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ABSTRACT

From 900 BCE to 323 BCE, the ancient Greek civilization advanced in all forms of science, economics, politics and art. During this time period, everything would change in the life of the average Greek citizen. Only 300 years prior, the Mycenaean civilization had collapsed, and a Greek Dark Age had descended over all of ancient Greek society. During the beginning of that Dark Age, as the Mycenaean empire collapsed, literacy and numeracy skills still existed, but were sequestered in literate scribes that were grouped into guilds, and were attached to the Mycenaean palaces that still existed throughout the Greek mainland and in Crete. As the Greek Dark Age progressed, even those guilds of scribes disappeared forever from Greek society. However, as the chaos of the Greek Dark Age receded, it was replaced by the order and stability of the Greek civilization's Archaic period. With the introduction of the new Greek alphabet, the new Greek numeral system, and the new Greek unitary system, which were introduced in the beginning of the Archaic period, ancient Greece transformed itself into one of the greatest economic powerhouses in human history (Scheidel et al., 2007). The new Greek alphabet, which was adopted and modified from the Phoenician phonetic alphabet, changed everything for the ancient Greek citizen. With the rapid adoption of the new Greek alphabet throughout the Greek-speaking population of the Aegean and eastern Mediterranean, literacy rates amongst the ancient Greeks not only quickly matched those of most other contemporary civilizations in the eastern Mediterranean, but also continued to rise, until it was eventually 10-fold greater than any other European or Near East civilization of that time (Missiou, 2011). With such an incredible increase in literacy amongst the Greek population came a consequent increase in numeracy. The characters of the new Greek alphabet were also used to represent the number characters in the new Greek numeral system (Powell, 1991). So, not only did the Greek citizen of the Archaic period of ancient Greece learn how to read, but they also learned how to count, and through counting, learned how to add. The new Greek numeral system quickly replaced the outdated Aegean numeral system that had preceded it. Through this symbiotic use of the new Greek alphabet characters to represent both words and numbers, numeracy increased at an accelerated rate throughout the ancient Greek population. The increase in literacy and numeracy also fueled an increase in economic trade with the surrounding civilizations of the eastern Mediterranean. That increased trade in turn created a need for standardization of weights and measures throughout the region. The new unified and standardized system of weights and measures eventually manifested itself in standardized Greek coinage, and that new Greek coinage quickly made the new Greek unitary system the hegemonic unitary system used throughout the eastern Mediterranean (Van Horn and Nelson, 2008). The new Greek unitary system had an inherent advantage over the other older and more established unitary systems of the time. By adopting this new unitary system, the Greek civilization began five centuries of the greatest economic growth that the ancient world had ever seen (Morris, 2004).

Keywords: Ancient Metrology, History of Science, Archaeological Standards, Ancient Greece, Unitary Systems, Evolution of Coinage.

