidents, which are amplified by investor psychology.[59] The non-linear nature of these shifts adds to the randomness. The abrupt currency devaluations during the AFC led to contagion spreading in ways that were

[57] Bikhchandani, Hirshleifer, and Welch (1992); Kindleberger (1978).
[58] Corsetti, Pesenti, and Roubini (1998).
[59] For reference, Kindleberger and Aliber (2011); in contrast, Gorton (1988) posits that market panics are not random.

not fully predictable in terms of timing or severity.[60] Moreover, the timing, magnitude, and scale of the sudden stop in capital flows triggered the AFC. To a certain extent, this involves aleatory uncertainty, the chance of randomness.[61]

3.2 *Geoeconomics*

Uncertainty can relate to geoeconomics, a subset of geopolitics. [62] Historically, geoeconomics has been a tool for achieving geoeconomic outcomes in which countries leverage "economic instruments such as trade, investment, aid, money, and energy" to gain "state power" and to advance "foreign policy goals." [63] It also refers to the "weaponization of interdependence", in which the states craft and devise the rules of the capital flow and often use them to "exploit vulnerabilities, compel policy change, and deter unwanted actions."[64]

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[60] Walker (1998), p. 1.
[61] Hofman (n 43).
[62] Blackwill and Harris (2016), pp. 20-23.
[63] Verdier (n 39), p. 243.
[64] Cited in *id*, p. 245.

Financial infrastructure may be used for strategic purposes. Geoeconomic factors may explain why certain economies utilize trade, financial resources, and economic strategies to shape their landscape. An example of this is the use of sanctions, and such a use of financial tools would also carry profound geoeconomic implications.[65] After World War II (WWII), the dollar's dominance was established and realized, with financial globalization being promoted. The restructuring of the global economic order in the aftermath of WWII provided the United States with considerable geoeconomic leverage. More broadly speaking, it is argued that the post-World War II Bretton Woods institutions served as a vehicle to promote laissez-faire economic policies and dollar hegemony, which disproportionately favored Western economies.[66]

Other measures include establishing a parallel payment system or limiting the influence of other major economies. Certain states may further explore their payment systems, encouraging the use of local currencies and

[65] Eichengreen (2022); Arner et al. (2022).
[66] Ruggie (1982).

reducing dependence on Western-dominated financial institutions and the US dollar.[67] Moreover, it is argued that a CBDC can serve as a "state-capitalist monetary policy tool", which affects the liberal financial order.[68] If so, these changes in the dynamics of economic interaction can potentially challenge the post-World War II liberal economic architecture.[69]

Geoeconomics can also impact the financial system in other ways. To illustrate, geoeconomics may undermine the effectiveness of international crisis management, as national officials may be hesitant to disclose sensitive information and less inclined to synchronize their responses and actions during a crisis.[70]

The limited understanding of geoeconomic dynamics may reflect epistemic uncertainty, given the lack of knowledge. The geoeconomic dynamics may

[67] Eichengreen (n 57).
[68] Johannes Petry and Andreas Nölke, *BRICS and the Global Financial Order: Liberalism Contested?* (Cambridge University Press 2024) 65
[69] e.g., Krause (2024).
[70] Verdier (n 39), p. 232.

involve aleatory uncertainty in certain circumstances, such as when actors' interactions are stochastic.

3.3. *Technology and uncertainty*

Technology has a compounding effect of uncertainty. While uncertainty does not necessarily equate to risk, failure to properly measure and control it could have disastrous implications. Current technologies, including blockchain, big data, machine learning, and artificial intelligence (AI), are changing the way the finance industry works.[71] By optimizing efficiency and lowering operation costs, AI can play an important role in strengthening risk management and prudential regulation.[72] However, improper management of AI can jeopardize financial stability, since factors like procyclicality, endogenous complexity, and possibly insufficient trust in AI may introduce new tail risks while intensifying existing ones.[73]

[71] Dańıelsson et al. (2020), p. 1.
[72] id.
[73] id

Dańielsson et al. (2020) argue that AI's specification-based decision-making system may provide unintended outcomes, given the 'complex social setting.' [74] This is because an algorithm typically requires specific instructions to perform a cost-benefit analysis in each and every predicted condition. Any '[m]isspecification of the structure of the problem will lead to suboptimal decisions.'[75] According to Kindleberger's argument,[76] human rational decision-making can destabilize the economy, and technological predictions may contribute to this instability. This can be explained as follows: Today's market is led by computer-driven investors who respond to technical factors and rapidly flowing data. However,

