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Achieving Sustainable Financial Transactions under Regimes without a Central Bank—An Intertemporal Comparison

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Abstract: In this paper, by performing an intertemporal comparison, we investigate two monetary policy regimes where a central bank is absent, and we further refer on the mechanisms they developed so as to ensure the reliability of transactions between the parties involved. In particular, we mainly focus on the economic–monetary institutions of Athens during the Classical period (508–322 BCE) and we argue that (in principle) there are inter-temporal similarities between the Athenian and the current digital currencies regimes regarding the auditing principles with which the reliability of financial transactions is ensured. We found that in both cases, what is crucial for the success of the system is to achieve trust on the currency. By focusing on Classical Athens, we analyze the nature of the mechanisms and the auditing techniques used to ensure reliable commercial transactions. We also briefly analyze the modern cryptocurrency techniques. We found that the success of both financial regimes was based on achieving: low transactional costs, speed in commercial transactions, and what we characterize as security regarding the commercial transactions.

Keywords: money without a central bank; Classical Athens; digital currencies; coin testing techniques

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1. Introduction

A key intertemporal axiom regarding the evolution of money is to ensure that state authorities are issuing reliable and stable currencies as a prerequisite to perform effective commercial transactions and achieve long term economic growth. By reliable currencies we mean, not counterfeited ones, because 'bad money drives out the good' as the famous Gresham's Law asserts.

Therefore, what is crucial for commerce and economic activity to flourish is the existence in practice of efficient oversight mechanisms that ensure the reliability of commercial transactions. Nowadays, the reliability of commercial transactions through digital money is ensured by specific practical norms regarding using machines for money transferring, such as ATMs, e-banking through authorized web-pages, money transfers from account to account, etc. These digital transactions either take place in national currency, if the transaction takes place at the national level, or in international currencies, such as the US dollar, the euro and the British pound if transactions take place at the international level. International digital transactions include, for example, interbank transactions such as purchases of goods and services from multinational companies such as Wal-Mart Stores, Inc., Costco Wholesale Corporation, Carrefour SA, Amazon, etc.

In this paper, we contribute on the discussion of the nexus between human and mechanical or digital character of financial activity by providing a paradigm from ancient times, the Athenian democracy during the Classical period (508–323 BCE), and then we compare our findings with the current digital currencies regime. One might wonder how and why the auditing mechanisms introduced by Athens during the Classical times is connected with the current situation and the new horizons that open up in the context of international trade due to the rapid spread of cryptocurrencies. The answer is that, by recognizing in advance the limitations of space and time, we have been inspired to

perform such an intertemporal analysis, since there is an important qualitative element that is found in both cases; The Athenian monetary structure and the current situation with the cryptocurrencies are accompanied by the fact that both cases thrive without the presence of a Central Bank.

In Athens during the Classical times there was no Central Bank authority and the decisions regarding the annual money supply in the economy were determined (i) by the assembly of citizens; and (ii) by the market forces themselves. In particular, money supply was determined by direct democracy voting procedures; at a given time of the year, the Athenians who were participating in the popular Assembly meetings decided also regarding the crucial issue of monetary policy, that is the determination of money supply for that year. The Athenians decided by voting after hearing the (sometimes different and contradictory with each other) views by those orators who were also financial experts such as Nicophon. However, the crucial element here is that the overall money supply was 'co-determined' by market forces themselves. In particular, wealthy citizens as individuals or consortia of businessmen who had bid in public auctions and were authorized to exploit particular tracks of the silver mines through leasing procedures, had then the right to use the silver bullion they earned by applying to the state silver mint and converting it to coins bearing the Athenian stamp (with a seigniorage cost) which they then could legally use and circulate in the economy, thus increasing the money supply [1–3]. We analyze this in Section 2.2. Furthermore, banks could also produce money and metics (alien residents who came to Athens for work) could also bring currency from their city-states of origin and this currency, if not being fraudulent coins, could be also accepted by the Athenian authorities and circulated within the Athenian economy.

These mechanisms in actuality denote that the exact amount of money circulated within the economy was not solely determined by the state, but in combination to the market forces themselves. In the same light, cryptocurrencies are in contrast to the official currency issued by the respective state monetary authority and in addition their purchase and sale are regulated by the market forces, as they are formed in these special cryptocurrency markets.

What is also crucial in our analysis is that, as we further argue, the success of both of these two monetary regimes is based on their ability to ensure the solvency and reliability of transactions between the parties involved, and of course this requires in practice the establishment of adequate auditing and monitoring mechanisms and institutions. In other words, such special kind of regimes were/are based on trust and a necessary condition to achieve it is to establish effective auditing mechanisms so as to ensure the reliability of financial-commercial transactions.