Introduction

As ancient Greece emerged from its Dark Age, and entered into the Archaic and Classical periods of its civilization, from 900 BCE to 323 BCE, it flourished in all aspects of its culture and civilization. Advances in science, mathematics, philosophy, theater and international trade all occurred on the backdrop of a prosperity that was created by a rapid economic growth throughout all of the collective Greek and Ionian city-states. From 900 BCE to 400 BCE, the ancient Greek population, as well as their aggregate consumption, increased 15-fold, while the average house size increased four-fold (Morris, 2004). Rarely, has economic growth throughout a society been greater than the growth that occurred during the Archaic and Classical periods of Greek civilization. During those five centuries, everything was constantly changing for the ancient Greek society of that era. During this time period, there were several novel and unique developments in literacy, numeracy and metrological standards that quickly disseminated throughout the Greek civilization. The new Greek alphabet was established during this era, and quickly spread throughout the Greek population, borrowing and adapting new phonetic characters from the Phoenician alphabet. The new Greek alphabet quickly replaced the rarely used Linear B script of the preceding Mycenaean civilization. Linear B script had been the predominant palace script used throughout the Mycenaean empire, but was not phonetic, and was only mastered by a small group of palace scribes. Literacy and numeracy virtually did not exist amongst the common Greek population during the Mycenaean civilization. The introduction of the new Greek alphabet into ancient Greek society in the early 9th century BCE had occurred due to an extensive Phoenician emigration throughout the eastern Mediterranean at that time. In Greece, this emigration centered on the Aegean islands, with a strong Phoenician immigration into Euboea. The spread of the new Greek alphabet throughout the ancient Greek world only accelerated over the following century, as extensive trade and cultural relations expanded between the Greek city-states, the Ionian city-states, and the Phoenician settlements along the Levantine coast. To say that literacy increased significantly amongst the Greek population of the time would be an understatement. It would be more appropriate to say that literacy for the common Greek citizen started at this time, having never truly existed for most Greek citizens prior to that time. Within 100 years, all of the Greek mainland, Ionia, and all of the Greek colonies had gone from a literacy rate of approximately 0.5% to the highest literacy rate in the ancient world of 5-10% (Woodard, 2013). This increased literacy rate of the Greeks was ten-fold greater than any other civilization of their day, due to the ease of use of the new phonetic Greek alphabet. The effective literacy rates for the Egyptian, Mesopotamian, Roman or Carthaginian civilizations at the time was approximately 1% (Baines, 1983). As a consequence of the great increase in literacy, numeracy also significantly increased amongst the Greek population. The symbols that comprised the new Greek alphabet were also seconded to represent the numbers of the new Greek numeral system. This symbiotic relationship between the new Greek alphabet and the new Greek numeral system was one of the major advances in communications technology at that time. The ubiquitous use of the characters for both writing and adding only reinforced its adoption by all literate citizens throughout the Greek civilization. The rapid and unequivocal adoption of the new alphabetic/numeric characters by the ancient Greeks quickly allowed them to become one of the greatest trading civilizations of all antiquity. The significant increases in numeracy and literacy that occurred between the 9th and 5th centuries BCE quickly provided the Greek citizens of that time with the necessary skills to extend their political and economic experiments over those five centuries (Scheidel et al., 2007). The economic growth during the Archaic and Classical periods of ancient Greek civilization was not matched again until the relatively modern industrial revolution that occurred in Britain in the late 18th century (Morris, 2004).

The custom of using coins (standardized weights made of precious metals) as monetary exchange also had a large bearing on the economic advances that occurred during that time. The standardization of weights, through the use of standardized coinage, certainly contributed to the exceptional increases in trade and prosperity that became evident throughout the ancient Greek civilization of this time. Coins from the 7th century BCE were being coined in both Lydia, on the Ionian mainland, as well as on the island of Aegina in the Aegean, a major competitor of Athens at that time. Within 100 years after that time, almost all transactions of commodities in the eastern Mediterranean would be conducted using coins as the monetary exchange mechanism. Within 150 years of that time, almost all retail transactions done throughout the entire Mediterranean would be using coins as the medium of exchange (Lahanas, 2015). It should always be remembered that coins were originally not accepted on their face-value, as we have come to use coins today. In ancient times, coins were always weighed against unitary weight standards. It was only after hundreds of years of coin use that coins were finally exchanged for their face-value, and then only coins of small denomination. Originally, coins were used simply as state-certified standard weights, used to accurately measure metal commodity weights. But, as the coin weights became more and more standardized and accurate, the precious metals they embodied gave way to their convenient acceptance as standards of monetary exchange, in addition to their representation of the standard weights of the contemporary unitary system. As coins became the common form of monetary exchange throughout the ancient Mediterranean, more attention was logically placed on the standardization of the unitary systems throughout the region, as well. The new unitary systems that the ancient Greeks adopted at this time (predominantly from Egyptian and Phoenician sources) unified the Greek mainland and Ionian city-states under one unitary system, with the Aegean islands using a similar, yet competing unitary system. These two competing unitary systems eventually coalesced, and afforded the ancient Greeks with a great advantage in trade and finance. The advantages toward trade and commerce were inherent in the creation of the new Greek unitary system. It differed significantly from the other unitary systems in use at that time by establishing primary lineal units that were very slightly larger than all of their competitor’s primary lineal units of that time. This naturally also made their areal units much larger than their competitors. In brief, this meant that importing from Greek merchants always gave an overseas importer a more profitable transaction than buying from domestic suppliers or importing from non-Greek competitors. Also, due to Greek coinage being directly related to the primary standards of weight in the unitary system, meant that Greek coins (especially Aeginetic coins) were slightly heavier than their competitors' coins, and more sought after (Rutter, 1983). In summary, if you were a foreign buyer, it was always far better to buy from Greek merchants, and it was always far better to hold Greek currency.

