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# Origins of arbitrage

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Following a review of the etymology and modern usage of the term 'arbitrage', this article explores the relevance of historical context to possible instances of ancient arbitrage activity. Types of possible 'arbitrage' associated with the use of overvalued coinage in regions of Greek influence are considered. Comparison with Roman civilization reveals the relevance of social attitudes and legal institutions to the ability to execute arbitrage trades. Specific attention is given to the possibility of arbitrage across the Roman frontier to India and the impact of debasements during the imperial period. Recognizing that sources prior to early modern times are scant, numismatic, epigraphic and literary evidence that is available to make inferences about ancient arbitrage activity is assessed.

**Keywords:** arbitrage, Greek coinage, bimetallism, Roman coinage, debasement

The competition between 'primitivist' and 'modernist' historiographies has produced a vast literature seemingly incapable of resolving whether the ancient societies did, or did not, have a market economy. Aiming to join numismatic evidence with textual, epigraphic and archaeological sources, this article seeks to determine the arbitrage trading mechanics of merchants that were involved in ancient financial exchange, primarily in the Greek and Roman eras. While scarce and 'often so one-sided' ancient sources do not reveal 'how much money circulated at any time, or how many "bankers" there were' (Meikel 1995, p. 176), there is evidence of entrepreneurial traders in the ancient world that did profit from activities of rudimentary financial institutions. Being primarily concerned with the characteristics of coinage, numismatists are satisfied with recognizing that profit was made from coinage, without detailing the trading mechanics. Similarly, economic and financial historians are more concerned with finding evidence, or not, for an ancient market economy than with details of how arbitrage trading was conducted in ancient societies. By contrasting ancient arbitrage activity with such trading in both modern and early modern financial markets, this article aims to provide insight into ancient financial institutions.

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## I

What is arbitrage? How does arbitrage trading differ from speculation? The modern concept of 'arbitrage' has a range of definitions. A common theoretical textbook definition used in the pricing of derivative securities is for a riskless trading strategy generating a positive profit with no net investment of funds. This perfect markets definition of arbitrage is exploited in the derivation of formulas for specific contingent claims, such as covered interest parity and the Black-Scholes option price, based on assuming an absence of arbitrage opportunities. It is well known that the textbook description can only approximate actual arbitrage trades (e.g. Shleifer and Vishny 1997). Studies about the 'limits of arbitrage' identify distortions that cloud the simultaneous execution of arbitrage trades with speculative overtones: difficulties and costs of 'shorting' and borrowing; execution lags; transaction and information costs; credit and settlement risk; capital constraints and so on. These limitations are documented in studies of empirical performance that encompass cash-and-carry arbitrage, municipal bond arbitrage, merger arbitrage, statistical arbitrage, risk arbitrage and convertible bond arbitrage. Motivated by a price difference at a given point in time that exceeds the perceived arbitrage bound, in practice the short–long strategies involved in arbitrage trading require some capital; are perceived as low risk; and have limited likelihood that trading profits can be negative.

Close examination of practical arbitrage execution at a given point in time reveals substantive details about the structure of financial institutions that facilitate the relevant trades. For example, consider the Japanese stock index arbitrage trades used to motivate the 'sociology of arbitrage' explored by Miyazaki (2007). The arbitrage is motivated by a difference between the price of a Japanese stock index futures contract and the associated stock index price at a given point in time. The arbitrageur reacts to momentary violation of an arbitrage bound by attempting to simultaneously short what is expensive and buy what is cheap. The use of Japanese stock index futures contracts and the ability to rapidly execute trades in a basket of stocks that proxy or replicate the index requires a sophistication in the structure of financial institutions that was unavailable until the later 1980s. Communication technology and computerized trading facilitate the aim of simultaneous execution of the short and long positions. In turn, the structure of financial institutions in previous historical periods is reflected in restrictions on the ability to execute arbitrage trades, narrowing the types of trades that can be executed without crossing the line between arbitrage and speculation.

Some evidence of considerable evolution in what constitutes arbitrage trading can be inferred from the etymology of arbitrage provided in the *Oxford International Dictionary* (*OID*; 1933), which defines arbitrage as: 'The traffic in Bills of Exchange drawn on sundry places, and bought or sold in sight of the daily quotations of rates in several markets. Also, the similar traffic in stock.' The initial usage is given as 1881. Reference is also made to 'arbitration of exchange' where the definition is: 'The determination of the rate of exchange to be obtained between two countries

or currencies, when the operation is conducted through a third or several intermediate ones, in order to ascertain the most advantageous method of drawing or remitting bills.' The singular position given to 'arbitration of exchange' trading using bills of exchange recognizes the practical importance of these securities in financial markets at that time. Significantly, the *OID* definition does not identify other arbitrages that were present at that time, such as gold-point arbitrage (Officer 1993) and triangular arbitrage for manual foreign exchange transactions, or that the arbitrage trading mechanics of inter-exchange arbitrage ('shunting') of 'stocks' could also apply to coinage, bullion and commodities (e.g. Poitras 2010).

Though it may be descriptive of most arbitrage trading at that time, etymological reference by the *OID* to 1881 for initial usage of 'arbitrage' is incorrect. Following the usage of 'arbitrage' in German and Dutch works in the 1860s, the term 'arbitrageur' in English appears with Ottomar Haupt, *The London Arbitrageur* (1870), though reference is still made to 'arbitration of exchange' as the activity of the arbitrageur. Haupt produced similar works in German and French that used 'arbitrage' to describe the calculation of parity relationships. A pamphlet by Maurice Cohn, *The Stock Exchange Arbitrageur* (1874), describes inter-exchange 'arbitrage transactions' between bourses but also uses 'arbitration' to refer to calculated parity relationships. Charles Castelli, *The Theory of 'Options' in Stocks and Shares* (1877), concludes with a section on 'combination of options with arbitrage operations' where arbitrage has exclusive use and no mention is made of 'arbitration' of prices or rates across different locations. In Henry Deutsch, *Arbitrage in Bullion, Coins, Bills, Stocks, Shares and Options* (1904), 'arbitration of exchange' is not used and the notion of 'arbitrage' is extended substantively beyond bills of exchange.

Recognizing an etymological origin in French, the first published usage of '*arbitrage*' in discussing the most profitable locations for issuing and settling a bill of exchange appears in Mathieu de la Porte, *La science des négocians et teneurs de livres* (1704, p. 452). From the brief reference in a glossary of terms by de la Porte, some French sources, including the section '*Traité des arbitrages*' by J. Mondoteguy in J. Le Moine, *Le negoce d'Amsterdam* (1710), and J. Savary, *Dictionnaire universel de commerce* (1730, second edition), developed a more detailed presentation of arbitrage transactions involving bills of exchange. An important eighteenth-century English source, M. Postlethwayt's *Universal Dictionary of Trade and Commerce* (1751), is an expanded translation of Savary, where the French word *arbitrage* is translated into English as 'arbitration'. This led to the common English use of the terms 'simple arbitrations', 'compound arbitrations' and 'arbitrated rates'. The practice of using 'arbitration of exchange' trading to describe arbitrage continues into nineteenth-century works by Patrick Kelly, *The Universal Cambist* (1811), and William Tate, *The Modern Cambist* (1848; first edition 1820).

The word 'arbitrage' originates from a Latin root (*arbitrari*, to give judgment; *arbitrium,* arbitration) with variants appearing in the Romance languages: the modern Italian variant, *arbitraggio*, for arbitrage, and the modern French variant *arbitrage,* for arbitration. Due to the dominance of Italian bankers in the late medieval and early

Renaissance era, a possible first etymological usage is the close variant, *arbitrio*. Surviving account books of Renaissance merchant banks remain as evidence of significant trading in bills of exchange that was possibly associated with 'arbitration of exchange' (de Roover 1963). There is a gradual appearance of *arbitrio* variants in Italian merchant texts discussing the use of bills of exchange (*lettera di cambio*). An early example is by Bernardo Davanzati, *Notizie de' cambj* (1581), that uses *'subito questi arbitranti'* in discussing the returns to round-trip *lettera di cambio* transactions from Florence (Firenze) to Lyon (Lione) and back to Florence (Firenze). With the appearance in Italian of *Il negotiante* (1638) by Giovanni Peri, a seventeenth-century Italian merchant, there is a detailed discussion using Italian variants of 'arbitrage' describing exchange dealings. Peri identifies the essential distinction between speculation on future exchange rate movements and the *arbitrio* concept of arbitrage: 'the profits from exchange dealings originate in price differences and not in time, with profits turning to losses if re-exchange is unfavourable' (Peri 1638, p. 150).