> [i]n times of stress, a particular combination of observations may cause financial institutions to behave in a particular way, for self-preservation purposes, like hoarding liquidity. That response is particularly damaging for stability, but since we do not know how an institution will respond, it is unclear whether a particular set of observations is.[77]

The use of digital technologies in the financial system has both positive and negative impacts. On one hand, it enhances competition and market

[74] id, p. 3.
[75] id.
[76] Kindleberger (n 49).
[77] Dańielsson et al. (n 61), p. 4.

efficiency; on the other hand, it introduces new potential systemic risks to financial stability and integrity. Digital platforms can rapidly disseminate information across institutions and borders, enabling faster responses than humans can process. This speed can amplify market uncertainty and potentially spread financial contagion throughout the system. However, cyber risks pose a challenge.

The high-frequency trading algorithm (HFT) is a relevant example in this category, which may provide insight for digitalization in the financial context. HFT typically refers to an automated trading platform used to execute large orders at high speeds. The system uses algorithms to analyze and predict market conditions. HFT has significantly transformed the market by implementing market-making, liquidity rebate trading, and statistical arbitrage strategies.

> It sounds like science fiction — something from *I, Robot* or *The Terminator,* where the machines take over. But automated "high-frequency trading" is part of the stock market right now — a big part.[78]

[78] Goldstein (2009).

It increased efficiency and order execution, but also created a single point of failure for an informational cascade. In HFT, rapid intraday trading, with positions generally held only for minutes or seconds, generates price fluctuations and short-term volatility in the trading market.[79] There is information asymmetry between HFT traders, who make decisions based on data-driven predictive models, and traditional investors, who follow market trends. Market uncertainty and informational opacity or asymmetry exacerbate the market stress and trigger a panic sell-off.

The dangers of HFT were revealed on May 6, 2010, when a flash crash in the U.S. trading market wiped out $1 trillion in half an hour. The Flash Crash arguably epitomizes the dark sides of informational cascades, how uncertainty affects the market, and how bad actors can weaponize the system.

The second example is the flash crash in the sterling-U.S. dollar exchange rate in 2016, caused by a "rogue algorithm" that drove the pair down by

[79] For a general analysis on the HFT, see Poirier (2012), pp. 451-455.

9.66% in just 40 seconds.[80] Experts suggest that during this event, algorithm-enabled automated market-makers responded to stress in ways similar to human traders, given pre-existing market volatility, and became more cautious in pricing risk.[81] Once certain thresholds were breached, they widened prices and stopped quoting altogether. Technology also quickly transports the stress of the cross-border market. Both the Bank for International Settlements and the Bank of England agree that the flash crash of sterling value was exacerbated by the "pause in trading on the [Chicago Mercantile Exchange] futures exchange, which led to a withdrawal of liquidity on other platforms."[82]

Human errors cannot be overruled in technological use, particularly when a "fat finger error" may have a spiraling impact on trading.[83] There is also a concern that bad actors may manipulate the system to create fictitious orders, thereby gaining an illegitimate advantage, a practice known as spoofing in the context of trading. For example, in 2010, a lone rogue actor,

[80] Condliffe (2016), p. 2.
[81] BIS (2017), p. 13.
[82] Bank of England (2017), p. 24.
[83] BIS (n 71), p. 17. It was used to explain the flash crash in sterling's value.

Navinder Sarao, a small London-based equity futures trader, engaged in illegal 'spoofing' activity that materially contributed to the Flash Crash.[84]

3.4. *Regulatory fragmentation and uncertainty*

One of the key sources of epistemic uncertainty in the development and roll-out of CBDCs is regulatory fragmentation. Indeed, unlike other monetary instruments, CBDCs sit at the crossroads of monetary law, financial regulation, data governance, and payment system regulation. The absence of a harmonized legal taxonomy in various jurisdictions, including with regard to the classification of digital money, the role of financial intermediaries, and the scope of supervisory powers, generates uncertainty about which rules apply, how they interact, and how they are enforced.