The Communications Revolution: The New Greek Alphabet and Numeral Systems

The Archaic and Classical periods of ancient Greece were a period of great Renaissance in the fields of politics, science and mathematics. Ancient Greek philosophers, mathematicians and scientists laid the fundamental bases for the great advances in Western civilization that still reverberate throughout our World culture today. Innovations that were initiated in Greece during the Archaic and Classical periods of their development still have few parallels throughout human history. During that time, the ancient Greeks were also amongst the greatest merchants and traders throughout the Aegean and the eastern Mediterranean. Questions naturally arise concerning how the Greek civilization emerged from the Greek Dark Age, after the fall of the Mycenaean civilization, to become such a progressive force in the development of Western civilization. The introduction of the new Greek alphabet quickly replaced the old, noble script of Linear B. The introduction of a phonetic alphabet into the Greek society of that time was comparable, if not greater, than the introduction of the telegraph and telephone into the society of the 19th century, or the introduction of the Internet into our own contemporary society. While the Greek population quickly increased their literacy rate from .5% to 10% in a period of approximately 100 years, the literacy rate in Egypt and Mesopotamia remained at 1% of the population during that entire time.

The importance of the introduction of the new Greek alphabet into the Greek population of that time cannot be under-rated. Its introduction eventually contributed to the freedom of thought that was to emerge in many parts of Greece between the 9th and the 5th centuries BCE. As the literacy rate increased exponentially amongst the Greek population, Greek citizens also experienced a consequent increase in numeracy skills (Carpenter, 1933). The introduction of the new Greek alphabet was nothing less than a communications technology miracle, which resulted in three significant developments for Greek society:

1. A significant increase in life expectancy throughout ancient Greek society (Angel, 1947).
2. A significant population increase throughout the ancient Greek society.
3. A significant increase in the standard of living of the individual Greek citizen.

The only way that all of these developments could occur at the same time is due to the economic phenomenon that accompanied the introduction of the new Greek alphabet into Greek society, and its associated rise in literacy and numeracy. These increases in population, life expectancy and the standard of living were a direct byproduct of the enormous increase in productivity that occurred due to more individuals being able to read, write and perform simple arithmetic. Words and thoughts could finally be recorded for posterity by the common man. Instead of only one man in 200 being able to read and write, one man in 10 could read and write. This brought written communication to all parts of the Greek civilization, and eventually to all the civilizations throughout the Mediterranean. Anyone could send a letter to anyone else, simply by visiting someone who could read and write, and the number of individuals that could do that was constantly growing. Words recorded poems, and songs, and memories. And, due to this new medium of communication technology, new knowledge spread even faster than literacy, further advancing productivity increases. Consequent to this communications revolution, the new Greek numeral system began using the new alphabetic characters to record commerce, as well as poems. By 700 BCE, merchants were routinely using the new alphabet and numbering system to keep track of finance, collateral, and inventory throughout the eastern Mediterranean. To count was to write, and to write was to be educated. This ability separated those individuals from others that could not write. The consequential increase in the numeracy rate at the same time as the phenomenal increase in the literacy rate was no coincidence (Carpenter, 1933). Unlike previously, the alphabet and the numeral system were now inextricably linked. As the ancient Greek civilization began keeping a greater and greater amount of written records, the demand amongst the population to possess numeracy and mathematical skills also naturally increased. At the same time, the standardization of weights and measures began to occur throughout the Greek city-states. King Pheidon, the king of Argos, and Protector of Aegina, was the first to establish the standard units of weights and measures for both liquids and dry goods throughout the Aegean ("Pheidon | king of Argos | Britannica.com,").

At the time that the new Greek alphabet was being introduced into the ancient Greek civilization, the old Greek unitary system was also being overhauled from its Mycenaean roots to become a newer, more Greek, and more trade-directed unitary system of weights and measures.