## II

A subtlety associated with the origins of arbitrage is the connection between historical context and commercial activity. The search for arbitrage trading in ancient sources needs to resist the temptation to 'stir the musty history into fascinating activity' (Frank 1910, p. 99); attempting to interpret ancient societies with a modern lens. Unfortunately, the difficulties of interpreting incomplete and 'often so one-sided' sources from ancient commercial history are compounded where the search for evidence of arbitrage trading is concerned. In contrast to the impersonal character of modern financial institutions, if such ancient trading was conducted, there are good reasons to expect the presence of specialized groups, most likely connected by strong affiliations such as kinship or 'bonding', centered in a small number of key commercial locations. Factors such as the threat of confiscation, legal and religious sanctions, negative social attitudes to commercial activities and desire to protect profitability provide strong incentives to avoid revealing details. In the face of such obstacles, what historical insights about ancient arbitrage trading, if any, are available? The answer to this question depends fundamentally on the 'limits of arbitrage' in ancient commerce.

Adapting an observation by Thompson (1979, p. 224) about ancient Athenian banking, the search for possible arbitrage trading in antiquity is confronted by 'scraps of evidence' in sources that are 'too meagre and too accidental' to sustain strong conclusions. Proceeding on the assumption that merchants would, if possible, seek out profits from potential 'arbitrage' opportunities, the historical record can be explored to identify arbitrage trades that could possibly be executed, even if details of such trading are absent in the sources. Working forward to later time periods for which more details of arbitrage trading are available could possibly facilitate identification of trading strategies adaptable to ancient historical context. Significantly, the almost certain absence of 'free-standing' derivative security contracts in ancient

markets eliminates possible use of modern strategies such as cash-and-carry commodity arbitrage, covered interest arbitrage and put-call parity arbitrage. Sources supporting the initial use of such contracts can be traced only to the sixteenth century (Gelderblom 2013). Ancient variants of such strategies, if available, would have had to exploit option or forward contracting features embedded in purchase and sale contracts. The sources are silent on the unlikely possibility of such trading.[1]

Consider the difficulty of identifying ancient arbitrage trading in commodities. Does a caravan merchant in Susa of ancient Elam taking on consignment a *mana* (2 kilos) of lapis lazuli for delivery in another location where prices were higher, such as Larsa in Sumer, constitute arbitrage trading? Does the answer change if, instead of consignment, the caravan merchant borrows funds using an ancient bill of exchange to purchase the lapis lazuli in Assur for sale in Kanesh, where the loan will be repaid with funds from the sale? What if the goods being transported were sacks of barley, a commodity money, to be exchanged for lead, an alternative base metal money? This raises the question: at what point does movement of goods or specie to exploit difference in prices between two locations become too speculative to be considered geographical 'arbitrage' instead of conventional trade? Even if the delivery price was set prior to transport, transportation of commodities, precious stones, coinage or bullion in ancient times was still risky and costly. The credit risk of non-payment at delivery would require a network of agents in remote locations to ensure settlement on delivery and eventual return of capital plus profit to the shipper.

Upon reflection, deeper exploration is required to identify whether and how the type of trading strategy involved constitutes 'arbitrage', somehow defined, in contrast to entrepôt trading, storage and distribution operations, traditional import–export activity and the like.[2] Without further clarification, reference to 'arbitrage' is too vague, especially in ancient markets where direct evidence of such trading is lacking and the historical context suggests practical complications in the ability to execute trades. Does the predominance of speculative elements and difficulty of matching sale and purchase transactions at a given point in time suggest that trade involving 'goods' or commodities is too speculative to be considered as 'arbitrage'? Consistent with later etymological evolution that relates arbitrage to financial transactions, the

[1] Bagnell (1977) discusses the reasons why ancient Egyptian contracts for the sale of crops for cash prior to harvest are appropriately treated as loans and, despite containing option features that would permit refusal to take delivery, were not amenable to speculation.

[2] Shiue (2002) is an example from eighteenth-century China where the mechanics of storage operations and the associated relevance of transportation costs are referred to as 'arbitrage'. Similarly, an important contribution to the debate on the rise globalization, Flynn and Giraldez (1995), refers to the long-distance transportation of silver to China in the early modern period as 'arbitrage'. Such colloquial usage of 'arbitrage' to refer to the 'arbitration' of commodity prices across locations at different points in time does not correspond to 'arbitrage' that involves difference in prices at a given point in time and the approximately simultaneous execution of short–long trades to exploit violations of arbitrage bounds.

search for arbitrage trading in ancient markets focuses on characteristics of money, credit and loans. This involves examining: the use of different metals for transactions and as units of account; differences in coinage and specie exchange ratios across or within geographical locations; the availability, credit risk and methods of granting loans; and the degree of market liquidity and restrictions on the ability to trade.

Where is the search for such possible arbitrage trading to begin? Though there is evidence appearing in some of the earliest surviving Sumerian cuneiform tablets from Bronze Age Mesopotamia, millennia prior to the introduction of coinage, involving rudimentary use of commodity money – especially silver – in commercial activities (e.g. van der Spek and van Leeuwen 2019, ch.5) and extensive trade using ancient bills of exchange (e.g. Poitras 2016, p. 32), available sources are too obscure to produce even vague conclusions.[3] With the introduction of coinage, the first discernible hints of arbitrage activity appear in sources that are, overwhelmingly, concerned with developments in Greek civilization. In addition to passing references provided in Herodotus, Xenophon, Demosthenes, Aristotle and the like, there is numismatic, epigraphic and other archaeological evidence that has accumulated dealing with relevant merchant activities in Greek city-states and regions of Greek influence. Recreating possible arbitrage trading requires sufficient market liquidity and the associated individuality of impersonal trading. This necessitated a social and political transition from an environment where wealth, especially precious metals, and the bulk of economic activity was largely under the control of aristocrats and religious institutions.

The introduction of coinage into the Greek *poleis* is a compelling intersection point of numismatics with economic, social and political history. Whereas numismatic concern centers on characteristics of the coinage, such as weight, size, metallurgical composition, method of production, markings and design, dating and location of issue, economic, social and political history focuses on: reasons coinage was issued; how, where and how much coinage was used; who benefitted from the issuance; what events occurred in conjunction and so on. The search for ancient arbitrage trading requires insights from both numismatists and historians. For millennia, trade

[3] Ancient bills of exchange found in Bronze Age Sumerian cuneiform tablets involved a loan of a weight of silver, typically made in one temple location to be repaid at a later date in a different temple location, say down or upriver. Such bills differ from early modern bills of exchange in having the same medium of exchange, using weight for the unit of account involved in the initial loan and later repayment. Historical context is provided by the stele for the Code of Hammurabi that makes reference to laws governing such bills. The sources are silent on details about connection with an underlying goods transaction, transferability, and the ability to simultaneously borrow and lend in one location for delivery and settlement in another location. The 'bill of exchange' involved in the *OID* definition and the early etymology of 'arbitrage' entailed borrowing (lending) funds in one location denominated in currency A with an agreement to repay the loan in another location in currency B. Such bill contracts involved both a loan and an embedded forward foreign exchange rate. Quinn (1996) discusses an early modern quasi-arbitrage between the Dutch–English bill of exchange and bullion markets.

was conducted using a combination of barter and media of exchange measured by weight. When exchange is localized, 'money does not have to be used. Information regarding partners is optimal and reciprocity is guaranteed by a system of values transcending trade' (Bresson 2016, p. 260). In contrast, the requirements for arbitrage involve a significant degree of precision measured in an agreed unit of account, impersonal transactions, market liquidity provided by some sources of demand and supply, and institutions ensuring legal protection for such transactions. As such, the introduction of coinage into the prevailing activities of important Greek city-states and regions of Greek influence seems to provide essential ingredients for arbitrage trading.