In this light, we consider it worthwhile to study the auditing mechanisms of the Athenian monetary policy system without a central bank in comparison with the corresponding mechanisms concerning cryptocurrencies, in order to draw conclusions that perhaps could be useful for today. Due to space limitations we chose to elaborate on the Athenian monetary institutional set up, which is less known than the current cryptocurrency regime. After all, there is a plentitude of recent studies which describe how cryptocurrencies function, such as [4–10]. To the best of our knowledge, this is the first contribution of such kind of research in the bibliography.

The paper is organized as follows: in Section 2, we present briefly the Athenian economy and the Athenian minting procedures during the Classical period. The Athenian economy's institutions were based on free market economic principles, as we know them today, even if in their primitive form. We also explain in brief that the Athenian monetary regime was based on a decentralized character, in the sense that there was no Central Bank authority with the exclusive privilege of determine the overall amount of money supply. Money supply was co-determined by the market forces themselves.

In Section 3, we explain what protocols of behavior and mechanisms were applied in practice by the Athenian authorities so as to ensure the protection of transactions from counterfeited coins (i) at the city-state ('national') level; and (ii) at the international level,

so as to ensure the establishment of the Athenian drachma as the leading currency for performing international transactions in the Mediterranean. The Athenians had understood that a pure and reliable in silver content drachma was critical so as to ensure their long-term economic prosperity.

Section 4 describes the main modern mechanisms that ensure the reliability of commercial transactions through cryptocurrencies. Finally, Section 5 concludes by comparing the ancient and the modern practices.

2. The Athenian Economy

Athens is perhaps the best known of the Greek city-states of the antiquity. During the fifth century BCE, when democracy was established, it had an estimated total population of approximately 400,000 inhabitants (citizens, alien residents and slaves) and a territorial area of about 3000 square kilometers [11]. The political system was mainly based on the Athenian popular Assembly of citizens who were taking decisions on a variety of state issues such as war and peace, foreign and economic policy. Every citizen could vote at the age of 20 that is, after fulfilling his military service, and being voted as a public magistrate at the age of 30. The second major political institution in Athens was the Athenian Council. It consisted by 500 members and its main functioning was to prepare the agenda of discussions for the meetings of the Athenian popular Assembly of citizens. It had also important executive and administrative tasks [1,12].

After repelling the second Persian invasion together with other Greek city-states during 480–479 BCE, Athens became the leading naval and maritime power in the Eastern Mediterranean and the center of a military alliance of city-states, known as the Delian League which developed into an empire of more than 300 city-states [13]. In order to repel the Persians the Athenians build a large ship of 200 warships, which was equal to the two-thirds of the whole Greek fleet, in two consecutive years, 482–481, and this 'turn to the sea' strategy not only resulted in their decisive victory against the Persians in Salamis in 480 but also transformed their economy from an agrarian into a maritime and commercially extroverted one, as it did happened with the economies of the United Provinces (Dutch Republic) and England during the 16th–17th centuries [12].

In parallel to the Delian League, a unified economic area by the same and even more members was gradually created where commercial transactions were freely taking place through an establishment of a parallel system of circulation of coinages where various kinds of currencies were exchanged by merchants. Among them, the Athenian *drachma* became the leading currency and the most commonly used by the allies due to its excellent purity in silver content, backed by the economic might and the strong geopolitical position of the city-state of Athens [3,13].

2.1. The Athenian Maritime Economy

Athens had an open free market type of economy with modern characteristics, such as: free movement of goods, capital and people to and from Athens [3,14–17], laws against profiteering, laws in favor of the protection of property rights and commercial contracts [18], advanced banking and insurance services [19], and sophisticated systems of public finance and monetary policymaking in practice [3]. For the first time in history, in Athens, the handicraft industry and services sectors contributed more to GDP and employment than agriculture, thus making Athens, according to [20], the "first modern economy". Considerable economic growth also took place especially during the 4th century BCE [1,3]. The Athenian economy, like nowadays was a "mixed" one, with the state being the biggest employer, mainly through its *trireme* type of warships fleet and public administration [3].