The Industrial Revolution: The New Greek Lineal and Areal Measurement Systems

A discussion of comparative unitary systems used by the Greeks in the Archaic and Classical periods of ancient Greece cannot be similar to a discussion of contemporary unitary systems. There were no dimensions of temperature, energy, power or entropy in the unitary systems that were current in the Archaic and Classical periods of ancient Greece. The dimensions that were predominant in the unitary systems of that time included units of lineal measurement, areal measurement, volume measurement and weight measurement. In all unitary systems that were in use at that time, units of lineal measurement were also used for areal measurement. Therefore, a Greek foot measurement was used to measure lineal distance, but was also used to measure areal measurement, in terms of square feet. Today, inherent in our unitary systems is the common knowledge that area is related to linear measurement by the relationship of length x width, and that volume is related to linear measurement by the relationship of length x width x height. To the ancient Greek citizen, lineal measure and areal measure were two independent dimensions. Although all of the regional unitary systems that were being used at the time had similar primary units, the objective measure of these primary units was not static across the entire region of the eastern Mediterranean and the Near East. As can be seen in Table 1 below, the Greek daktylos, which is the smallest unit in both lineal and areal dimensions in the new Greek unitary system, is larger than any of the other regionally-based smallest lineal and areal measurement units used in competing unitary systems that were in common use throughout the Aegean and eastern Mediterranean. This smallest and most primary of all Greek lineal and areal units was not a length that was arbitrarily chosen. Like all of the other primary lineal and areal units that were in use at that time, the daktylos was equivalent to a replicable physical standard. The daktylos, as well as every other primary lineal unit of the time was traditionally considered to be the width of a person’s finger. The ancient Greeks simply decided that their fingers were wider than individuals from other cultures, as is shown below.

Table 1. *Comparison of Smallest Primary Units of Contemporary Civilizations in Europe and the Near East*

	Modern Centimeter	Egyptian djeba	Mesopotamian ubanu	Roman digitus
Greek daktylos	1.928 centimeters	1.030 djeba=1 daktylos	1.170 ubanu=1 daktylos	1.043 digitus=1 daktylos
Egyptian djeba	1.871 centimeters	1.0	1.13 ubanu=1djeba	1.012 digitus=1 djeba
Mesopotamian ubanu	1.650 centimeters	.88 djeba=1 ubanu	1.0	.892 digitus=1 ubanu
Roman digitus	1.849 centimeters	.99 djeba=1 digitus	1.121 ubanu=1digitus	1.0
Modern meter	51.81 daktylos=1 meter	53.45 djeba=1 meter	60.61 ubanu=1 meter	54.08 digitus=1 meter

Table 2. *Comparison of Higher Order Lineal Units to the Greek Daktylos and Pous*

Name of Unit (As related to the Daktylos)	Daktylos	Meters
01-Daktylos	1	0.01928
07-Pous	256	0.31
13-Orguia	9216	1.85
17-Plethron	2560000	30.8
Name of Unit (As related to the Pous)	Pous	Meters
01-Pous	1	0.31
05-Orguia	6	1.85
07-Plethron	100	30.8
10-Stadion	600	184.98
18-Milion	4800	1479
22-Parasanges	18000	5548
23-Schoinos	24000	7397

Table 1 above, in comparing the smallest units of lineal and areal measurement amongst the unitary systems that were in use at the time, demonstrates the inherent advantage that the new Greek unitary system had over its contemporaries in lineal and areal measurements. Shown in Table 2, is a comparison of the derived lineal and areal measurements that were used in the new Greek unitary system that measured larger lengths and areas, but still were integer multiples of the smallest unit of measurement, the daktylos. At the end of the Greek Dark Age, the Greek daktylos measured only 18 mm in Athens and the surrounding countryside. But, in most of the other mainland Greek city-states, the daktylos measured a minimum of 20 mm, with it measuring as long as 21 mm throughout much of the Aegean islands. Only the early Delphic standard of the daktylos was significantly shorter at 15.9 centimeters. However, as the Greek Archaic period continued, even the late Delphic standard was increased to 18 centimeters (Gyllenbok, 2018). Since this was the smallest primary unit of length in the ancient Greek unitary system, it was of primary importance to all of the integral multiples of this smallest unit of length. Since units of length were also used to describe units of area, the differences between the daktylos, the djeba, the digitus and the ubanu become even more acute when we examine the square of these units of length. As a comparison of all four of these primary units of area, please see Table 3 below.