## III

Archaeological evidence dating from the late seventh to fourth centuries BCE indicates widespread minted coinage use in disparate civilizations from China to the Indian subcontinent to the Mediterranean.[4] Throughout the ancient world, a wide variety of metals were used in such coinage: especially gold, silver, copper, bronze and electrum – a 'white gold' mix of gold and silver. Introduction of coinage in the regions of Greek influence followed the initial appearance, *c.* 630 BCE, of struck electrum coinage in the Lydian kingdom of Asia Minor (Herodotus, *Histories* 1.92–4; Kagan 1982; Wallace 1987, 2016). The use of electrum as a medium of exchange raises complications as this form of bullion may involve an uncertain combination of gold and silver. Consequently, as electrum was an important source of bullion in the Lydian region, 'the guarantee of redeemability by the state was a means of stabilizing the value of the precious metal' (Wallace 1987, p. 397).[5] In addition to providing stability to the value of electrum, coinage in general exhibited a number of other desirable features for the state including: potential revenues from the minting process; avoiding the 'medium of exchange' difficulties associated with determining the weight and fineness of bullion; and enhanced local political cohesion associated with a medium of exchange bearing a revered religious idol, relevant inscription or aristocratic personage (e.g. Martin 1996; Motta 2014, ch. 3).

[4] Debates surrounding the origins of coinage are longstanding (e.g. Kroll and Waggoner 1984; von Redden 1997; Goyal 1999; Scheidel 2010). These debates cover a range of topics, such as why coinage was introduced, where coinage was introduced and so on. Though numerous sources credit the introduction of coinage to the Lydians, the archaeological and numismatic evidence is not definitive. The overwhelming amount of scholarly literature on ancient Greek coinage biases attention to that venue and facilitates the focus on Greek evidence in the search for arbitrage trading.

[5] Redeemability is an essential motivation for acceptance of early electrum coinage that had different weights and combinations of gold and silver, making it difficult to determine the 'bullion content'. The presence of a seal and other markings represented assurance that the coinage could be used in payment to the issuer, such as for tax payments to a royal issuer. This would restrict the area over which a specific electrum issue could circulate.

Following the introduction of electrum coinage, there was either a rapid or somewhat longer interval for numerous Greek city-states to adopt locally minted coinage.[6] Though the early coinages of Lydia and Ionia were based on electrum, and some important Greek jurisdictions such as Miletus, Chios and Thebes also later struck substantial electrum coinage (Gardner 1920; Gartland 2013), the bulk of Greek city-states that minted coinage used silver and, to a lesser extent, bronze and, in some cases, gold. Coinage issued in a specific locale would circulate according to local rules, but that coinage outside the locale would be subject to a conversion agio, with a possible exception of coinage (and acceptable copies) from the important minting locations, especially Aegina, Athens and Corinth, that were accepted where local rules permitted. The value of bullion coins was typically determined by weight, with variation across locations in the agio used in exchange. With notable exceptions, the units for 'standard' silver coinage were the Attic *drachma* (4.3 grams), Corinthian *stater* (8.6 grams) or Aeginetan *drachma* (6.1 grams, a 10:7 ratio to the Attic standard). The Aeginetan standard also included a *stater* (*didrachm*) of 12.2 grams. From these units, coins of lesser and greater value were determined, e.g. the Attic *didrachm* of 8.6 grams or *obol* of 1/6 a *drachma*.[7] Where possible, arbitrage trading could arise from market-determined agios for conversion between local and foreign coinage, between bullion and coin and, recognizing the standard metallic weight of coins, from one metal to another.

Included among the epigraphic sources providing essential insight into coinage usage and minting in regions of Greek influence is the marble stele discovered in 1970 at the *Agora* excavation in Athens (Stroud 1974; Mørkholm 1982). Most likely introduced *c.* 375 BCE, the stele provides the law of silver coinage – the so-called 'Law of Nikophon' (Engen 2005; Ober 2015) – applicable to the *Agora* at Athens and the *emporium* at the port of Piraeus (Peiraieus) for that period. The law identifies a 'public slave', the *dokimastes,* who sits among 'the tables' at the *Agora* or the *emporium*, responsible for determining whether silver, struck to the Attic standard, is legal tender or counterfeit. The law states that such coinage could be of foreign origin. As Ober (2015, pp. 69–75) and van Alfen (2002) observe, such 'pseudo-owls' sufficiently similar to the Attic standard began to appear in the fifth century and had become 'very common' by the early fourth century 'being produced extensively in Egypt and the Levant'. By the end of the fourth century the minting of pseudo-owls

[6] Using a crude estimate of about 2,000 separate Greek city-states, evidence from numismatic finds indicates that more than half issued coinage, with most large city-states issuing with the exception of Sparta until the third century BCE. In addition to coinage issued by city-states, coinage was issued by military leaders and in the name of gods, without attribution (Psoma 2008). Davis (2014) dates the adoption of coinage in Athens *c.* 546–535 BCE.

[7] As Psoma (2016) reports, this classification is decidedly simplified. There were other standards, such as the Persian, Phocaic, Chian, Samian and Lydo-Milesian. The Attic standard is more accurately referred to as the Euboic-Attic standard to recognize the historical evolution of this standard. Local coinage standards did change over time. The prototypical 'Athenian owl' was a *tetradrachma* coin (16.24 g.) with an owl on the reverse side, though other Athenian coins could also feature an owl. Minting of owls appears at approximately the same time as the emergence of Athenian democracy.

'had spread to Babylonia, Bactria (roughly modern Afghanistan) and South Arabia' (van Alfen 2002, p. 32).

The Law of Nikophon indicates that 'pseudo-owls' that were 'approved' by the *dokimastes* could circulate as 'owls', indicating that 'standard' Attic coins could be produced elsewhere than the Athens mint and that there were methods available for testing whether coinage had bronze or lead cores (before 'striking across' to indicate a counterfeit).[8] In addition, the 'fineness' of the silver was a related consideration that could be tested.[9] The salary of the *dokimastes* was to be paid from the same source as that of the mint workers, most likely the approximately 5 per cent minting charge captured turning commercial bullion into coinage. Stroud (1974, pp. 165–6) and Kroll (2011, esp. n. 23) provide evidence that such testers were employed by 'private banks in Athens'; that this practice was followed in other Greek city-states; and that a *dokimastes* was 'already an established Athenian official'. There is debate about whether the law permits a refusal to accept pseudo-owls that had been approved indicating such practices were happening prior to the law (Ober 2015, p. 71).

## IV

Though numismatists do recognize connections between coinage and profit (e.g. Howgego 1990, pp. 17–20; Sosin 2002, p. 338; Katsari 2011, pp. 75–85; Meadows 2014, pp. 186–90), details of such connections relevant to possible arbitrage trading are not explored in any detail. A useful illustration of the local coinage function is provided by an account of Boeotian coinage left by the Theban military commander Pompidas, *c.* mid second century BCE (Sosin 2002). It appears that, while the Boeotian silver *drachma* was a unit of account based on the Aeginetan standard, there was local coinage (*symmachic drachma*) that, while lighter than the standard, by rule of law circulated as a standard *drachma* for purposes of local exchange. Outside the locality where such local coinage would be assessed according to weight, this coinage would be considered overvalued. Though payments by Pompidas to his troops would most likely contain local coinage, the unit of account for such payments would be calculated using the Boeotian *drachma* as some troops, possibly mercenaries, would be traveling or returning to sites outside the locale. An additional complication appears with the use of local bronze *drachma* coinage that, by law, circulated one-to-one with the local silver *symmachic drachma*. However, it appears that in some transactions payment in local silver *drachmas*, not bronze which was overvalued relative to *symmachic drachma*, would be preferred or, perhaps, necessary.

[8] Engen (2005, pp. 368–76) provides an overview of the numerous interpretations of the law. The fact that 'imitation' Athenian coins struck with similar but not identical dies have been found in hoards across various locations does not rule out the use of official dies outside Athens. The roving mints identified by Fischer-Bossert and the associated sharing of dies support such an interpretation.

[9] Though from a later period, Pliny (*Natural History* 33.44) indicates that rudimentary methods of testing fineness by heating were well known.

