Long-run patterns in market efficiency in the Seleucid and Roman Empires and their successors, ca. 500 BC – AD1800[1]

Bas van Leeuwen, Peter Foldvari, and Jan Luiten van Zanden

Abstract

In this paper we analyze market efficiency in the Near East and the Roman Empire and its successor states between ca. 500BC and AD 1800. We find that that the economies became increasingly capable of handling unexpected supply and demand shocks, which resulted in a decline of price volatility and, as a consequence, a rise in market efficiency in both the Western Europe and the dry-land agricultures in the Near East. In the irrigated areas like Iraq and Egypt, however, we find no evidence for improving market efficiency.

The improvement in market efficiency can be explained by four factors: technology, diversification of consumption, trade, and storage. We find that whereas such factors underwent significant development in the West from the 9th to 15th century, the Near East was characterized by long-run stability.

From the 15th century onwards, we find a further increase in market efficiency in the Western countries. However, a geographical shift took place: countries that had relatively efficient grain markets in the 16th century were relatively inefficient in the 18th, even though the absolute level of market efficiency increased for almost all countries in our sample. We explain this by the finding that urban concentration, which was initially bad for market efficiency, had a positive effect on trade and efficiency from the 17th century onwards, largely because of reduction in transaction costs.

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I

Market efficiency, that we define, following Foldvari and Van Leeuwen (2011), as the capacity of the market to absorb unexpected supply or demand shocks[2], is often seen as a driving force in economic development.[3] Whereas some authors emphasize the connection between increasing market efficiency and growth in the early modern period, others have stressed the presence of well working markets in the medieval world.[4] This latter view seems to be consistent with recent research showing that per capita income in the late medieval period was already higher than hitherto assumed.[5] At the same time, studies of classical economies find little evidence of a lower per capita income in the classical period compared to the medieval world.[6] Given the consensus that market efficiency is connected with economic development[7], this suggests that market efficiency in the ancient economies must be comparable to that of the medieval world.

Market efficiency is often measured through the volatility of the price series. The underlying idea is that the more volatile a price series of a good, the less its institutional structure is apparently able to reduce the effect of shocks on the supply (and demand) for that product. Hence, the less efficient a market is. Since volatility measures like the variance or the standard deviation are level dependent (the higher a price, the higher the variance or standard deviation will be), in recent literature it became more common to use the Coefficient of

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[2] Foldvari and Van Leeuwen, "What can price volatility tell us".
[3] See for example Allen and Unger 'The Depth and Breadth of the Market for Polish Grain 1500-1800'; Persson, *Grain Markets in Europe*; , Findlay and O'Rourke, *Commodity market integration, 1500-2000;* Jacks, 'Market Integration in the North and Baltic Seas'. The term 'market efficiency' should not be confused with the term 'efficent markets' central to financial economics.
[4] E.g. Masschaele, 'Transport costs in medieval England'; Clark, 'Markets and Economic Growth'; Galloway, 'One Market or Many? '.
[5] E.g. Prados de la Escosura and Álvarez-Nogal, 'The Rise and Decline of Spain'; Malanima, 'Italian GDP 1300-1913'; Broadberry *et al* , 'British economic growth, 1300-1850'; Van Leeuwen and Van Zanden, 'The origins of 'modern economic growth?'.
[6] E.g. Maddison, *The World Economy.* See also the recent studies from Amemiya, 'Economy and economics of ancient Greece,'on Athens and from Lo Cascio and Malanima, 'GDP in Pre-Modern Agrarian Economies (1-1820 AD): A Revision of the Estimates,' Table 8, who finds a slightly decreasing GDP per capita up to the middle ages in Italy.
[7] E.g. North and Thomas, 'The Rise of the Western World'; Studer, 'India and the Great Divergence.'