Table 3. *Comparison of Areal Units of Measurement*

	length	Length Difference	Percent Longer	Area Percent Increase
Daktylos	1.928 cm	0.0	0.0 %	0.0%
Djeba	1.871 cm	.057 cm	3.046 %	6.092%
Ubanu	1.65 cm	.278 cm	16.85 %	33.70%
Digitus	1.849 cm	.079 cm	4.273 %	8.546%

In all of the unitary systems prevalent throughout the ancient world at that time, each unitary system based all of its larger lineal and areal measurements on similar integer multiples of the smallest lineal primary unit in their respective unitary systems. For instance, the Greek foot was comprised of exactly 16 daktylos. The orguia, which we commonly think of as the fathom, was comprised unofficially of six Greek feet, but more exactly was comprised of 96 daktylos. The stadion, which was nominally thought of as 600 Greek feet, is more exactly measured as 9600 daktylos. Similarly, the ancient Egyptian units were established as multiples of their smallest primary lineal unit. The Egyptians smallest primary unit was the djeba. And, similar to the Greek unitary system of the time, all larger lineal units within the Egyptian unitary system were based as integer multiples of this smallest unit of lineal measure, the djeba. The Egyptian djeser, which was comparable to the Greek foot, was comprised of 16 djeba, just as the Greek foot was comprised of 16 daktylos. The smallest primary lineal unit of measurement in the Roman unitary system at this time was the digitus, which was also much smaller than the daktylos. It took 1.030 Egyptian djebas to equal one Greek daktylos, and it took 1.043 Roman digiti to equal one Greek daktylos. However, any commerce that was transacted in the eastern Mediterranean at the time considered all three of these smallest primary units to be exactly the same. And, considering the uncertainty associated with the standardized measurements of each of these three primary lineal units, in many cases they may have been very similar to one another.

The greater problem was that these smallest lineal units of measurement were not only used for lineal measurements, but were also used for areal measurements, as is demonstrated in Table 3 above. So, although it took 1.030 djeba to equal one daktylos, it took 1.061 square djeba to equal one square daktylos. The conversion factor between the Greek daktylos and the Roman digitus was even more pronounced. Even though it only took 1.043 Roman digiti to equal one Greek daktylos, it required 1.088 square digiti to equal one square daktylos. Since all of the larger units were based as integer multiples of the base unit of lineal measurement, all of the lineal measurements between the Greek and the Egyptian unitary systems had a discrepancy of approximately 3%, with the discrepancy between their areal measurements being approximately 6%. The difference between the Greek and the Roman unitary systems produced a discrepancy of approximately 4.3% for all lineal measurements, but produced a discrepancy of almost 9% for all areal measurements. Therefore, when buying commodities that were based on lineal measurement, such as string, thread or rope, the Greek merchants were always giving the purchaser 3-4% more than their Egyptian or

Roman counterparts. But, the discount was even more pronounced when buying commodities that were based on areal measurement, such as cloth, blankets and cloaks. In these instances, the Greek merchant was giving 6% to 9% more than their Egyptian and Roman counterparts, respectively. Although most individuals that were living during this period did not understand the mathematical relationship between lineal measurement and areal measurement, they did inherently understand that they were receiving more for less, just as consumers do today. Even though it was only a 5-10% better deal than their competitors, the Greek merchants of the time benefitted much more greatly than that, at the expense of the Egyptian, Syrian and Roman merchants.

The primary units of volume in the ancient world were similarly interrelated between the various unitary systems in use at the time. It should be no surprise that the smallest primary unit of volume in all of the regional unitary systems of that time was based on the “spoon”. The smallest primary unit for volume used in the Egyptian unitary system was the “ro”, which was equivalent to a contemporary tablespoon measure (15 mL). In the new Greek unitary system that was being introduced at that time, the smallest unit of volume was the kochliarion, which was equivalent to a contemporary teaspoon measure (4.5 mL). And, in that way, was equivalent to a physical standard. The next largest unit of volume measure, the kotyle (60 kochliarion), was also equivalent to a physical standard. It is the volume of barley that can be held in two cupped hands. The smallest unit of volume in the Roman unitary system of the time was the ligula (11.4 mL), which was exactly midway between the smallest Greek and the smallest Egyptian units of volume. Like the Egyptians, the Mesopotamian unitary system’s smallest unit of volume was the “gin” (16.6 mL). Although these were the smallest units of volume in each of these four regional unitary systems, these were not the primary units of volume in any of these four different unitary systems. In actuality, these regional unitary systems had their primary units of volume much more closely related to the amount that a person could drink, rather than what could be held in a “spoon” measure. For instance, the Egyptian, Roman and Greek primary units of volume measurement were more closely related to the contemporary pint or half-liter. Only the Mesopotamian unitary system used a primary unit of volume that was more closely related to the liter than the half-liter.