In the case of city-state regions such as Boeotia that were not major trading locales like Athens or Corinth and did not possess substantial natural sources of metal, the presence of overvalued local currency suggests possible arbitrage activity by merchants melting standard coins or bullion and minting into local coins. Restriking or punching of coins was also possible if local and standard coin weight and fineness were more-or-less equivalent, but this was not the case with *symmachic drachma* in Boeotia.[10] Such arbitrage requires private access to mint facilities. Though evidence for (or against) private minting in specific locations is scant (Mørkholm 1982, p. 292; Wallace 1987, p. 386; Howgego 1990, p. 16; Bransbourg 2011, p. 95, n. 36; Bresson 2015, pp. 132–8), there are some factors to consider. If, as Fischer-Brossert (2018, p. 59) maintains, 'monetary policy of the Greek city-state was focused on enforcing the proper currency in the local markets, thereby forcing foreign traders to change money', then any such arbitrage by local merchants would benefit the city-state by generating revenue from minting charges and providing a supply of coinage if local sources of metal were limited. Though the city-state could legally require foreign merchants to exchange standard coins for local coin directly with local treasury officials, presumably at 5:5 for the *symmachic drachma* in the Boeotian case, the presence of 'money-changers' identified in the sources strongly suggests there was a market-determined agio (e.g. Sosin 2000, p. 79).

Various qualifications to details of possible arbitrage trading are appropriate due to the scant evidence in the sources. If substantive limitations of determining weight and fineness were not present, bullion would be slightly cheaper to convert to local coin. However, the presumption that arbitrage trading was done with coins, not bullion, is seemingly supported by archaeological evidence from hoards in regions of Greek influence that contain coins from other city-states and little bullion (*hacksilber*) after the late fourth century.[11] In addition, while forgery using copy-cat dies or unscrupulous mint workers illegally coining with official dies was possible, it is difficult to verify such activity in the sources. More relevant is overvaluation due to an insufficiency of local coin. In this case, there would be a need to encourage foreign coin or bullion imports and discourage local coin exports. Based on an estimated standard to overvalued local silver content ratio of 6:5 in the Boeotian case (Sosin 2002, p. 338), the relevant question is whether negotiation associated with a market agio permits possible

[10] Melting would presumably be required if the local coin weight was less than the standard. Fineness is a complication that requires adjustment if, say, copper was added in the melting process. Kroll (2011) discusses the techniques of restriking Athenian coinage in the demonetization reform *c.* 353 BCE. Davis (2014) details the costs of mining silver at Laurium. Vermeule (1957) examines ancient minting techniques. An early discussion of overstriking is Sutherland (1942).

[11] See Balmuth (2001). Colburn (2020, ch. 6) provides evidence from Egyptian hoards. Crawford (1970) summarizes evidence on the absence of bullion in Roman empire hoards. It is possible that the absence of *hacksilber* in hoards is because the incentive to convert bullion to coinage was sufficient to deter the holding of bullion.

arbitrage profits sufficient to encourage the conversion of foreign coinage into local *drachmas* to alleviate limited local silver supply concerns.

Recognizing the absence of direct evidence in the sources, consider an example of possible arbitrage trades associated with conversion of standard coin imports. Such trading could commence with a foreign merchant coming to a money-changer's table in the *agora* at Thebes where an agio would be quoted to exchange Aeginetan for the local *drachmas* needed to conduct trade in Boeotia. As the silver bullion content of the Aeginetan *drachma* was 20 percent more than the local Boeotian coinage (assuming no difference in fineness), a lower 'excess supply' arbitrage bound on the quoted agio would reflect a minting charge plus a 'shoe leather' charge for money-changing services plus an additional allowance for melting and flan moulding required to convert the bullion in the Aeginetan *drachma*s for minting.[12] If the 'arbitrage' further required no net investment of funds, the money-changer's charge would also include the cost of borrowing the local *drachmas* from a banker. It follows that local 'absence of arbitrage' provides a calculation for a lower arbitrage bound on the agio quoted by money-changers.[13]

The possible trades for the upper 'excess demand' bound are decidedly more complicated and only constitute a *quasi-arbitrage* bound on the agio. Satisfying the excess demand for standard coin would involve borrowing the standard *drachmas* in the cheapest foreign location, transporting and exchanging for local *drachmas* and, somehow, settling the loan (or return of capital) required for the initial purchase of standard coin. In contrast to the lower arbitrage bound, the addition of transportation risk plus need for a method of loan repayment (or return of capital) are the reasons for reference to quasi-arbitrage bound. Shipping local coinage back to the foreign

[12] Arbitrage bounds are more accurately depicted as 'no-arbitrage' bounds as the possibility of doing a combination of simultaneous trades that generate a 'certain' profit violates the 'no-arbitrage profits' requirement for rational market pricing. Due to practical rigidities involved in executing trades, arbitrage provides an upper and a lower bound on a market price at a given point in time: the 'long arbitrage' trade involves buying at the current price and the 'short arbitrage' trade involves selling at the current price. Quasi-arbitrage occurs when some feature required for 'arbitrage' is not available. In modern markets, this can occur where 'internal' funds are used instead of financing the arbitrage using 'external' borrowing. In ancient markets for coinage, quasi-arbitrage arises where the transport of coin restricts simultaneous execution.

[13] There is a substantial literature on estimates for money-changers' fees and methods of weighing coin and bullion reviewed by Kroll (2011, n. 23). As an example calculation of arbitrage bounds, assume a 3% minting charge, 0.5% less due to melting and 2% for shoe leather and interest on local *drachmas* used for exchange. Then the lower 'excess supply' arbitrage bound for the money-changer would be calculated as $x\ (1.02) = 6(.965)$ for a quote of 5 foreign Aeginetan for 5.676 local. For the 'excess demand' arbitrage bound, as the overvalued local coin would not be legal tender outside the locality, Aeginetan *drachma*s would be borrowed in the cheapest offshore location and transported to Boeotia to exchange for local *drachmas*. In the unlikely case that the local *drachmas* would then be shipped back offshore for minting, assuming 2.5% for shipping, shoe leather and borrowing charges and the same melting and minting costs, $x = 6(1.025)(1.035)$ produces an upper quasi-arbitrage bound of 6.365 local *drachmas* for 5 Aeginetan.

location for melting, minting and repayment of the loan would be an unlikely process to settle the initial loan. Though the sources are silent on such details, there is a strong suggestion of a connection to the 'economics of trust' associated with the networks of specialized groups, centered in a small number of key commercial locations, connected by strong affiliations such as kinship or 'bonding'. Studies supporting the economic role of such networks stretch from the Bronze Age (e.g. Veenhof 2010), to the present (e.g. Landa 1994). Hayden (2018, pp. 153–7) recognizes that: 'Private associations were active in mercantile activity throughout the Hellenistic Mediterranean.'[14] Shipton (1997) provides evidence for the importance of 'trust networks' in the private banking of fourth-century Athens arising from the participation of metics, ex-slaves and 'outsiders', generally, and the activities of the successful banker Pasion, specifically.[15]

In contrast to the scant evidence on the overvalued coinage of Boeotia, there is substantially more evidence from another such locale within the Greek sphere of influence – territories of Ptolemaic Egypt (Bresson 2015; Hayden 2018; von Reden 2007) – that had a 'closed coinage system' where the circulation of foreign coins was banned and merchants, arriving primarily by ship, were required to exchange foreign coins for Egyptian money upon arrival. While Egyptian coinage prior to conquest by Alexander was focused on pseudo-owls, 'coins only became widespread under the Ptolemies' (Hayden 2018, p. 161). Under Ptolemy II, *c.* 265 BCE, a network of royal banks responsible for handling monetary payments to the state, plus conducting other banking activities, was established and functioned alongside concessionary ('farmed' or 'leased') banks. In conjunction with the expansion of bronze coinage under Ptolemy II, the state required payment in silver; the right to exchange silver for bronze coinage, at a fixed 10 percent fee, was farmed to concessionary banks providing another avenue for the state to profit from coinage. This practice ended with Ptolemy IV in 210 with a shift from a bronze to silver standard for coinage.