The Athenian mercantile marine comprised about 300–500 open sea ships plus many smaller coastal ships, fishing boats, etc., giving employment to perhaps 5000 men. Many professions were related to the commercial fleet and the navy (warships) of Athens, which had significantly expanded from their pre-existing, pre-Classical period. Among these were professions related to timber (for the production of ships, oars, etc.), forges, iron and

bronze workshops, shops for ropes and paint, as well as a variety of products that were related to the shipping industry such as hemp, pitch, flax [12]. Other services included all those around the port of Piraeus, the biggest harbor and entrepôt of the Mediterranean, like ship loading, taverns, hotels, banking services, etc. According to [19], the port of Piraeus became the international entrepôt of antiquity, as was Alexandria during the Hellenistic times, Amsterdam during the 17th century AD and among others, Hong Kong, Shanghai, and Rotterdam today.

Handicrafts within the city of Athens were well developed and the famous philosopher Xenophon lists about 170 different types of professions, which included stonemasons, smiths, utensil makers, clothes makers, shoemakers, jewelers, carpenters, furniture makers, etc. Some enterprises employed more than 100 people (some, mainly slaves) although usually most were operated by self-employed persons assisted by perhaps one apprentice and one or two slaves [21]. Institutionally, even primitive forms of insurance companies and joint-stock companies were developed in Athens, primarily for maritime trade [19,22].

2.2. Mining and Cutting the Athenian Drachma

During the Classical period, the city-state of Athens possessed rich silver ores at Laurion, in a large area which was located at the southern region of Attica. In order to extract the ore, the Athenian state established a body of public servants known as *Board of Poletai*, literally meaning, "Board of Sellers", which was responsible for selling/auctioning plots of public land in the silver-producing area to the highest bidder, who then extracted the metals (mining leases). These bidders were either (wealthy) individuals or private consortia whose members were seeing the mining procedures as a business investment from which they could earn profit.

The Athenian state taxed each private bidder with an approximate 4.125% on the revenue from the extracted silver. State taxes and rents amounted to about 10% of the market value of the extracted silver. The rest belonged to the consortia or individual entrepreneurs, who received their profit in the form of bullion, silver ingots. They then were free to either selling it to the state or in the free market. If they chose the first option, they were receiving coins at a discount of about 10%. This discount covered an estimated cost of minting in the Athenian silver mint known as *Argyrocopeion*, of about 2%, the remaining 8% being profit or *seigniorage*. The largest volume of such coins was the so-called *tetradrachms*, (meaning four *drachmae*, each supposed to weigh 17.24 g) [3]. Smaller silver denominations were also issued known as *obols*, very useful for day-to-day market transactions, such as buying bread. One *drachma* was equal to six *obols* [13]. Bronze value coins of even smaller value known as *chalkoi* and *kollyboi* were issued by private consortia or individuals, so that very small value transactions to be able to take place effectively [2]. The Athenian mint probably found the minting of small-value bronze coins to be uninteresting. Perhaps they did not have the capacity to do so, or perhaps the profit margin (seigniorage) was too small. This private currency could be seen as a precursor of today's private digital currencies.

2.3. Money Decentralization under Alternative Means of Money Supply Determination

The Athenian currency, the famous Athenian drachma was silver made since and was a kind of commodity money, like every other kind of currency of the time. Thus, it had an intrinsic value, a situation which is totally different to the modern practice of fiat money. The annual currency production by the state silver mint was determined by the Athenian Assembly citizen's decisions as to the proper amount of money supply that should be produced annually so as to cover the annual needs of the state [13]. Thus, issues of monetary policy were decided by the assembly. Experts on monetary issues discussed and even debated in the assembly as to the proper mixture of monetary policy and money to be produced so as to cover the state needs. Citizens having previously heard speeches and suggestions by these financial experts such as Nicophon then decided (under direct democracy procedures) on the annual money supply of the state [3]. This

is a major difference with today's situation in which monetary policy is entrusted to non-elected 'experts' and 'nonpolitical' bodies like the Central Banks which (in principle) are independent of political manipulation.

The city-state of Athens, through its 'budget', had to cover the payments of various posts of public magistrates such as, those who served on the navy, cavalry, and infantry, the construction and maintenance of fortifications and public buildings such as temples. Further expenses included the costs of the administration, such as the wages of the 700 public magistrates who worked in various government agencies such as police services, water supply, street cleaning, maintenance of the city's walls, maintenance of the city's temples, the education of orphans whose fathers were lost in war, foreign embassies, etc. [23,24]. All these payments were made in silver currency, so the supply of coins had to be sufficient to cover these expenditures.