Variance (CV).[8] The CV, which is defined as the standard deviation divided by the mean, has as a big advantage that it can be compared between economies with different absolute price levels. However, the disadvantage is that it captures both the explained and unexplained variance. Since the explained variance, such as caused by a differential agricultural structure, may differ across regions without changing market efficiency, Foldvari and Van Leeuwen (2011) have proposed a simple method to remove this expected volatility from the CV.[9]

In this paper, we use this method to analyse market efficiency over time in the Near East. In the next section we discuss the data. Section 3 discusses volatility and market efficiency using a standard CV. We find that market efficiency increases in the West and Turkey, but remains remarkably table in Iraq and Egypt between ca. 500 BC and AD 1500. After 1500, market efficiency increased further. In Section 4 we discuss the possible reasons underlying these deviations, i.e. technological change, changing consumption patterns, trade, and storage. In Section 5 we offer a "sneak peak" in the period after 1500. We end with a brief conclusion.

II

In order to calculate the CV as a measure of market efficiency between 600 BC and AD 1800, one needs to collect time series for periods with sometimes scarce data. In this paper we limit us to the prices of the main staple crops since these data not only are the most abundant but, as argued by Adam Smith, also capture the value of labour.[10]

For the period between 600 and 500 BC the data are taken from Jursa.[11] These data refer not only to Babylon, but also to neighbouring Uruk, Sippar, Nippur, and Borsippa. Theoretically, it would be preferably to estimate a dummy regression in which we regressed

[8] See, for example, Persson, *Grain markets*; Soderberg, 'Grain Prices in Cairo and Europe in the Middle Ages,' Jursa, *Aspects of the Economic History of Babylonia*; Ó Gráda, 'Markets and Famines in Pre-Industrial Europe.'
[9] Foldvari and Van Leeuwen, "What can price volatility tell us".
[10] Smith, 'An inquiry,' p. 33.
[11] Jursa, *Aspects of the Economic History of Babylonia*, pp. 443-457.

the prices on dummies referring to place, year, and month as suggested by Clark.[12] In that way we can correct for regional and monthly variation. Furthermore, this kind of regression improves with the number of observations. Since our sample is small and the price level among the different cities did not strongly deviate, we decided to take the simple annual averages of the prices.

For the period ca. 500-50 BC we take the data for the city of Babylon only.[13] These data are based on the Astronomical Diaries. These diaries are best described by Hunger and Pingree as 'record(s) of observed phenomena carefully chosen from the realms of the celestial, the atmospheric, and the terrestrial.'[14] In other words, astronomers tried to predict events based on the position of the planets. One thing they noted down was the level of the prices of six commodities: barley, dates, cuscuta, water cress, sesame and wool. Theoretically, these prices exist for the period ca 400-50BC monthly, or even daily. However, many observations are missing. Still, out of a possible 4079 months, we still have observations for 512 months.[15] This allows us to correct the prices for seasonality using a regression with monthly dummies.

For other regions we have far less data. The best dataset outside of Babylon is possibly for Egypt. Von Reden reports prices for Egypt between ca. 300 and 90 BC.[16] These data are largely representative for the more densely Greek dominated parts of the country. As Von Reden (2008) points out, however, the prices are representative of normal market behaviour in Egypt. In the same paper, she also presents data for Delos, taken from Reger (1994)[17], and Athens. Further, we use data for the second great Empire in this region, Rome, from

[12] Clark, 'The price history of English agriculture.'

[13] Slotsky, *The bourse of Babylon*; Vargyas, *A history of Babylonian prices*.; Slotsky and Wallenfels, *Tallies and trends*. These data are made consistent, extended and made electronically available by Van der Spek (Personal communication).

[14] Hunger and Pingree, *Astral sciences in* Mesopotamia, p. 141. The name 'Diary' was coined by Abraham Sachs on the basis of the colophon-title *naṣāru* (EN.NUN) *šá ginê*, 'regular observation'.

[15] Average of the number of available observations on barley and dates.

[16] Von Reden, 'Price fluctuations.'