An unresolved issue arising with overvalued coinage arbitrage was whether foreign coin was in 'excess supply' or 'excess demand'. Bresson (2015) provides a translation of a letter to the Ptolemaic *diokētēs* (finance minister), most likely from a mint worker responsible for processing gold coins, reporting difficulties at the Alexandria mint in 258 BCE that provides a rationale for 'excess supply' due to insufficient minting of local coinage:

[14] See also Cohen (1992) for further detail on Athenian banking. Terpstra (2019) makes a forceful argument about the important role of trading communities using private means to enforce contracts.

[15] In practice, instead of melting and minting coin, money-changers would typically hold the standard *drachmas* purchased at a market agio below the 6:5 coinage bullion ratio but above the arbitrage bound, seeking to exchange the foreign *drachmas* at an agio slightly above the coinage bullion ratio with, say, local merchants traveling outside the locality to areas that used the standard coinage.

the foreigners who come here by sea, the merchants, the wholesale buyers and others, [that] bring their own fine coins … are furious since we refuse the coins at the banks … and they cannot send their agents into the country to purchase merchandise, but they say their gold coins lie idle and that they are suffering great loss … and cannot easily dispose of them to others even at a lower price.

Though the writer of the letter was responsible only for exchanging gold coins, Bresson (2015, p. 128) suggests there was similar difficulties with silver coinage. The Boeotian and Ptolemaic overvalued coinage illustrates the significance of the process for accessing the mint: was access available to local merchants to present foreign coin or bullion for minting? If foreign merchants were allowed mint access, at what agio to exchange coin (or bullion) for local *drachmas*? The Bresson letter indicates that foreign merchants in Ptolemaic Egypt could not access the mint directly and were required to exchange coinage with 'banks', presumably concessionary banks, creating a milieu for arbitrage trading.

What of possible ancient arbitrage in locales without overvalued coinage? In contrast to locales that lacked a supply of bullion for coinage and required coinage imports are locales where coinage was typically a net export. Due to the productive mines at Laurium and the periodic inflow of tribute payments, Athens was typically a commercial exporter of silver; though this depended on expenditure demands of the interminable wars not exhausting the available supply of silver at a given point in time. The Law of Nikophon verifies that approved foreign pseudo-owls could circulate as owls for trading purposes, indicating Athenian coinage was not locally overvalued. As Xenophon observes:[16]

merchants, in most other cities, must barter one commodity for another; for the inhabitants use coins that will not pass beyond the limits of the region; but at Athens, while there is an abundance of goods, such as merchants require, for exportation, still, if merchants do not wish to barter, they may carry off an excellent freight by taking away our silver, for wherever they dispose of it, they will always gain more than its original value.

This clarifies the lack of incentive for the Athenian state to create an overvalued local coinage: instead of the state extracting a minting charge for conversion of foreign coin to overvalued local coin, the minting charge revenue was obtained by minting a flow of silver for export and local use. The relevant unanswered question implied by Xenophon is how the value of exported silver will 'gain more than its original value' upon export. Ignoring mint discount and 'medium of exchange' complications associated with the difference between Athenian *drachmas* and the commercial value of silver ingots (e.g. Mørkholm 1982, pp. 291–2), the exported coin or bullion was possibly being used in quasi-arbitrage trades, converted to overvalued local coinage at favorable agios; or used to buy foreign goods at discounted

[16] Xenophon, 'On the means of improving the revenue of the state of Athens', from *Minor Works*, trans. and compiled by J. Watson. London: George Bell, 1898, ch.3, sec.2.

prices in regions without 'closed coinage systems'; or the silver was converted to an alternative metal in regions with a favorable bimetallic agio; or used to mint 'pseudo-owls'.

Comparison with the Parisian black market gold quasi-arbitrage during World War II (Gallais-Hamonno *et al.* 2019) is revealing. In the Parisian case, Swiss francs were borrowed in Zurich to buy gold coin that was shipped to Paris and sold on the black market for French francs which, to repay the initial loan, were either converted to Swiss francs in Paris and sent back to Zurich or, if possible, a bill of exchange drawn on Zurich was purchased in Paris. The quasi-arbitrage profit originated due to the geographical difference in gold prices being higher in Paris than for the Swiss to French franc exchange rate. Does the overvalued paper currency correspond to the overvalued coinage in the Boeotian case? In the Parisian case, the overvaluation results from the fixed mint parity imposed by the French government for French francs being too high relative to the black market French franc price of gold coin. In the Boeotian case, arbitrage profit from 'excess supply' of standard coinage in Boeotia, if any, originates from a market agio that is below the lower bound determined by costs of changing the standard to local coinage. The Parisian quasi-arbitrage corresponds to 'excess demand' for standard coin in Boeotia resulting in borrowing owls (or bullion) offshore in Athens, shipping to Boeotia and exchanging at a market agio above the upper arbitrage bound and, somehow, repaying the initial loan or, if possible, using an early modern-style bill of exchange to settle the offshore standard coin borrowing.

## V

The possibility of arbitrage profit in coinage was a sophisticated opportunity for ancient merchants; the Greek city-state benefitted from the minting charge and, where local mining was also present, from additional charges. Recognizing 'how fundamentally Greek coinage was subject to state control and how fully Greek governments were able to manipulate this control for monetary gain' (Kroll 2011, p. 230), raises the question: why would the state not also seek to capture revenues of merchants from coinage exchange? The authority of the state determined the legal institutions governing the issue of coinage and it would be possible to make it difficult, or illegal, for merchants to convert foreign into local coin by denying direct or indirect access to minting and requiring such conversion be done only through a treasury official at the legally specified exchange rate. In the Roman empire, as Burnett (1977, p. 42) observes: 'It is clear that there was no such thing as "free coinage" in the Republic and early empire: it was not possible for a private individual to have his silver bullion coined at the mint.' The emergence of black markets associated with debasements of Roman coinage in the third and fourth centuries CE suggests practical limits to state control (Elliott 2014). If available, private access to minting facilities in the Greek *poleis* can be attributed to merchants in relevant city-states performing useful services and, possibly, also exercising influence over state activities for personal

gain.[17] Comparisons of Greek city-states with the Roman empire are complicated as the latter had an extended reach and used one standard unit of account eliminating the possibility of arbitrage arising from overvalued local coinage (e.g. Scheidel 2010). Over time, the connection between bullion content and the monetary value of Roman coinage became distorted by debasements and revaluations undermining the type of arbitrage that, possibly, was executed in Greek city-states where coinage was closely aligned with bullion content.

Can answers to questions related to the exercise of state control over profits from coinage be found in a social and political context? As Bresson (2016, p. 268) observes: 'the world of the Greek city-states was a world whose center was the agora. This public square was a place of exchange among equals in which, in the operation of exchange itself … inequalities of birth or fortune were of little or no importance.' Equality before the law inherent in the politics of the *demos* extended to exchange transactions. The Greek *polis* was the common possession of the citizens with exchange constituting the definition of political speech in the assembly. Arbitrage both epitomizes and transcends these sentiments, moving exchange to a substantively higher level of individualized, political and quantitative sophistication. In contrast, ancient imperial empires such as the Roman and Persian were socially stratified with the emperor or king holding supreme power leading to a 'hierarchical circulation of wealth' restricting exchange among equals where social relationships were fundamentally asymmetrical. Political speech was monopolized, precious metals were closely held by an aristocratic class leaving little room for trade based on equality. In such ancient societies, arbitrage trading by merchants would be problematic.