What is crucial is that money supply was also determined from the private sector. Money supply could be further increased by the melting and monetization of silver bullion held by private agents. Anyone who had silver bullion could convert it into drachmae at a small fabrication and seigniorage cost. For example, individuals or consortia of individuals who had been granted by the state the exploitation of areas in the silver mines of Laurion through land lease (as mentioned in Section 2) could use the bullion they earned by converting it into currency through the Athenian mint [3]. They could then use this currency for various economic activities. Of course, this new amount of money that was being circulated into the economy essentially increased the money supply in the market. Thus, the mint undertook a function which looks similar to modern Central Banks practices, in terms of influencing liquidity through their interest rate (discounting) for the acceptance of bullion.

In accordance with the above, a third way of influencing money supply by the private sector was by issuing small-value bronze coins by private persons as described in Section 2.2. Fourth, war booty in the hands of Athenian privates was also a means of increasing the money supply in the economy, even if in an 'unorthodox' way. A fifth source of money supply should be attributed to the existence of banks. In Section 3.2, the issue of the plethora of banking services that were practiced in Classical Athens is further analyzed. The ordinary interest rate for someone who borrowed money from a bank varied between 12% and 18%. What is important in relation to our analysis is that since the Athenian commercial banks did give credit, we assume that they increased the overall money supply in the economy. However, we do not have statistical evidence/cliometrics data available to calculate the size of the money multiplier and in general the effect of money supply by the banking sector. A sixth way should be attributed to *metics*. As already mentioned in Section 2, *metics*, alien residents who came to Athens for work purposes could bring currency from their city-states of origin and this currency, if not being fraudulent coins, could be also circulated within the Athenian economy if it was found to be pure, that is, not being fraudulent coins (see Section 3).

Finally, as [3] argue that the Athenian state could also borrow money when in need from the so-called Treasury-Temples of Athena and the Other Gods in order to finance military or other state expenses. These treasuries were related to the temples of Athens and Attica as a whole. They were receiving various remittances such as donations of believers to the gods and then could use them to provide loans to the state. This was another indirect way of increasing the money supply in the market.

3. Institutional Mechanisms and Laws against Fraudulent Coins

In this section, we focus on the institutions and mechanisms of safeguarding the purity of the Athenian drachma that were adopted by the Athenian policymakers. As it will be further argued below, these mechanisms were a key reason for the Athenian *drachma* to become the leading international currency of the Classical period.

3.1. Argyramoiboi (Moneychangers)

In Athens many *argyramoiboi* (moneychangers) were active in the economy. This occupation was older than the Athenian banks and dates back to the end of the sixth or the beginning of the fifth century, i.e., during the period when many city-states first issued their own coins and commerce was gradually expanding throughout the Mediterranean. In order to facilitate exchanges between merchants from different cities, using different coins, the moneychangers undertook the tasks of assessing the value of coins according to their content in precious metal, usually silver, and determining their exchange rate.

According to [19] an *argyramoibos* was anyone engaged in the testing or conversion of coins and precious metals. Usually, they charged a fee of 5–6% of the value of the exchange. However, gradually the functions that moneychangers performed were taken over by other institutions and their importance in the economy declined due to the rise of banks and the *dokimastai* as we describe below. The ways of testing the coins included checking the coin by sight, palpation and through touchstone materials. A touchstone is a small tablet of dark stone such as slate or lydite, used for assaying precious metal alloys. It has a finely grained surface on which soft metals leave a visible trace. This rock has a very strange property. When a piece of gold or silver is rubbed on it, a trace of a specific color is engraved on its body. For example, if instead of pure gold, an alloy containing gold is rubbed on the stone, then the trace has a different color. The more gold or silver the alloy contains, the more intense is the color of the trench.

3.2. Athenian Bankers

The next step after moneychangers were the Athenian bankers which did more than just testing and exchange of money. The seminal book [19] *Athenian Economy and Society* describes in detail the plethora of banking activities that were practiced on the Athenian economy. Athenian bankers: (i) accepted deposits; (ii) carried out payments on behalf of their customers; (iii) provided loans to various business operations, such as maritime loans; (iv) financed consumer credit; (v) exchanged Athenian coins with foreign currencies; (vi) facilitated export-import activities by settling payments to merchants abroad; (vii) provided insurance services; (viii) provided consultancy services to important customers; (ix) provided collateral, for example, of the ship in the case of maritime loans; (x) accepted documents and valuables for safekeeping (they did not act in the capacity of pawnbrokers); and (xi) made partnerships with each other so as to create a common financial pool and then provide (mostly) maritime loans to merchants in need. They created a primitive version of the later joint stock companies of Early Modern Europe period.