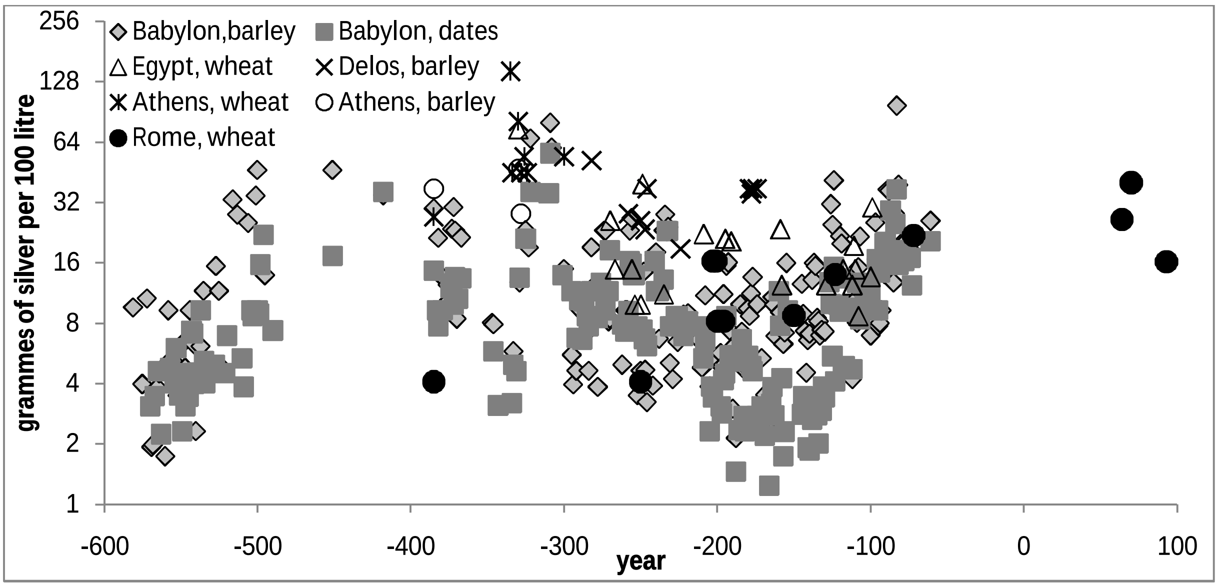
[17] Reger, *Regionalism and change*.

Rathbone.[18] For the later periods from ca. 1200 onwards we have data from Iraq, Egypt, Syria and Istanbul.[19] The earlier estimates are normally taken from contemporary economic historians, often reporting extreme prices, while the Istanbul data refer to retail prices.[20] The data for the period after 1500 are more abundant. We included the retail prices for wheat from Istanbul as well as data from Tuscany, Modena, and Naples.[21]

Three problems surround these data. First, some authors, in the Finleyian[22] tradition, have doubted whether the prices from antiquity are "real" market prices. Yet, as

Figure 1A

Grammes of silver per hectoliter (log 2 scale), 600BC-AD100



Source: Jursa (2010); Vargyas (2001); Von Reden (2008); Van der Spek (2010); Rathbone (2011)

[18] Rathbone, 'Mediterrenean grain prices.'

[19] Ashtor, *Histoire des prix*; Mortel, Prices in Mecca'; Pamuk, ''Prices in the Ottoman Empire.'

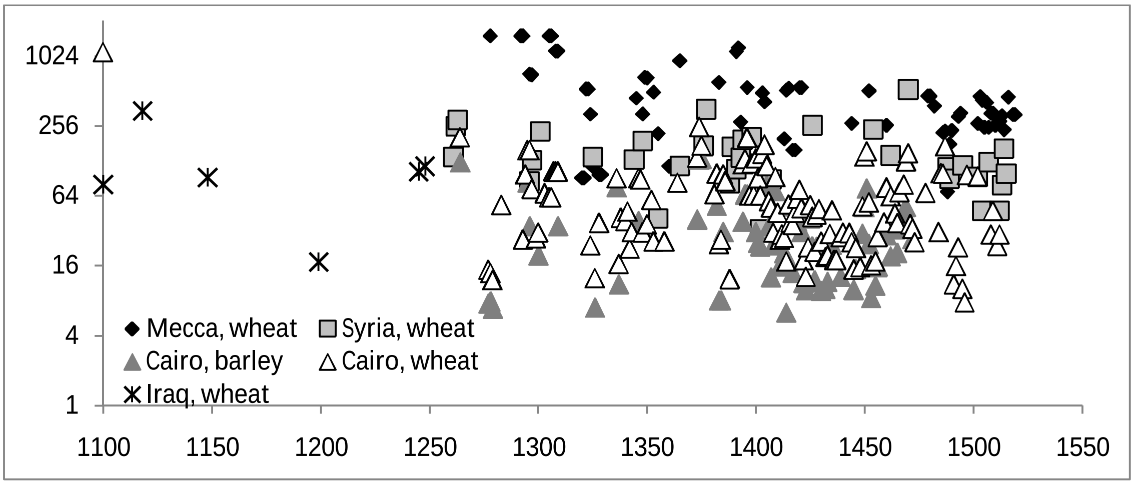
[20] Pamuk, Prices in the Ottoman Empire,' p. 452.