King Pheidon, the king of Argos during the 7^{th} century BCE not only introduced silver coinage to the world through the mint on Aegina, but also introduced the first standardized units of dry and liquid measurement to the new Greek unitary system (“Pheidon | king of Argos | Britannica.com,” n.d.). Later, in Attica, and throughout the Greek mainland, Solon reformed and unified those units of volume measurement. But, from the time of their introduction, both the Attic and the Aeginetic system of volume measurement was much more standardized than any of the other competing volume units use by competing unitary systems of the time. A listing of the Attic volume measurements in use at the time is shown in Tables 4 and 5 below.

Table 4. *New Greek Unitary System Liquid Volume Measurement*

Unit (liquid volume)	Equal to	Metric equivalent
kochliarion		4.5 ml
kotylē,	60 kochliaria	272.8 ml
xestēs	120 kochliaria	545.5 ml
chous	720 kochliaria	3.27 liters
keramion	5760 kochliaria	26.2 liters
metrētēs	8640 kochliaria	39.3 liters
(Smith, William, Sir, 1851)		

Table 5. *New Greek Unitary System Dry Volume Measurement*

Unit (dry volume)	Equal to	Modern equivalent
kochliarion		4.5 ml
kotylē or hēmina	60 kochliaria	272.8 ml
xestēs	120 kochliaria	545.5 ml
choinix	240 kochliaria	1.09 liters
hēmiekton	960 kochliaria	4.36 liters
hekteus	1920 kochliaria	8.73 liters
medimnos	11520 kochliaria	52.4 liters
(Smith, William, Sir, 1851)		

The Financial Revolution: The New Greek Weight and Coinage Systems

The key to the economic phenomenon that was Greece in the Archaic and Classical periods of ancient Greece depended principally on the introduction of the new Greek alphabet. However, as the alphabet and the new Greek numeral system spread literacy and numeracy throughout the Greek civilization, the average Greek citizen started to learn more about the world around them, which manifested itself in increased trade throughout the eastern Mediterranean. To buy and sell goods profitably, each Greek merchant had to have their own sets of weights, and those weights had to be standardized throughout the trading region, so that the same amount of commodities could be exchanged between any two parties. The primary units of weight for each of the four regional unitary systems that were in use throughout the eastern Mediterranean at the time were related to their smallest units of volume. The smallest unit of weight used in the Egyptian system was the qedet. The qedet was defined as the weight of a “ro” (tablespoon measure) filled with barley, and was approximately 9.33 g. In the new kingdom, 10 qedets were supposed to be equal to 1deben, which was the Egyptian unitary system’s primary unit of weight (Bosak, 2014). But, from many of the existing weights that have been measured, the deben was closer to approximately 91 g, rather than 93.3 g. It was interesting that the Egyptian unitary system was unified at the base level of volume and weight, and that unification was based on the common commodity of barley. The smallest practical unit of weight in the Mesopotamian unitary system at that time was the "gin" or "shekel", which was approximately 8.40 grams. Originally, sixty gin comprised a mana, which was the primary unit of weight in the Mesopotamian unitary system (504 g). But, eventually, that figure became 50 gin, or shekels, to a mana, rather than sixty. The Mesopotamian mana developed into the Phoenician and Greek mina, which became the most common primary measure of weight throughout all of the Mediterranean. The smallest unit of weight in the Greek unitary systems was the "obol", but the primary unit of weight was the "mina" (431 g), which was comprised of 600 obols (.718 g), or equally comprised of 100 drachma (4.31 g). The mina, as the Greek primary unit of weight, was adopted from the Phoenician unitary system originally, just as the new Greek alphabet and numeral system had been adopted.