The ordinary interest rate for someone who borrowed money from a bank varied between 12% and 18%. However, maritime loans could rise even as high as up to 100% due to the great uncertainty that was related to maritime trade and the safeguard of the cargos, [19]. Thus, interest rates varied according to the type of activity. Ref. [19] states that in Classical Athens not less than 30 bankers are attested by name. The available information does not allow an estimate of the contribution of the banking system to employment and GDP; however, according to [3], due to the fact that all these bankers were heavily engaged with the commercially oriented aspect of the Athenian economy on the 'international' level, their contribution must have been important. This means that the Athenian bankers were responsible for a large percentage of money transactions within the economy. Of course, when the Athenian bankers were performing transactions, they had the experience to evaluate efficiently the purity (or not) the coins with which they were about to do business with their customers (mainly, merchants). They could easily adopt the methods that moneychangers were used to. Essentially, the bankers provided to the Athenian state an indirect service; to evaluate the reliability of the currencies that they were circulated in the economy.

3.3. The Law of Nicophon and the Money-Testers

In parallel to the creation of the Delian League a new monetary network which comprised the League's members was created in 478/7 BCE. From hoards found in the Athenian *Agora*, the marketplace, which was the center of the commercial activity of the city, we know that foreign coins were also exchanged in the Athenian economy in parallel to the Athenian drachma, such as coins from the island of Chios, Aegina, Megara, and Chalkis [13,25–28].

In 449 BCE, the Athenians tried to impose the so-called Coinage Decree, a decree on their allies to use only Athenian coins, weights and measures in their financial transactions. In practice the Athenians did not manage to either prohibit the minting of coins by other city-states or forbid the parallel circulation of their coins [13]. However, because of the economic and geopolitical might of Athens but also because the Athenian coins were of excellent craftsmanship and pure silver content, the Athenian *drachma* became the leading currency among the allies and in the East Mediterranean in general.

Because of the international reputation of the Athenian *drachmae*, other mints, such as from Syria, Egypt, the Levant, the Near East, even from Arabia and Babylon struck imitations of the Athenian coins. Many of these imitations were of good silver and proper weight. However, counterfeit owls—copper, lead, or bronze ores plated with silver—were also produced. In the early fourth century BCE, counterfeit foreign pieces circulated side by side in Athens with genuine silver owls of greater intrinsic value, creating a grave problem for merchants and purchasers alike [1,13,28,29]. This was a serious threat for the smooth operation of the economy, since would lose faith in the Athenian drachma as a means of exchange and in the Athenian market [1].

To deal with this situation and in order the Athenian drachma to retain its dominant position as the leading currency in the Mediterranean, a critical decision was the introduction of the so-called Nicophon's Law of 375/4 BCE after the proposal of the lawgiver Nicophon and its acceptance by the Athenian popular Assembly of citizens. This law which came as an evolution of a pre-existing law who dated back to 398/7 BCE required, among other things, that all foreign-made imitations of the Athenian *drachmae* entering the Athenian economy for the purpose of conducting commercial transactions, were allowed to be circulated freely in the economy providing that: (i) these coins were of the exactly the same silver content like a genuine Athenian *drachma*; (ii) bearing the same stamp, like a genuine Athenian *drachma*. In other words, if the coins under examination were evaluated to be genuine imitations of the Athenian *drachma*, they were returned to the foreign traders who could use them freely in the Athenian economy for any kind of transaction, such as purchase of goods and services [1,13,28,30–32]. In any other case, e.g., if those coins found with less silver content or having a bronze or lead core, they should be confiscated immediately by the state authorities. Counterfeited coins issued either by individual forgers or by foreign states as part of a policy of deliberate debasement [30].

The inspection of the coins was undertaken by a new special service, two public slaves known as *dokimastai* (testers) who each had a counter in the *Agora* of Athens and Piraeus and inspected the currencies of foreign traders regarding their purity (or not). Some categories of public slaves performed tasks that carried great responsibilities and had direct effects on the lives of citizens. Such a category included also the *dokimastai* [33]. As has already mentioned an earlier version of the institution of the *dokimastai* was dated back to 398/7 [30,34]. As was the case with all the posts of magistrates in Athens, the two testers were fully accountable during and after the end of their term. They were under strict supervision by a state body known as the *syllogeis* (collectors) [3]. The testers should be highly experienced slaves and if the Athenian Council did not find the right man so as to perform such a duty, they had to go out and appoint one, possibly, a banker or a silversmith. According to Nicophon's Law, if the testers did not sit or did not validate in accordance to the law, the *syllogeis* were responsible to strike them 50 lashes with the whip [30,33]. This severe punishment was a real motive for the testers to perform their duties effectively. If, after testing of each coin, there was still an Athenian merchant who

did not trust these foreign-made coins, he should be deprived of all the products he was selling that day. Quite simply, his products were confiscated, apparently as a punishment because he did not trust the state's institutions that carried out the relevant audit.