[21] Pamuk, Prices in the Ottoman Empire,'; Malanima, *Aspetto di mercato e prezzi,*; Basini, *Sul mercato di Modena*; Coniglio, "La revoluzione dei prezzi,"; Romano, R., *Prezzi, salari e servizi.*

[22] Finley, *The Ancient Economy*.

Figure 1B

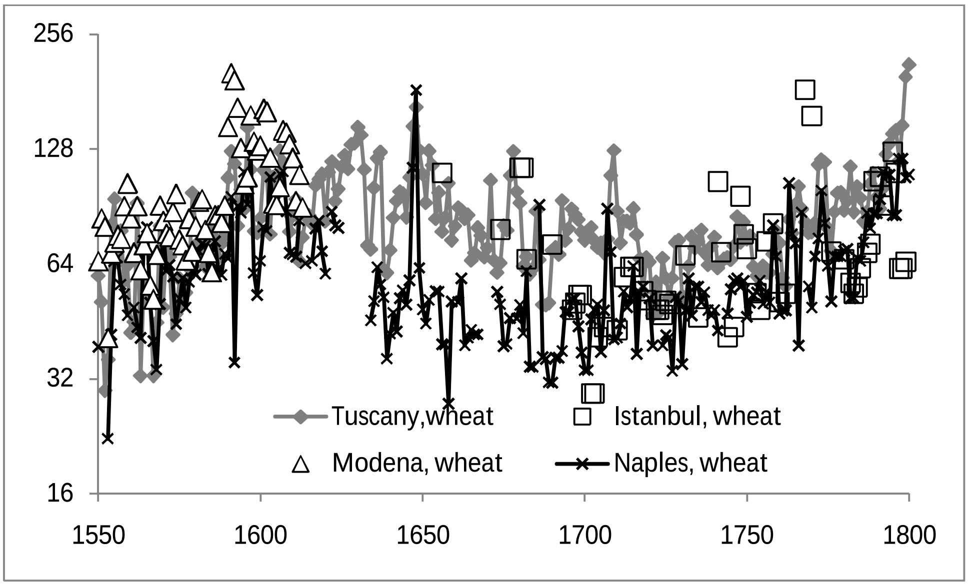
Grammes of silver per hectoliter (log 2 scale), AD1250-AD1550



Source: Ashtor (1969); Mortel (1989); Pamuk (2004).

Figure 1C

Grammes of silver per hectoliter (log 2 scale), AD1550-AD1800



pointed out by Von Reden, the Egyptian, Athenian, and Delian prices exhibit relatively strong seasonal variation. At the same time she argues that imports increased during periods of high prices, all evidence that a working market existed. The same has also been argued for Babylon by a variety of authors like Temin, Romero *et al.*, Foldvari and Van Leeuwen, and Van der Spek.[23] Van der Spek even explicitly states that '[t]he very fact that these prices need to be predicted based on the position of the planets shows that they are unpredictable and, hence, market prices.'[24] The same finding of a working market has been argued for the Roman Empire as well by Rathbone and, from the perspective of active trade relations, by Kessler and Temin.[25]

The second problem is that not all prices are of barley. Wheat was generally preferred in the Eastern Mediterranean and was the main staple in Egypt. However, barley, and to a certain extent dates, dominated food supply in Babylon. This was largely caused by salinization of the soil. Since wheat is less resistant against salt than barley, wheat was slowly replaced by barley in Babylon.[26] In addition, a litre of barley has around 20% less nutritional value as wheat. On the other hand, the Babylonian did not have the opportunity to choose wheat since it was not locally grown and trade was difficult. Furthermore, as argued by Van der Spek and Van Leeuwen, the price difference in between wheat and barley was around 60% in Egypt where wheat was the preferred grain, a ratio that we also encounter in present day Iraq.[27] Also Von Reden (2008, 12) argues that wheat prices in Athens are around 20-30% higher than barley prices, a difference not unlike the one found in Egypt.[28] Since barley is the preferred grain in Babylon, however, Van der Spek and Van Leeuwen argue that its price must be closer to that of wheat.[29] Hence, since barley was the main foodstuff in Babylon