General statements about social, economic and political context in Greek city-states have to be interpreted cautiously, taking account of substantive evolution from Archaic to Classical and Hellenistic periods. On various levels, the Greek *poleis* were not homogeneous entities with Sparta, specifically, being especially anomalous. Resistant to external trade and coinage – Sparta engaged in periodic expulsion of foreigners (*xenēlasiai*) and used iron bars until silver coinage was introduced on a limited scale in the mid third century BCE – Sparta exhibited a hierarchical social structure headed by the *homoioi* ruling over the *perioikoi* of the surrounding regions with *helots* serving as a serf class. This backdrop informs the search for arbitrage in the Roman state. Driven more by desire for conquest than for mutual benefits from exchange, and with no substantial source of mined silver prior to acquiring Spanish mines by conquest during the Punic Wars, as both Livy (*History of Rome*, Bk. XV) and Pliny the Elder (*Natural History* 33.13) report, the Romans did not coin the silver *denarius* until 268/9 BCE preferring bronze weight and copper issues prior to that time. Subsequently, the 'siphoning off of the gold and silver of the Mediterranean world into Roman hands had a numismatic corollary in the ending

[17] Sosin (2004) provides evidence for such influence by wealthy landowners borrowing from endowments at Delphi.

and withdrawal from circulation (whether gradual or not) of most of the existing non-Roman precious metal coinages' (Howgego 1992, p. 5). The notable exception was the eastern provinces (Katsari 2011; Elliott 2014) where bullion content of local coinage adjusted, precisely how is unclear, to changes in imperial measures (Katsari 2003, esp. pp. 30–1).[18]

Due to lack of substantial literary sources for the Roman Republic until the corpus of Cicero, it is difficult to tell if possible arbitrage between standard and local coinage effectively disappeared in many regions of Roman territory as the silver *denarius* evolved into the primary coinage, joined by substantial minting of the gold *aureus* from 46 BCE. As no mint records from the Republican period have survived, tracing the disposition of the immense amount of booty that came to Rome is complicated; Livy (*History of Rome*) indicates numerous times that much was deposited in the treasury with Pliny (*Natural History* 33.17) providing details on amounts. As in most Greek city-states, the state reserved exclusive control over the issue of coinage at Rome, with power over silver and gold coinage passing under Augustus to the emperors. The monetary and financial system that evolved during the late Republic and Principate is decidedly more complex than that which prevailed in the Greek city-states. The activities of *argentarii* and *nummularii* detailed by Andreau (1999) were restricted by social status with large-scale extension of credit concentrated among the *equites* and, to a lesser extent, the senatorial class. With the emergence of such credit, new avenues for arbitrage emerged.

Though now largely discredited as a general claim, Crawford (1970, p. 46) provides useful insight for the Republic: 'Coinage was probably invented in order that a large number of state payments might be made in a convenient form and there is no reason to suppose that it was ever issued by Rome for any other purpose than to enable the state to make payments.' Though the exact details are subject to debate, it is possible that during the Republic, 'the volume of coinage struck fluctuated as the number of legions in the field went up or down and as other state expenses rose or fell'. Compared to Greek city-states, Republican Rome was substantively less concerned, if at all, with revenue from coinage. It was not until the second half of the second century BCE that the *nummularii* at Rome, the money-changers and coin-testers, appear in the sources (Crawford 1970, p. 45; Andreau 1999, ch. 3). Concentrating on coinage for day-to-day transactions, the initial activities of the *nummularii* most likely focused on identifying counterfeits and exchanging copper *as* and *denarii* and, at times, some coin of foreign origin, especially 'Roman provincial coinage'. Excepting the volumes of coinage and bullion that flowed overland and through Egypt by sea to India, Arabia and other locales identified in sources such as the

[18] Though the state had authority over coinage at Rome, various parts of the eastern provinces retained traditional measurements for issuing local coinage (Katsari 2011, p. 74 for a list). These provincial mints were required to adjust to the imperial standard when the state mandated changes in fineness and the like.

Muziris Papyrus and the *Periplus Maris Erythraei*, the Roman empire functioned without the need to move large amounts of coinage for payment.[19] Instead, there was a sophisticated system of credit, based on a network of *amicitia* and patronage among the elite (Verboven 2002). The activities and composition of the *equites* in this network are described in detail by Nicolet and others.

The presence of an extensive network of credit, albeit concentrated among members of the elite, expands the arbitrage landscape. Possible evidence for such arbitrage during the late Republic and beginning of the Principate is provided by Suetonius (*Lives of the Twelve Caesars* 1.2.39, trans. A. Thompson):

> With the assistance of ten senators, [Augustus] obliged each of the *equites* to give an account of his life: in regard to those who fell under his displeasure, some were punished; others had a mark of infamy set against their names. For the most part he only reprimanded, but not in the same terms. The mildest mode of rebuke was by delivering tablets to them, the contents of which, confined to themselves, they were to read on the spot. Some he disgraced for borrowing money at low interest, and letting it out again upon usurious profit.

Though the general outline of arbitrage involving borrowing at a lower rate and lending at a higher rate is obvious, the mechanics of such arbitrage described by Suetonius are far from apparent. Perhaps Augustus was concerned with 'keeping the *equites* up to old-fashioned aristocratic standards' (Harris 2006, p.10), rebuking the widespread practice of lending and pursuit of profit among the elite. Or, alternatively, those *equites* being 'disgraced' were involved in borrowing through *amicitia* and largely lending for consumption loans (*mutuum*), engaging in nefarious usury practices traceable to Bronze Age empires. Such loans would not be riskless and often did not have a purely monetary objective that is a key feature of arbitrage. As is often the case with descriptions of Roman commercial activity, the Latin in Suetonius (*Lives*) is not transparent to translate ('*quod pecunias levioribus usuris mutuati graviore faenore collocassent*'). There are more questions than answers about such possible arbitrage.

## VI

Recognizing the lack of merchant mint access and the eventual disappearance of overvalued local coinage, were there opportunities for merchant arbitrage derived from coinage and bullion within the Roman empire? During the Republic, slight hints of possible arbitrage opportunities appear with distribution and coining of substantial

[19] Harris (2006) examines the capacity of the Romans to undertake long-distance transfers of funds without moving actual coins. *Barbaricum* in this case refers to the regions beyond the Roman frontier and not the locale in Scythia at the mouth of the Indus of the same name. Howgego (1992, pp. 5–6) recognizes outflows of coin for the imperial period to the *barbaricum* across the frontiers to northern and eastern Europe: 'Gifts and subsidies to client kings and peoples beyond the border of empire [that] grew into regular and substantial payments, and in due course became necessary to buy off threatened attacks.'

mine output following the second Punic War; the passage of legal tender laws in the second century, possibly as late as the early first century (Lo Casio 1981, p. 77); and the presence of different gold:silver commercial bullion market agios in locales across the empire. The ban on export of gold and silver bullion from Puteoli in 63 BCE raises a question about whether there was a quasi-arbitrage profit motive for such exports. However, compared to the imperial period, the evidence from the Republic is too scant to make reasonable inferences about possible arbitrage trading. One anomalous instance from the early Principate, where the sources provide useful detail on possible arbitrage, occurs with the sack of Jerusalem in 70 CE that: 'liberated so much gold that gold coin passed for half its usual value in terms of silver coin in Syria' (Howgego 1992, p. 5).

Compared to the usual inferences based on vague ancient allusions, the source for changes in the market price of gold in Syria – Josephus (*The Wars of the Jews* 6.6.10, 5.13.4, trans. Whiston 1895) – is comparatively clear: 'And now all the soldiers had such vast quantities of the spoils which they had gotten by plunder, that in Syria a pound weight of gold was sold for half its former value'; and, 'there was a great quantity of gold in the city, insomuch that as much was now sold [in the Roman camp] for twelve Attic [drams], as was sold before for twenty-five'. Absent the possibility that soldiers were involved in activities related to arbitrage profit, Howgego (1992, p. 29) refers to the presence of 'bankers' at military sites. These 'bankers' presumably acted as conduits for the gold booty seized by the soldiers to enter the bullion market in Syria. Quoting of the exchange in terms of Attic standard indicates the gold entered the region of provincial coinage, most likely in Tyre or Antioch, which issued *drachmas* on the Attic standard (Katsari 2011, p. 73). As imperial and provincial coinage minting was closely controlled by the Roman state, it is not clear whether 'in Syria' refers to the gold bullion being sold as a commodity; shipped across the frontier; or traded for silver coinage on the black market.

Why were 'soldiers' willing to sell gold at 12 compared to the previous value of 25 which, presumably, refers to the official imperial exchange rate of one gold *aurieus* for 25 silver *denarii*? As the dating corresponds to a metallist period when the silver fineness of the *denarius* had not been debased, the 1:12 exchange rate reflects a market where legal silver coinage was being exchanged for gold that had, in a sense, been obtained illegally. Though there is modern debate over the precise details (e.g. Churchill 1999), a portion of booty, *manubiae*, was reserved for the commanding general, in this instance Titus, after a military triumph. Apparently, according to Josephus, a large number of auxiliary troops, 'Arabians and Syrians', and legionaries had acquired booty from 'deserters' fleeing Jerusalem. Despite Titus wanting those involved put to death, the numbers involved were so great this could not be done. As gold was more readily secreted, it is likely that much of this booty was gold bullion, not the main coinage of the 'deserters', the silver Jerusalem shekel. Consequently, soldiers would be anxious to dispose of such booty for fear of being found in possession. The need to convert large quantities of illegally obtained gold bullion into legal tender created an arbitrage opportunity for local 'bankers'.