The issue of regulatory fragmentation is particularly salient in a fragmented regulatory environment, where overlapping areas of responsibility may arise between authorities. This is most apparent in cases where overlapping jurisdictions among central banks, financial regulators, and data protection

[84] *CFTC v, Sarao*; *USA v. Sarao*.

authorities govern CBDC regulation. Indeed, such multiplicity of institutions can make the regulatory environment more complex, increasing legal costs and deterring private actors from engaging with CBDCs.[85]

At the international level, regulatory fragmentation also contributes to epistemic uncertainty around CBDCs. Indeed, for international CBDCs to work, it is not only necessary to consider issues of technological standardization, but also of legal standardization, including with regard to issues of settlement finality, data protection, and capital controls.[86]

4. CBDCs and uncertainty

The ongoing exploration of CBDCs, the digital representations of fiat currency (alternatively, a digital legal tender), by central banks is a result of the COVID-19 pandemic. This unexpected event significantly altered our lives, societal interactions, and financial and economic systems. During the

[85] Wang and Gao (2024) (n 4).
[86] IMF (2020).

pandemic, disruptions to global supply chains and lockdowns stunted economic growth, prompting central banks to intervene on an unprecedented scale. Their unconventional monetary policies and fiscal stimuli aligned with macroeconomic objectives.[87] Simultaneously, the increasing demand for contactless payments and remote work accelerated the drive for rapid digitalization worldwide.[88]

One of the defining moments was Meta's Libra (later renamed Diem) initiative. Diem was proposed as a stablecoin designed on a permissioned blockchain network and pegged to a basket of currencies and assets.[89] The project faced significant backlash from global regulators because of its large consumer base and potential to serve as a payment method that could bypass regulatory safeguards.[90] Concerns also arose regarding the financial stability risks associated with the initiative.[91] It also had the potential to become an informal 'currency'— "a unit of account, store of value, and a

[87] Tooze (2021).
[88] Jaumotte (2023).
[89] Guseva, Gazi, and Eakeley (2025).
[90] id.
[91] Gorton and Zhang (2023).

medium of exchange that could threaten the stability of sovereign currency."[92] Libra's substantial consumer reach and potential for currency substitution may affect small economies, particularly in the absence of regulatory oversight.

Blockchain and its native assets have been in the market for a while. However, Meta's Libra moment marked a pivotal shift in how policymakers and regulators approached the complexities and potential of digital assets. On a positive note, Diem also demonstrated that the state and the market could leverage a technological solution to address unmet customer needs. A CBDC is the central bank's effort to capitalize on advanced technology to provide a more efficient means of unit of account and offer a modern, advanced digital payment solution.

CBDCs bring not only benefits but also uncertainty to the international economic system. Diversification in design, features, characteristics, and technological choices could fundamentally shift the current economic and

[92] Himino (2019).

financial order. While CBDCs could be a modern and efficient alternative to cash and bank-based digital payments, their long-term effects on the international financial system and monetary policy remain uncertain. CBDCs may face uncertainty, much like past innovations discussed above.

A CBDC differs from traditional financial systems and challenges our conventional understanding of uncertainty. CBDCs face an endogenous form of uncertainty—a CBDC's design is the state's prerogative, informed by its public goals, leading to variations in CBDC design. Efforts are being made to manage the risks in this regard by developing principles for the consideration of CBDC issuance. First, CBDCs should enable central banks to implement their public policy goals ("do no harm"[93]). Second, CBDCs should coexist with existing payment instruments, including cash, reserve accounts, and settlement accounts. Finally, CBDCs should enhance the efficiency of the payment system.[94]

[93] G7 (2021), p. 6.
[94] BIS and Group of Central Banks (2020), p. 10.

If not properly managed, CBDCs can disintermediate the two-tiered financial structure, destabilizing the traditional banking sector and exacerbating capital flight from bank deposits to CBDCs.[95] CBDCs' technological fluidity, coupled with design variations and trade-offs, may potentially compound their uncertain impacts on the financial system.[96] Other possible uncertainties that could emerge as a result of the CBDC deployment across economies include:

- Digital bank run: Digital bank runs, though anchored in a bank-centric and dollar-based financial system, have dynamics that are important for CBDCs, as they reveal the potential for systemic vulnerabilities along different dimensions. The primary source of uncertainty relates to the characteristics and distribution methods of CBDCs, which may bypass banks and increase their operating costs. In this context, the programmability and near-settlement attributes of CBDCs may catalyze the rapid transmission of shocks through

[95] BIS (2020), pp. 3-5, 17-19.
[96] Auer and Böhme (2020); Adrian and Mancini-Griffoli (2019), chap 3.

both domestic and international financial networks. Just as financial liberalization in the AFC era facilitated rapid capital mobility, CBDCs may catalyze the instantaneous movement of digital assets, compressing the time dimension of crises.

Behavioral patterns observed in the AFC era may be accentuated in a CBDC environment. The presence of risk-free CBDCs may create scope for rapid deposit substitution, where agents may shift deposits from traditional commercial banks to CBDCs in reaction to perceptions of financial instability. Such responses may assume the form of digitally enhanced bank runs. The rapidity of digital transactions and the rapid dissemination of information through contemporary communication channels may catalyze herd behavior, allowing for coordinated responses on an unprecedented scale.