Another diastasis in this discussion is that an Athenian merchant could demand from a foreign merchant that they both apply to the testers only if he was not sure of the authenticity of the coins that the foreign merchant brought with him to carry out the transaction between them. However, in the event that the Athenian merchant had confidence in the foreign currency, it was not necessary for them to apply to the testers [25]. In other words, Nicophon's Law did not demand the mandatory inspection of all the foreign traders' currencies. The law served as a mechanism for securing confidence between trade parties and according to [1] as mechanism to reduce transaction costs. According to modern financial economics theory, transactional cost reduction based on [35,36] theoretical concept is a crucial element for performing financial/commercial transaction efficiently, fast, and profitably. Of course, it must be acknowledged that there was always the possibility (even small) of counterfeit foreign currencies to be circulated in the Athenian economy. The above views are verified by the eminent historian of money in Greek antiquity [13].

3.4. Coin Testing Techniques

In practical terms, the testers were using a series of techniques so as to find out if a coin was a counterfeited one or not. Below we describe these techniques based on the important findings of authors who are experts on the topic, such as [1,13,25,30,33,34,37,38].

i. Checking by sight
ii. Palpation
iii. Sound diagnosis
iv. Smell
v. Test cuts
vi. Using special scales
vii. Cupellation
viii. Touchstones
ix. Dies differences
x. Countermarked coins

Regarding 'checking by sight', the sight of a coin was the first element of inspection and an important source of information that was crucial for an experienced currency tester before he reached his final verdict. Regarding 'palpation', the coin testers had a lot of experience and the daily touch of coins had become almost their second nature. By palpation, they could have a pretty good first view about the purity or roughness of these coins. Palpation would be more difficult for plated coins, but with debased coinage, even c. 15% copper could create a different texture on the coin.

Regarding 'sound diagnosis', the coin testers threw the coin on a hard surface for sound diagnosis. In particular, the coin testers were familiar with specific sounds indicating whether a coin was pure in content or counterfeit. Regarding 'smell', this was another method of inspection of a currency's purity. Bronze and silver have distinct smells and when the coin was warmed by rubbing in the hand, it would be possible for a trained nose to smell if there was bronze inside a counterfeited coin. Another method was 'test cuts' through which a coin tester could carefully inspect suspected coins, was making small test cuts on the edge with a small chisel to see if there was a plated core. Many surviving Athenian *drachmas* bear such test cuts.

A further method was 'using special scales': there were special precision scales, sealed and certified by the city's official authorities that testers could use to determine whether or not the weight of the currency in question corresponded to the correct weight of a pure and legally circulated silver coin in the economy. These special scales were placed in the *metroon*, the place where the archives of the laws of the state were also kept.

Another method was 'cupellation': cupellation is a refining process in metallurgy where ores or alloyed metals are treated under very high temperatures and have controlled

operations to separate noble metals (like gold and silver), from base metals (like lead, copper, zinc, arsenic, antimony, or bismuth) present in the ore. The process is based on the principle that precious metals do not oxidize or react chemically, unlike the base metals, so when they are heated at high temperatures, the precious metals remain apart, and the others react, forming slags or other compounds [39]. A similar method to cupellation is described by Aristotle (*Problemata* 936b) and it is further elaborated by [40] known as spirting technique. According to Ober (2008, 237), although it cannot be verified, it is possible that the testers were engaged in tests by cupellation, when they were not on duty at their tables. The truthiness of Ober's claim is further supported by [38], an expert on ancient metallurgy, who argues that the processing and melting of various types of metal, such as iron, was already known to the Ancient Greeks, at least from 900 BCE. More specifically, [38] provides evidence (i) regarding how coins from silver or other material were made; (ii) that cupellation regarding silver ores from Laurion mines was a common practice. The silver mines of Laurion were worked, from very early times, even since the Mycenaean times, that is, before 1100 BCE [38]. Obviously, during the period we describe (508–323 BCE) melting and cupellation practices became more advanced due to aggregated knowledge from earlier times. As a final comment, cupellation techniques made the testers more experienced and capable to recognize and separate more easily the pure from the fraudulent coins.