Unlike the other standards for lineal and areal measurement in the new Greek unitary system, there were two competing standards for the primary unit of weight in the ancient Greek unitary system. One of these standards was promulgated by the Aegean island of Aegina. As trade flourished in the Aegean and the eastern Mediterranean between 800 BCE and 500 BCE, standardized weights were necessary to assure that the trade of commodities was conducted fairly. In an examination of ancient weights that have been discovered in archaeological excavations, differences as great as +/- 1-2% have been noticed between different sets of similar weights, which signifies that a 1-2% difference between different merchants, or between different unitary standards, was acceptable in commerce during that time. The introduction of coinage, as standardized weights of precious metals to be used in certified commodity exchanges in Lydia, quickly spread throughout the Ionian Greek population. This use of standardized weights as value exchange continued to spread into the Aegean population, and through extensive minting of "turtle" weight standards on the island of Aegina in the eighth century BCE, spread throughout the entire Mediterranean basin. As standardized weights made of gold and silver became prevalent throughout the Aegean and Phoenician trading regions, the convention of using standardized weights of precious metals as an exchange and storage mechanism of monetary value rapidly gained acceptance amongst the Greek population. Although small weights that were used as monetary exchange mechanisms have uncertainties associated with their weight of 2-3%, the larger weights that were used to weigh precious metals have been discovered to have much more exact tolerances, due to their use of exchange between various municipalities or city-states. Just as the characters that were used in the new Greek alphabet also helped to increase numeracy through their use as Greek numeral characters, the new coinage helped to spread and popularize the new Greek unitary system, as its use permeated the trade of the Aegean and eastern Mediterranean. Not only did it become more lucrative to buy from Greek merchants, but it also became more convenient due to the new form of monetary exchange that could be used. In Ionia and the Aegean, standardized weight coinage was minted predominantly in gold and silver, with the ratio between the weights for silver and gold being 15:1. The ratio between iron and gold at the time was 400:1, and the ratio between bronze to gold was 30:1. From that point forward, with the introduction of coinage, all Greek citizens had to become at least somewhat numerate, because all of them would need to use coinage, and to determine the value of their goods in terms of coinage equivalencies.

Kessler and Temin point out that early Roman coinage began for several reasons. First, the introduction of coinage served to advertise the suzerainty of the issuing authority. Secondly, the introduction of coinage provided for a more consistent and broadly recognized valuation of commodities, as well as a much more convenient payment method (Kessler and Temin, 2008). The ease and convenience of coinage for the exchange of commodities also consequently increased trade throughout the eastern Mediterranean. Just as the convenience of using the euro across the European continent today has drastically increased trade amongst the individual European nations, the original introduction of drachmae in the 6th century BCE rapidly increased trade throughout the Aegean and the eastern Mediterranean.

If the economic miracle that occurred between the eighth century BCE and the fourth century BCE is examined in GDP growth rates per capita, it is clearly evident that in those four centuries, consumption per capita increased ten-fold to fifteen-fold, as compared to consumption at the beginning of that time period (Scheidel et al., 2007). The greatest single reason for this incredibly large rate of increase in consumption over those four centuries was predominantly due to the fact that Greek society was extremely impoverished at the end of the Greek Dark Age, and any increase in consumption would have been substantial. But, such an incredible increase in personal consumption was certainly not expected. The greatest increases in Greek economic activity that occurred between 800 B.C.E. and 323 BCE were entirely due to two factors. First, the life expectancy in Greece and the Aegean during that time increased markedly. And, secondly, the overall population of the Greek mainland and Ionia, as well as the Greek colonies in Italy and Sicily, increased exponentially during those five centuries. Those factors spawned a cultural, educational and financial Renaissance throughout the eastern Mediterranean.

Conclusions

It is always interesting to analyze how a society that is in chaos can transform itself into a powerhouse of innovation and prosperity. Usually, the other outcome is more common. But, in the case of Greek civilization, the void left by the collapse of the Mycenaean empire allowed the population to search out new methods that would increase productivity through an increase in education. That educational breakthrough allowed the population to attain new powers and skills that allowed it to become captains of industry and trade throughout the eastern Mediterranean. By standardizing their unitary system, they accidentally introduced coinage into the commerce of the Aegean and the eastern Mediterranean, which contributed to the continued increase in productivity of the region.

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