- Geoeconomic fragmentation: Nations may try to develop CBDCs to regain monetary sovereignty and improve cross-border trade payments. In fact, the use of CBDCs may reduce the reliance on

traditional reserve currencies such as the U.S. dollar.[97] China's CBDC, for instance, may promote China's currency internationalization agenda while decreasing its dollar settlement dependency.[98] The impact of the rise of an alternative currency on cross-border payments, as well as on the global financial architecture and monetary systems, is yet to be seen. Developing countries heavily rely on their dollar reserves to formulate their monetary policies and currency valuation. The adoption of CBDCs in various economies could reshape the international monetary system.[99] This may be the case if a CBDC serves as a reserve currency for economies looking to reduce their reliance on the dollar and the impact of a dollar-dependent monetary policy.

- Loss of monetary policy and financial control: In countries with weaker financial systems, introducing foreign CBDCs could undermine local monetary policy, reducing the central banks' ability

[97] BIS (2021), pp. 85-89; IMF (2020) (n 87), pp. 34-38.
[98] Wang (2023), p. 10.
[99] Wang (2025b), p. 1.

to control inflation and stabilize the economy.[100] CBDCs can offer an instrument for enforcing sanctions and tracking financial flows.[101] Yet, countries under sanction might advocate for their CBDCs or other arrangements, thereby affecting the efficacy of the envisaged financial controls.

- Technological failure or obsolescence: A CBDC should not suffer technological failure. A large-scale cyberattack on a CBDC network could paralyze the financial infrastructure, disrupt payments, damage public confidence, and trigger systemic financial instability. Central banks also face the challenges of keeping up with the latest technological developments. This includes enhancing cybersecurity mechanisms to ensure a robust central banking system. This may appear to be oxymoronic. Digitalization is a way to manage uncertainty, risks, and unpredictability, but it also comes with its

[100] BIS (2018), pp. 10-14; Mancini-Griffoli et al. (2018), pp. 29-31.
[101] Farell and Newman theorize that the weaponization of interdependence in informational and financial networks creates highly asymmetrical power relations across countries. Farrell and Newman (2019), p. 42.

own set of risks. The impact of any potential issues with CBDC technology on the economy is not always clear.

- Cross-country capital flight and financial contagion: If users lose confidence in a CBDC during a financial crisis, sudden capital outflows could occur, draining reserves and leading to currency devaluation, especially in smaller or emerging economies.

These unpredictable incidents could lead to financial instability and disrupt the international monetary order. Given the increasingly turbulent international relations, the success of CBDCs will be affected by central banks' ability to maneuver policy tools to curb multi-dimensional black swan effects and ensure financial stability.[102] How can central banks respond to this unpredictability?

[102] Gazi (n 32).

Typically, central banks are mandated to ensure price stability and the safety and integrity of the financial sector.[103] Contemporary body literature discusses central banks' constraints, particularly their inability to pursue more than two policy goals simultaneously. Even in the context of stablecoins—a privately issued digital token designed to maintain stable value relative to a reference asset —literature posits similar views. Known as the 'stablecoin trilemma', the literature suggests that stablecoin issuers cannot achieve all three objectives: balancing stability, decentralization, and capital efficiency.[104] Other literature suggests that a stablecoin can avoid at most two of three risks: (1) downward price instability from moral hazards, (2) downward instability from external market risks and poor performance, and (3) upward instability from limited coin supply.[105] Scholars also highlight the central banks' trilemma in the case of a CBDC, too, arguing that central banks can achieve at most two among the three goals of

[103] Aloysius Donanto H. Wibowo, 'Role of Payment and Settlement Systems in Monetary Policy and Financial Stability: Integrative Report' in Aloysius Donanto H. Wibowo (ed), *Role of Payment and Settlement Systems in Monetary Policy and Financial Stability* (The South East Asian Central Banks (SEACEN) Research and Training Centre 2012) 3
[104] Kartavchenko et al. (2024).
[105] Potter et al. (2021).

efficiency, the absence of runs, and price stability.[106] In the context of CBDC, there could be additional trade-offs regarding legitimacy, economic benefits, and geoeconomic considerations.

In light of these challenges, particularly the need for public trust in digital currencies and the imperative for the technological robustness of CBDC infrastructure, central banks must adopt resilient policy frameworks to mitigate systemic risks.