Another method had to do with 'touchstones'. According to a variety of authors such as [30], the coin testers employed touchstone techniques so as to reveal if a silver coin was pure or counterfeited [41]. Another way that was of help to an experienced coin tester to separate a pure Athenian *drachma* from an imitation or a fraudulent coin made abroad, was 'dies differences'. This had to do with the size differences between the dies from which the coins were made. Athenian dies were smaller and made a deeper impression in the flan, Athenian flans were often more oblong and Athenian dies often had finer details [30,34]. Ref. [37] discusses the importance of special die axis and how Athens in the Classical period struck its reverses in an attempt to thwart counterfeits.

Finally, another method was 'countermarked coins': A countermarked or counter-stamped coin was a coin that had some additional mark or symbol punched into it at some point after it was originally produced while in circulation. Countermarking involved placing a design, with a small punch, on a coin to verify its purity and/or validate it for acceptance. Starting in the late sixth and early fifth centuries, originally, countermarks were probably marks made by bankers and money-changers, but certainly by the fifth century this practice was introduced also by city-state authorities as well as a way to denote that a particular coin was genuine [13,25]. The fact that numerous test cuts and countermarked Athenian coinages have been verified by the archaeological evidence denotes the fear that many merchants and individuals had of receiving counterfeit coins.

As a sum up of the above, checking the purity or not of the coins was based (i) on the human factor (cases (i)–(v)); (ii) on the technological factor (cases (vi)–(x)). As a final element regarding the Athenians' understanding of the importance of using reliable currency for undertaking efficient (trade) transactions was their decision to punish by death those who were trying to circulate debased/fraudulent coins for making personal profit. This attitude of the Athenians comes as a proof of the great importance that the Athenians recognized on the role of money, among other things, as an important component that guaranteed the prosperity of their state in the long run.

4. Methods of Ensuring the Reliability of Modern Forms of Money

Evolution at the domain of currencies has brought to the surface highly innovative forms of liquidity. The most modern form of currency is digital currencies that serve as means of transactions and in a lesser extent as units of account or stores of value. There are many authors who are raising their concerns regarding digital currencies such as bitcoin, on the following issues:

i. No one is backing them, meaning an official authority
ii. It is not a generally accepted form of currency
iii. Users are not protected from hackers
iv. Digital currencies are too volatile and for many they should not be considered as a reliable form of currency
v. Digital currencies are speculative assets in nature (we owe these key clarifications to one of the referees).

There is no doubt that an effort to highlight all the aspects related to these five points is very important but, due to space limitations, it goes beyond the analysis carried out here. However, in the following part of this section, we provide a brief overview on the current existing literature on the topic regarding the purpose of digital currencies in practice. It should be emphasized that methods for ensuring the trustworthiness of digital currencies do not focus on testing their physical characteristics because such currencies are immaterial. It should be noted that digital currencies have no centralized issuer and are fiduciary since they are not backed by precious metal. Thereby, trust is the basic characteristic in order to preserve transactions by digital currencies to continue [5]. Intriguingly, these currencies are not backed by the premises of a banking institution and they are usually denominated in their own units.

The characteristic that mainly distinguishes digital currencies from previous forms of money—such as metallic, fiat, or plastic money—is that they function through a universal distributed ledger, which is called the 'blockchain'. This system undertakes the strenuous task of confirming all transactions based on digital currencies and enables keeping track of individual balances of them. It should be emphasized that the responsibility for such recording of transactions is taken by a network of highly sophisticated machines, i.e., computers. This is in stark contrast with the primitive technology employed in order to test the purity of metallic coins. The databases of financial records contain all the transactions that have taken place by the digital currency. Moreover, the balances of all people that make counterparties in such transactions are recorded. It is of the utmost importance that no fake money flows could emerge as no double spending can be achieved by digital currencies as it is checked whether these units were part of previous transactions and have been used again in the past. This means that no fake digital money can be created out of nowhere. This could be parallelized with the fight of Athenians to prevent the falsification of metallic currency.

Thus, for authors such as [6] Blockchain technology, as a distributed digital ledger technology ensures transparency, traceability, and security in transactions and is showing promise for easing some global supply chain management problems, and can ensure supply chain sustainability. Ref. [7] further argue that the real revolution of blockchain is that redefines "trust" as "high-trust computing", as you no longer need to trust anyone but an algorithm. It brings reliability, transparency, and security to all manner of data exchanges: financial transactions, contractual and legal agreements, changes of ownership, and certifications.