The anomalous arbitrage trading associated with the theft of booty from Jerusalem deserters raises questions such as: Who were the 'bankers' that acted as conduits? How was trading in the military camps conducted? Does reference to 'Arabians' among the auxiliary soldiers involved in the theft of booty indicate that some booty did not end up in Syria? Such bimetallic arbitrage and quasi-arbitrage opportunities were unusual in the imperial period as the expansion of territory was muted following Augustus.[20] The search for possible bimetallic arbitrage trading that could have been conducted during the imperial period leads elsewhere. As private access to coin minting was not permitted by the Romans, relevant questions arise concerning the disposition of vast stores of gold and silver booty accumulated in the treasury from the period of conquest, as well as the considerable mining output from the conquered territories. In addition to what was coined, was some of this booty sold in commercial bullion markets? Was there a black market for such bullion? How much of the coinage and bullion transfer across the frontier to Arabia, India and elsewhere was motivated by quasi-arbitrage? Answers to such questions become increasingly complicated as the Roman monetary unit decoupled from the intrinsic metal content from Nero onwards.

Consider the possible arbitrage and quasi-arbitrage opportunities arising from coinage and bullion exchange associated with the substantial expansion of trade with India, Arabia and the *barbaricum* during the imperial period (e.g. Cobb 2015). Stimulated by the intervention of Pompey in Palestine in 63 BCE that resulted in vassalage of the Nabataean kingdom and the subsequent conquering of Egypt by Augustus in 31 BCE, substantial amounts of Roman bullion began to be sourced to Arabia and further east by land and through Egypt by sea to South Asia and other locales (Casson 1989; Vickers 1994; Cobb 2015). Numismatic and literary sources indicate a 'staggering' amount of gold and silver crossed the frontier in exchange for goods. Strabo (*Geography* 16.4.22, trans. Hamilton and Falconer) states that the Arabians 'were very wealthy, and exchanged their aromatics and precious stones for silver and gold, but never expended with foreigners any part of what they received in exchange'. About the sea trade with India Pliny (*Natural History* 6.26, trans. Bostock and Riley) observes 'in no year does India drain our empire of less than five hundred and fifty millions of *sesterces*, giving back her own wares in exchange, which are sold among us at fully one hundred times their prime cost'. While some traffic in gold and silver may have involved quasi-arbitrage derived from 'networks of trust', when only goods were involved on the return journey such activity is more appropriately characterized as commercial trade by the Romans, not financial arbitrage trading.

[20] As the geographical expansion of imperial Rome culminated with Trajan, this statement is not historically correct. However, sources from the reign of Trajan are scant and unrevealing. It is almost certain that the conquest of Dacian (101–2 CE) resulted in the acquisition of considerable silver and, especially, gold booty. It is likely that some of this booty was used in both the minting of new issues of *aureii* and *denarii* and in trade across the frontier.

Ancient history is replete with instances of 'one-sided' sources and the search for arbitrage arising from Roman trade with Arabia and India is no exception. Only hints of potential arbitrage activities of those civilizations trading with the Romans can be gleaned from the difficult to interpret archaeological and numismatic evidence from the Red Sea to India and scattered references from Roman literary sources such as Pliny and Strabo. A strong hint of such arbitrage is captured in, arguably, the most significant source, the *Periplus Maris Erythraei* (49, trans. Casson):[21]

> In this port of trade [Barygaza] there is a market for: wine … copper, tin, and lead; coral and peridot (?); all kinds of clothing with no adornment or of printed fabric; … yellow sweet clover (?); raw glass; … sulphide of antimony; Roman money, gold and silver, which commands an exchange at some profit against the local currency

The trades involved in 'exchange at some profit' are unknown. Unfortunately, there is 'no elaborate literature on [early Indian coinage] and the acute paucity of materials makes it difficult to describe accurately the mint-places or towns where the ancient money was minted' (Thakur 1973, p. 265). Ignoring details of the debate on the origin of coinage in South Asia (e.g. Goyal 1999; Reddy 2014), the numismatic evidence and hints in literary sources such as the *Visuddhimagga* only establish a variety of coinage issued in different locales and kingdoms. Evidence from Kerala, which includes Muziris, only indicates that coinage in that region was under the control of kingdoms (Whittaker 2009, pp. 7–11; *Periplus* 54–6).[22]

## VII

The search for arbitrage in the imperial era of debasement and revaluation that commences with Nero and continues to the Severan dynasty and beyond dovetails with the modern debate over metallism versus 'nominalism' (Scheidel 2010) or 'chartalism' (Katsari 2011).[23] The transition from the 'metallism' of Roman coinage that roughly

[21] Barygaza was located in the locale of the Indian port of Bharuch in modern Gujarat. Casson (1989, pp. 5–10) details significant philological difficulties with the text of the *Periplus*. Recognizing Limyrike was a region located on the Malabar coast that most likely contained Muziris, one instance of relevance arises in (60), which Casson translates: 'There is a market in these places for all the [sc. Western] trade goods imported by Limyrike, and, generally speaking, there come to them all year round both the cash originating from Egypt and most kinds of all the goods originating from Limyrike and supplied along this coast.' The suspect Schoff (1912) translation makes no reference to 'cash', while Whittaker (2009) translates the key words as 'the money brought from Egypt'.

[22] Reference to bimetallism ignores the additional presence of small-denomination bronze and copper coinage used in daily transactions. With some exceptions, bronze and copper coinages were not profitable enough to be the source of any significant arbitrage activity despite also having legal and market exchange rates with silver and gold.

[23] Metallism is a theory in which the intrinsic value of money is connected to the value of precious metals; thus, money is treated as commodity. Chartalism is a theory that the intrinsic value of money originates from the role of the state as an issuing authority, stamping with insignia that guarantees the value. The physical composition of money as gold, silver, bronze, copper, or some other

reflected bullion content to the 'nominalism' of a debased coinage that did not speaks to historical context. The 'socially 'caged' Roman coin users of this debasement period 'lacked attractive alternatives to state-issued currency' for day-to-day transactions, the payment of taxes and so on (Schiedel 2010, p. 95). Absent 'more fragmented currency systems where diverse issues were free to compete on intrinsic quality', a debased coinage still retained advantages compared to barter or use of *hacksilber*. However, trade across the frontier was outside the 'social cage'. Though evidence of Roman trade with India dates from the second century BCE, perhaps earlier, trade expanded significantly from Augustus, arguably reaching a peak from the first to second century CE before declining in the third century, eventually petering out in the fifth century.[24] Recognizing that debasement commencing with Nero was in silver *denarii*, not gold *aureii,* it is significant 'that no specimen of gold coin before the time of the Kushanas [first to fifth century CE] has been found in India'. Thakur (1980, p. 99) attributes the emergence of gold coinage in India 'to the extensive volume of trade between India and Rome in the early centuries of the Christian era'. Cobb (2015, p. 384) observes that few post-Nero *denarii* have been found in Indian hoards.

The sources do provide some, albeit meager, evidence on the possibility of arbitrage involved in the conversion of silver *denarii* and gold *aureii* into Indian gold and silver coinage. In the Andhra region ruled by the Satavahana dynasty from the late second century BCE to the early third century CE – a region that was important in Roman trade and the location of a large number of Roman coin hoards – 'Roman traders were made to exchange their gold and silver coins for the lead coins of Satavahanas. Left over lead coins were no use for the traders and a large number of such dumps were found near the ports on the western coast of India' (Reddy 2014, pp. 69–70). The sources are silent on the details of the forced conversion. It appears that Roman coins did circulate after the Roman authority had been nullified by striking across the visage of the Roman ruler and imprinted marks of local authority added. There is also archaeological evidence that Roman gold coins were incorporated into gold chains for use as jewelry. Oddly, excavations have also uncovered imitations of Roman coins made of base metals.

commodity is not relevant. In contrast to metallism where the value of money is connected to the market place, in chartalism the value of money depends on government acceptance for payment of taxes, state fees and dues. Recognizing the origin of the term 'chartalism' is traced to a contribution by Georg Knapp in 1905 (Katsari 2011, p. 245), 'nominalism' is another more descriptive term used to denote chartalism.