CBDC sits at the unique convergence of national monetary systems and geoeconomic orientation. Its development and proliferation extend beyond the central banks' impetus to enhance payment systems' efficiency; it may redraw the architecture of international monetary interconnectedness and regional economic cooperation. Although there are only a small number of viable CBDC projects in operation, countries are increasingly exploring the opportunities to capitalize on CBDC infrastructure to reorient their geoeconomic and economic interests. Some examples are relevant in this

[106] Schilling, Fernández-Villaverde, and Uhlig (2020).

context. Multi-CBDC projects like mBridge, Jura, and Jasper-Ubin demonstrate that countries have initiated collaborative efforts to design interoperable CBDCs to facilitate cross-border value transfers.

Additionally, international standard-setting bodies and central banks are in the pursuit of standardizing the design of a CBDC amidst a wide range of features and technical specifications. The philosophy behind such cooperation hinges on the idea that CBDC must not destabilize the current international framework and must coexist with cash and all other forms of money.[107]

In hindsight, CBDC introduces technological complexity and new institutional fragility, exposing the digital infrastructure's susceptibility to risks such as network outages, cyberattacks, interoperability failures, and access asymmetries. CBDC's promise of modernizing the payment system is also contingent on its frictionless settlement mechanism; legal and regulatory fragmentation may potentially hinder the prospect.

[107] BIS and Eight Central Banks (2020).

As more states are frontrunning CBDC projects, the broader political economy of CBDCs is becoming increasingly relevant amid new technological uncertainties. This also requires state actors to adopt an integrated approach to the governance and regulation of CBDCs while preserving trust and technological reliability.

5. The US and EU approach to CBDCs and uncertainties

The United States and the European Union are examples of divergent approaches to regulating CBDC uncertainty. In the case of the United States, its stance is decentralized and market-based, with its institutions being fragmented. In other words, authority over digital assets is distributed among various agencies, such as the Federal Reserve, the Securities and Exchange Commission, and the Commodity Futures Trading Commission. Recently, the United States has adopted the GENIUS Act with a view to promoting stablecoins as an alternative payment means.[108]

[108] GENIUS Act

A separate legislative approach also includes regulating other digital assets, such as cryptocurrencies, as commodities.[109] In tandem, there is also growing negative sentiment toward CBDCs—a legislative proposal would prohibit the Federal Reserve from issuing one in the future.[110] This reflects an overall governance framework favoring growth through innovation, with tools such as stablecoins being allowed to flourish in place of or in addition to a CBDC. However, this also entails some epistemic uncertainty.

For example, institutional uncertainty arises from the absence of a settled allocation of authority between federal regulators. The Clarity Act attempts to establish clear jurisdictional boundaries between securities and commodities regulators, but in coexisting with the GENIUS Act, which is dedicated to the regulation of stablecoins, it leaves the role of CBDCs uncertain in the event of their issuance. This is because of underlying structural uncertainty about whether digital money should be regulated as a payment vehicle, a financial asset, or a government liability.

[109] Clarity Act
[110] Anti-CBDC Surveillance Act

In contrast, the European Union is following a centralized and rule-based framework in its regulation of digital currencies with an aim to reduce uncertainty via harmonization. In other words, it is creating a framework of rules to define how markets should behave ex ante. This reduces legal uncertainty by imposing uniform rules across its Member States. However, there are other uncertainties embedded in the geoeconomic implications.

The GENIUS Act mandates that each stablecoin must have 100% reserve backing with dollars or short-term treasuries. The current U.S. administration also made it clear that the widespread adoption of dollar-backed stablecoins is essential to furthering the dollar's dominance in the global economy.[111] Other legislative efforts and a proposed ban on the future digital dollar indicate that the current policy approach aligns with the regulated, privately issued digital dollar. Geoeconomically, this matters because it allows the United States to extend the use of the dollar through private rails while avoiding the domestic political and constitutional controversies associated with a retail CBDC. In other words, the U.S. can

[111] White House Fact Sheet (2025).

defend dollar centrality by exporting dollar stablecoin liquidity, rather than by exporting a digital dollar issued by the Fed.

From the EU perspective, the key issue is not whether the dollar will disappear from the global monetary system. It won't, at least not in the near future. The Federal Reserve's 2025 survey projected that the dollar would still account for 58% of disclosed global official reserves as of 2024, while the euro would account for only 20%.[112] The issue for the EU is more specific and pressing. In the digital payments layer, will the euro become increasingly tied to private infrastructure linked to the U.S. and dollar-denominated digital instruments?

[112] Bertaut, Beschwitz, and Curcuru (2025).