As concerns the creation of new units of money, it should be stressed that cryptocurrencies such as Bitcoin are characterized by capped total supply which continues in a steady rhythm until it reaches a specific number of coins and then no more units are produced. Users engage in problem-solving concerning a mathematical puzzle that is based on already existing contents of the group of transactions. Thereby, they get rewarded by new units of digital currencies and this process is called 'mining' [4].

Mining makes sure that the historical ordering on the chain of all blocks abides by the entire network transactions. Notably, miners by continuing to work and displaying their solution to the puzzles imposed for creating new coins use the new parts of the chain of blocks to reveal that they agree about the record of transactions realized by the digital currency. It is often that six confirmations are needed in order to be ascertained that transactions are recorded and that no double spending has occurred. This confirmation procedure takes about an hour to be completed. Due to these procedural steps, some

authors who are working in the frontiers of these technological developments regarding digital currencies, such as [42] even go as far as to declare that:

> A more energy efficient and secure form of Bitcoin will possibly emerge as a World Currency, like the Globo. An easily programmable blockchain ledger, like Etherium, will possibly emerge as a replacement for Stocks and Bonds, and other contracts that are securities. The Bitcoin equivalent in Etherium, Ether, can possible also emerge as a World Currency.

On the other hand, it can be argued that Bitcoin and relevant cryptocurrencies apart from being innovative forms of liquidity constitute highly speculative investment assets that display inefficiency in their markets and exert spillovers to other financial assets [43–45] and bear far from large similarities with gold [10]. Moreover, investors that prefer to be holders of technological companies' stocks consider Bitcoin and other digital currencies to be a highly revolutionary technology that could display growth of an exponential rhythm. This gives further credence to the notion that such innovative forms of money could present bubble characteristics in their market values that could not be easily predictable by the large base of investors. Therefore, they could lead to skyrocketing flourishing markets that would also be empowered by the mimicking behavior among uninformed investors [46]. Moreover, [47] support that if Bitcoin is primarily used as a currency for transactions it will compete traditional national currencies—such as the US dollar—and will result in affecting monetary policy decision-making. Up to the present though, cryptocurrencies are mainly used as investment assets so they have become competitors with government bonds, stocks, and securities.

Intriguingly, their drawback as currencies—that is, high fluctuations—renders them more attractive for risky investors as higher risk is characterized by higher possibility for profit-making. This corroborates the findings of [48] that provide evidence of the speculative component of Bitcoin being very large and leading to large bubble formation. Moreover, [5] contend that the majority of cryptocurrency addresses are not active while those that are active are mainly used for gambling or speculation. Notably, even though [49] states that Bitcoin fails to satisfy the three mains functions of money, [50] identifies that their inflexible supply and their wildly fluctuating demand are the principal drawbacks of cryptocurrencies and emphasis should be given on their credibility in order to ameliorate the probability of enjoying a 'legal tender' status.

5. Conclusions and Findings

From the above analysis a number of conclusions emerge. First of all, a crucial element for the success of a monetary regime without a Central Bank such as that of Classical Athens and the current digital currencies establishment is to ensure the reliability of currency. The two cases analyzed with this paper verify the intertemporal axiom that in order to ensure reliable financial-commercial transactions, sound money is required. To achieve this Athenians had established an efficient system of checking the soundness of their currency through the existence of (i) the Athenian moneychangers; (ii) the Athenian bankers; (iii) the *dokimastai* (coin testers).

In fact, this was a triadic process where the private sector (moneychangers and bankers) and the state (the coin testers) were significantly involved. Moneychangers and bankers were involved indirectly; no one of them could accept either debased or fraudulent currencies since this would lead to a personal loss (loss of profits). In fact, these two groups provided auditing services as far as sound money is concerned, and this, in a wider sense was to the benefit of the society as a whole. Regarding the current digital currencies establishment, the reliability of currency is ensured through blockchain techniques.

In both cases achieving the reliability of the currency had a series of positive feedbacks which ensured the success of these regimes. These included: (i) low transactional costs relative to (ii) speed in commercial transactions which is a very crucial qualitative element regarding the success of an economy's commercial orientation; (iii) security, in Classical Athens achieved due to the techniques (i)–(x) described in Section 3.4. Security under a dig-

ital currency regime of transactions is achieved through the 'blockchain' which technology ensures the integrity of transfers. The reverse is also true: the lack of these preconditions jeopardizes and completely calls into question the success of such monetary regimes.

Recognizing the limitations of our analysis argument as we compare two long-distance monetary regimes, we believe, however, that our findings may be the starting point for further research by the academic community on related issues, which connect the current monetary phenomena with monetary paradigms of the past.

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