[24] There is a vast literature on the details and chronology of ancient trade between the Mediterranean and regions to the east, especially with India. Included in this literature that covers activity over several millennia is debate about the precise chronology of Roman participation in the Indian Ocean trade. Cobb (2015) argues for a late first-century CE peak, with others claiming the possibility of peaking either earlier (Julio-Claudian 30 BCE – 68 CE) or later (mid to late second century CE). Cobb (2015) provides a useful survey of available evidence.

The nominalist coinage system that emerged from Nero to the Severan dynasty involved widely used silver *denarii* and base metal coinage with gold *aureii* seldom used for transactions (Harris 2006, p. 4). Comparison with bimetallic arbitrage of later 'metallist' periods (e.g. Friedman 1990; Nogues-Marco 2013) reveals key incentives for trading arising from the presence of sufficient difference across locations between the fixed legal exchange rate for gold and silver coinage and the variable market agio for exchanging bullion. Absent merchant mint access combined with a 'caged' monetary system, such bimetallic arbitrages were not possible. Even though coinage exchange rates 'were fixed by the central or municipal authorities' during this period, Elliott (2014, p. 141) observes that for the second and third centuries CE the epigraphic, legal and numismatic 'evidence can be taken to mean that [coinage and bullion] prices were functionally determined in marketplaces, not by law' leading to the emergence of black markets in response to debasement. Despite hints of possible arbitrage opportunities, scattered and unreliable evidence makes it difficult to know exactly how the process for valuing coinage and bullion worked in any detail.

With warranted caution Elliott observes that for this period of substantial debasements there is incomplete knowledge of specific mechanisms and institutions that existed for dealing with differences in weight and fineness standards. However, in general, grounds for denying such practices is insufficient. Though procedures may be unknowable, it may still be possible to determine the motives behind such practices, as well considering what such practices indicate about ancient attitudes toward the valuation of coinage and bullion. While hints of substantial coinage arbitrage trading, albeit on black markets, are apparent in sources such as the inscription from 210 CE at Mylasa (in Muğla province of southwestern modern Turkey) where 'anyone, in any manner whatever … caught exchanging or buying currency shall be brought to face the banker … before the council', details are absent (Elliott 2014, p. 144). Reference to 'the evil-doing and wickedness of some few who raid and embezzle the public moneys' due to 'a currency exchange that has invaded the market place' suggests bronze coinage – that could be minted by local authorities – was involved in possible arbitrage. The dating of the inscription corresponds to the substantial Severan *denarius* debasement that breeched the legal exchange ratio between silver and bronze resulting in a potential arbitrage involving the melting of undervalued bronze (e.g. Wassink 1991; Elliott 2014, p. 137).[25] The end of the Severan dynasty (235 CE) marks the beginning of a crisis period in the Roman empire. As Wassink (1991) and others observe, the crisis was accompanied by a dramatic increase in prices ending in hyperinflation, which generated attempts at

[25] This arbitrage involves borrowing silver *denarii* and exchanging at the official 1:16 exchange rate for undervalued bronze coinage, melting the coinage and selling bronze ingots on the commercial market for *denarii* that would be used to pay off the loan. Prior to the Severan debasement, bronze coinage was 'token' in terms of *denarii*.

substantive reform epitomized by the ill-fated Diocletian price edict of 301 CE. As numerous instances of hyperinflation have appeared in historical records stretching from antiquity to the present, it is well known that hyperinflation wreaks havoc on nominal currencies, whether token coinage or paper, stimulating the use of commodities – especially gold ingots or 'hard currency' – as a store of value. Other functions of money – unit of account and medium of exchange – can also be impacted. Elliott (2014, p. 150) provides the text of a fourth-century Egyptian papyrus requesting the sending of 'money quickly' in order to buy gold as 'everyone is looking for [gold] *solidi* and the price is going up every day'. While useful in indicating possible arbitrage involving 'money' – presumably debased *denarii* – being exchanged for gold coinage, such literary sources raise questions about the method for sending money, how the purchased gold was sold – on the black market for melting? – and whether there were features of trade in Egypt that differed from other regions of the empire.

As reflected in the price edict of 301 CE, dramatic price increases, accelerating remarkably in the last decade of the third century, characterized the early Dominate period that followed the crisis. The rant in the preface to the edict against 'unprincipled and licentious persons [that] think greed has a certain sort of obligation' provides hints, but not details, about the commercial aspects of quasi-arbitrage during this period. As the edict imposes equality of prices across locations, capital punishment is dictated for 'sellers and buyers whose habit is to go to ports and visit foreign provinces' to take advantage of price differences in different locations. Though the edict makes only passing reference to gold, silver and 'exchange', hints of arbitrage trading are reflected in subsequent sporadic edicts restricting gold and silver transport or melting. One such edict was issued by Constantius II in 356 CE (Katsari 2011, p. 100; *Theodosian Code* 9.23.1.1, trans. C. Pharr):

> Whoever is found either melting down or transporting coins to different regions in order to sell them let him come under the sentence of sacrilege and suffer capital punishment … No one amongst the traders is to carry on his animals more than a thousand *folles* in coins established in public use (*pecuniae in usu publico constitutae*) for the purpose of expenses.

Unfortunately, as much of the coinage during this period was debased, interpretation of the arbitrage associated with such edicts is far from transparent. That transport and melting, essential features of bimetallic arbitrage or geographical quasi-arbitrage, were a serious concern for the imperial Roman state during the Dominate is apparent. This edict makes specific reference to transport by ship (*Theodosian Code* 9.23.1.2):

> For we order that merchants should not carry every kind of coin in their ships, and in fact we permit only such coins as are established in public use to be so carried, and similarly only such goods as are customarily carried to different regions by merchants to be bought. But it shall be entirely unlawful for anybody to buy or handle forbidden coins, because it is proper for the price of a thing to be in coins established in public use and not in merchandise.

Reference to 'forbidden coins' indicates that more is involved in such possible arbitrages than the incentives related to the working of 'Gresham's Law' that 'bad money drives out good money'.

## VIII

What implications does the possibility of arbitrage trading have for the competition between 'primitivist' and 'modernist' historiographies regarding whether the ancient societies did, or did not, have a market economy? The search for the origins of arbitrage in antiquity lies at the compelling intersection of numismatics with economic, social and political history. Though numismatists do recognize connections between coinage and profit, details of such connections relevant to possible arbitrage trading are not explored in any detail. Recognizing variation in modern usage of the term 'arbitrage' and evolution in the etymology over time, ancient arbitrage is associated with trading in coinage and bullion for profit. As the obscurity of sources from Bronze Age civilizations defies plausible identification of arbitrage trading, the search commences with the introduction of coinage in regions of Greek influence starting in the late seventh century BCE. Epigraphic, literary and numismatic sources provide hints of possible arbitrage in regions with local coinage overvalued with respect to 'standard' silver coinage issued in Athens and Aegina. Substantive differences in social and political context between Greek and Roman civilizations translate to practical differences that altered the 'market economy' milieu for arbitrage trading.

While the agio for converting between standard and overvalued coinage underpinned market mechanisms for possible arbitrage trading in certain Greek *poleis*, the Roman empire had socially 'caged' coin users. During the Republic and early years of the Principate, the 'metallist' approach to coinage resulted in the value of silver *denarii* and gold *aureii* being roughly consistent with bullion content. This fueled possible arbitrage trading beyond the frontier in India, Arabia and the *barbaricum*. Starting with Nero, evidence from Roman coins in Indian hoards indicates that gradual debasement in Roman silver coinage undermined the metallist basis for possible arbitrage trading of silver, but not gold, in locales beyond the frontier. Debasement of the silver *denarius* led to a nominalist coinage system and eventual emergence of the hyperinflation that characterized the crisis and early Dominate periods. Imperial edicts restricting the melting and transport of coinage strongly suggest a transition of arbitrage trading to the black market economy during this period, effectively eliminating the possible survival of any sources detailing the types of trades involved.

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