6. Conclusion

The historical experience shows that technology is capable of both stabilizing and destabilizing. The example of HFT and the Flash Crash shows how new technologies that increase efficiency can, in complex, poorly governed systems, produce fast-moving, opaque volatility. However, it is unlikely that CBDCs will reduce uncertainty; rather, they are likely to rearrange it. This uncertainty is not only driven by concerns about financial stability, such as disintermediation or liquidity shocks, but also by technological factors, including cyber threats and system failures. Rather, it is also driven by geoeconomics, which is linked to differences in regulatory approaches, monetary policies, and even currency hierarchies.

If we consider all of this, the difference in approach between the United States and the European Union is particularly interesting. The United States appears to be moving towards a model of digital monetary power that is centered on regulated private instruments, above all on stablecoins that are backed by dollars. However, it is institutionally and politically not in a position to engage in CBDC. The European Union, on the other hand, is

pursuing a more harmonized approach that combines regulation with the potential for the development of a digital euro that is understood as an instrument of monetary sovereignty. However, what is at stake here is more than just institutional differences. Rather, what is at stake is geoeconomics.

These uncertainties are compounded by the persistent difficulty in forging successful international cooperation in a fractured geoeconomic environment. Differing national interests, competing financial regimes, and incomprehensive governing structures all inhibit the collective capacity to contain spillover impacts of a transnational character. As a result, it becomes more challenging for central banks to adhere to national monetary goals while responding to the demands of an increasingly interconnected global environment.

Addressing these multidimensional uncertainties demands adaptive governance structures, technological and institutional resilience, and

geoeconomic sight.[113] Central banks and policymakers need to design CBDC implementation as more than a technocratic exercise but rather as a transformative point in the development of a new monetary regime. This requires continued international debate, mechanisms of trust-building, and agile regulation. More broadly, the digital age calls for coordinated and long-term strategies that align innovation with public interest, such as financial stability.

[113] Geoeconomic sight usually denotes the capacity of states and regulatory authorities to recognize and anticipate the geopolitical implications of economic interdependence and policy spillovers in a fragmented global economy, particularly where financial, monetary, and technological instruments are increasingly deployed for strategic purposes.

References

Akyüz Y (2000). Causes and Sources of the Asian Financial Crisis. UNCTAD. https://unctad.org/system/files/official-document/ux_hi_akyuz.en.pdf. Accessed 30 Sept 2025.

Akyüz Y (2012). The boom in capital flows to developing countries: Will it go bust again? Ekonomi-tek – International Economics Journal 1(1): 63-96.

Akyüz Y (2014). Internationalization of finance and changing vulnerabilities in emerging and developing economies. UNCTAD Discussion Papers No. 217, UNCTAD

Arrow K (1962). Economic welfare and the allocation of resources for invention. In: The rate and direction of inventive activity: economic and social factors. Princeton University Press, Princeton, pp 609–626. https://www.nber.org/system/files/chapters/c2144/c2144.pdf.

Auer R and Böhme R (2020). The technology of retail central bank digital currency. BIS Quarterly Review (March).

Backhouse R and Mauro B (2014). Uncertainty in economics. In the Oxford Handbook of the History of Economics. Oxford University Press, Oxford, pp. 57-60.

Banerjee AV (1992). A simple model of herd behavior. Q J Econ 107(3):797–817. https://doi.org/10.2307/2118364.

Bellamy Foster J, Magdoff F (2009). The great financial crisis: causes and consequences. NYU Press, New York

Berliner LM (1992). Statistics, probability, and chaos. Stat Sci 7(1):69–90

Bertaut C, Beschwitz BV, and Curcuru S (2025). The international role of the U.S. Dollar- 2025 edition, July 18, 2025, https://www.federalreserve.gov/econres/notes/feds-notes/the-international-role-of-the-u-s-dollar-2025-edition-20250718.html

Bikhchandani S, Hirshleifer D, Welch I (1992). A theory of fads, fashion, custom, and cultural change as informational cascades. https://snap.stanford.edu/class/cs224w-readings/bikhchandani92fads.pdf. Accessed 30 Sept 2025.

BIS and Eight Central Banks (2020). Central Bank Digital Currencies: Foundational Principles and Core Features. https://www.bis.org/publ/othp33.pdf. Accessed 08 October 2025.

Bishop R (2011). Metaphysical and epistemological issues in complex systems. In: Hooker C (ed) Handbook of the philosophy of science. Elsevier, New York, pp 105–136.
Blackwill RD and Harris JM (2016). War by other means: Geoeconomics and statecraft. Cambridge University Press, Cambridge.
Blaug M (1997). Theory in retrospect. Cambridge University Press. Cambridge, pp. 579-83.
Chowdhury A, Zuk P (2018). From crisis to crisis: capitalism, chaos, and constant unpredictability. Econ Labour Relat Rev 29(4):375–395
Committee on Payment and Settlement Systems, IOSCO (2012). Principles for financial market infrastructures. Bank for International Settlements
Condliffe J (2016). Algorithms probably caused a flash crash of the British Pound. MIT Technology Review. https://www.bankofengland.co.uk/-/media/boe/files/working-paper/2017/the-october-2016-sterling-flash-episode.pdf. Accessed 30 Sept 2025
Corsetti G, Pesenti P, Roubini N (1998). What caused the Asian currency and financial crisis? Part I: a macroeconomic overview. NBER Working Paper No. 6833. https://www.nber.org/system/files/working_papers/w6833/w6833.pdf
Danielsson J, Macrae R, Vayanos D, Zigrand JP (2020). Artificial intelligence and systemic risk. Artif Intell Law:1–10
Duffie D (2020). Interoperable payment systems and the role of central bank digital currencies. SSRN. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3604665. Accessed 30 Sept 2025
Eichengreen B (2022). Sanctions, SWIFT, and China's cross-border interbank payments system. CSIS. https://www.csis.org/analysis/sanctions-swift-and-chinas-cross-border-interbank-payments-system
Farrell H and Newman AL (2019). Weaponized interdependence: How global economic networks shape state coercion. International Security 44(1): 42-79.
Fernández-Villaverde J, Guerrón-Quintana P, Kuester K, Rubio-Ramírez J (2015). Fiscal volatility shocks and economic activity. Am Econ Rev 105(11):3352–3384.
Fisher I (1930). The Theory of Interest. MacMillan, London.

Fisher I (1933). The debt-deflation theory of great depressions. BIS Working Paper No. 176. https://www.bis.org/publ/work176.pdf.
Foster B (2008). The financialization of capital and the crisis. Monthly Review 59(11): 1-19.
G7 (2021). Public Policy Principles for Retail Central Bank Digital Currencies.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1025235/G7_Public_Policy_Principles_for_Retail_CBDC_FINAL.pdf.
Gazi S (2023). Unlocking the potential of central bank digital currencies for developing countries. In: Zatti F, Barresi RG (eds) Digital assets and the law: fiat money in the era of digital currency. Routledge, London
Gorton G, Zhang J (2023). Taming wildcat stablecoins. Univ Chic Law Rev 90:909–950
Gulen H, Ion M (2016). Policy uncertainty and corporate investment. Rev Financ Stud 29(3):523–564. http://www.jstor.org/stable/43866019. Accessed 15 May 2025
Hacking I (2011). An introduction to probability and inductive logic. University of Toronto Press, Toronto.
Hofman B (2022). The Asian financial crisis 25 years on. NUS EAI Commentary No. 54. https://research.nus.edu.sg/eai/wp-content/uploads/sites/2/2022/07/EAIC-54-20220712.pdf
Hsu H, Kunaratskul T, Sandhu P (2024). Implications of central bank digital currency for monetary operations. World Bank. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099607406262426195/idu18726d4e913edd14b8a1adcf1671ab7d8ebac
Huifeng L et al. (2023). Disintermediation in a portfolio choice model. IMF Working Paper No. 236
Hyman M (1986). Stabilizing an unstable economy. Yale University Press, New Haven.
IMF (2020). Digital money across borders: Macro-financial implications. Washington DC.
Jaumotte F (2023). Digitalization during the COVID-19 crisis. IMF Staff Discussion Note No. 003
Knight FH (1921). Risk, uncertainty, and profit. Houghton Mifflin, Boston

Kindleberger CP (1978). Manias, panics, and crashes: a history of financial crises. Basic Books, New York
Kindleberger CP, Aliber RZ (2011). Manias, panics and crashes: a history of financial crises. 6th edn. Palgrave Macmillan, New York
Krause D (2024). The future of global payments: BRICS Pay and the evolving financial order. SSRN. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5043142. Accessed 30 Sept 2025
Kuhlmann M (2014). Explaining financial markets in terms of complex systems. Philos Sci 81(5):1117–1130
Lane T (1999). The Asian financial crisis? What have we learned? Finance Dev 36(3). https://www.imf.org/external/pubs/ft/fandd/1999/09/lane.htm. Accessed 30 Sept 2025
Liang JG, et al. (2012). The 1997 financial crisis in Asia and self-fulfilling prophecy. J Inf Optim Sci 33(1):41–58. https://doi.org/10.1080/02522667.2012.10700133
Marshall A (1920). Principles of Economics. 8th edn. Macmillan, London
McClarren RG (2018). Epistemic uncertainties: dealing with a lack of knowledge. In: Uncertainty quantification and predictive computational science. Springer, Cham. https://doi.org/10.1007/978-3-319-99525-0_12
Milliken FJ (1987). Three types of perceived uncertainty about the environment: state, effect, and response uncertainty. Acad Manage Rev 12(1):133–143. https://doi.org/10.2307/257999. Accessed 15 May 2025
Montes MF (1998). Global lessons of the economic crisis in Asia. East-West Center. https://www.files.ethz.ch/isn/28411/api035.pdf. Accessed 30 Sept 2025
Packard MD, Clark BB, Klein PG (2017). Uncertainty types and transitions in the entrepreneurial process. Organ Sci 28(5). https://doi.org/10.1287/orsc.2017.1143
Palley TI (2007). Financialization: What it is and why it matters. Levy Economics Institute Working Paper No. 525 (December).
Palley TI (2013). Financialization: the economics of finance capital domination. Palgrave Macmillan, London
Patnaik P (2016). Capitalism and its current crisis. Mon Rev 68(1). https://monthlyreview.org/2016/01/01/capitalism-and-its-current-crisis/

Peterson WC (1978). Stagflation and the crisis of capitalism. Norton, New York
Petry J, Nölke A (2024). BRICS and the global financial order: liberalism contested? Cambridge University Press, Cambridge
Pistor K (2013). A legal theory of finance. Columbia Law School. https://scholarship.law.columbia.edu/faculty_scholarship/2283
Shackles GLS (1949). Expectation in economics. Cambridge University Press, Cambridge.
Shackles GLS (1949). Expectation, enterprise and profit. Allen & Unwin, London.
Soderberg G, Bech M, Hancock J (2023). How should central banks explore central bank digital currency? A dynamic decision-making framework. IMF Fintech Note No. 008
Stiglitz JE (2000). Capital market liberalization, economic growth, and instability. Columbia University. https://business.columbia.edu/sites/default/files-efs/pubfiles/1479/Stiglitz_CapMktLiberaliz.pdf.
Taleb NN (2007). The black swan: the impact of the highly improbable. Random House, New York
Tosi HL, Aldag RJ, Storey RE (1973). On the measurement of the environment: an assessment of the Lawrence and Lorsch environmental uncertainty subscale. Adm Sci Q 18(1):27–36
Tooze A (2021). Shutdown: How COVID shook the world economy. Viking, New York
Verdier P-H (2025). International finance and the return of geopolitics. Am J Int Law 119:229–245
Walker WC (1998). Contagion: how the Asian crisis spread. Brookings Institution, Washington, DC
Walters DJ, Savarese R, Chen M, Klein P (2020). Investor behavior under epistemic and aleatory uncertainty. SSRN. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3695316. Accessed 30 Sept 2025
Walters DJ, Savarese R, Chen M, Klein P (2023). Investor behavior under epistemic vs. aleatory uncertainty. Manage Sci 69:2762–2779.
Wang H (2023). How to Understand China's Approach to Central Bank Digital Currency? Computer Law & Security Review 50: 1-17.

Wang H (2024). Addressing governance challenges of digitalisation and sustainability: the case of central bank digital currency. Rev Eur Comp Int Environ Law 33:647–659
Wang H (2025a). Understanding disputes over digitalization: a perspective of cross-border central bank digital currencies. Emory Int Law Rev 40:35–73. https://scholarlycommons.law.emory.edu/eilr/vol40/iss1/3/
Wang H (2025b). "Dollar Challenger? CBDCs, Complexities, and Monetary Hegemony," Virginia Journal of International Law. 66 (3) (forthcoming): https://www.researchgate.net/publication/397013026_Dollar_Challenger_CBDCs_Complexities_and_Monetary_Hegemony
Wang H, Gao S (2024). The future of the international financial system: the emerging CBDC network and its impact on regulation. Regul Gov 18:288–306
Wibowo ADH, 'Role of Payment and Settlement Systems in Monetary Policy and Financial Stability: Integrative Report' in Wibowo ADH (ed), *Role of Payment and Settlement Systems in Monetary Policy and Financial Stability* (The South East Asian Central Banks (SEACEN) Research and Training Centre 2012)
The White House, Fact Sheet: President Donald J. Trump Signs GENIUS Act into Law, July 18, 2025, https://www.whitehouse.gov/fact-sheets/2025/07/fact-sheet-president-donald-j-trump-signs-genius-act-into-law/
Petry J and Nölke A, *BRICS and the Global Financial Order: Liberalism Contested?* (Cambridge University Press 2024)