[23] Temin, "Price behavior in ancient Babylon"; Romero *et al.*, "Correlated walks down the Babylonian markets"; Foldvari and Van Leeuwen, "The structural analysis of Babylonian price data"; Van der Spek, "The volatility of prices of barley."
[24] Van der Spek, "The volatility of prices of barley."
[25] Rathbone, "Mediterrenean grain prices"; Kessler and Temin, "Money and prices in the early Roman Empire."
[26] Jacobson and Adams, *Salt and silt;* Artzy and Hillel, 'A Defense of the Theory of Progressive Soil Salinization.' However, for a critique see Powell, 'Salt, seed and yields.'
[27] Van der Spek and Van Leeuwen, "Quantifying the integration of the Babylonian economy."
[28] Von Reden, 'Price fluctuations.' p. 15.
[29] Van der Spek and Van Leeuwen, "Quantifying the integration of the Babylonian economy."

while wheat had that role in the rest of the Mediterranean we might consider them as identical, as "grain". Yet, even if we would not accept that the prices of barley in Babylon and wheat in litres may be reasonably close, it is still important to stress that we use these prices solely to calculate relative price volatility, which is independent of the level of the prices.

Finally, we have to convert all prices series to a common value, in order to make them comparable. In this paper, all price series were therefore converted into grams of silver per 100 litres. Only for the period after AD1000 this contains a problem because gold coins entered into circulation and some prices are expressed in terms of gold. Therefore, where necessary, we follow Soderberg (2004) and use the Cairo bimetallic standard for Near East up to 1500.[30] Although this not necessarily always correct, available evidence shows that this ratio for later periods remained almost constant. Indeed, since this is almost equal to the ratio in Mecca AD1200, this is an acceptable simplification. For Babylon this question is less relevant since the money was silver based anyway. For the other series we simply use the silver contents of the coins.

III

A simple visual examination yields already a few interesting features of these price series. First, from Figure 1A it becomes clear that the average level of prices in Delos is much higher than the other regions. A possible reason, as argued by Reger, is that barley and wheat on Delos were largely imported, increasing the prices because of high transportation costs.[31] The same applies to Athens which economy was characterised by large scale grain imports (see Table 1). Second, it is remarkable that Egyptian wheat prices and Babylonian barley prices were almost equal (the Babylonian prices being fractionally lower) since a litre of barley has about 20% less nutritional value than wheat. Yet, as argued in the previous section, since

[30] Soderberg, "Grain prices in Cairo."
[31] Reger, *Regionalism and change*.

wheat was the preferred grain in Egypt, this had a downward pressure on the barley prices. In Babylon, due to salinization, no wheat was grown, hence, with the absence of significant grain trade, barley became the preferred grain. This caused the prices of Babylonian barley and Egyptian wheat to act in a similar way, since both were the preferred staple crops.

Third, we can see that in the second half of the sixth century BC barley prices rose faster than dates prices. This is explained by Muller by arguing that the price increase is caused by a demographic increase, while the faster increase in the price of barley is caused by the "agricultural stress", e.g. it is more difficult to increase the output of barley than dates.[32] An alternative explanation is offered by Jursa, who argues that most of the price increase is caused by an increasing amount of money in the hands of the ordinary man. The reason why dates prices started to increase later than almost all other products, he attributes to land reclamation and a conversion from barley to dates production around Sippar. Likewise, the supply of barley, possible combined with an increased demand due to population growth, declined.[33] These explanations, however, seem problematic if one considers the whole period up to 50 BC. Whereas barley prices go up around 20 years before dates, the decline of dates prices in the 4th century is faster than that of barley. Likewise, the increase of dates prices around the first century BC is again faster than that of barley. In other words, after ca. 550 BC, barley prices almost continuously stay high while dates prices go down in the third century and up again in the first century BC. Barley prices, however, do not react strongly to the price movement of dates. This seems to contradict an inflation based argument since it seems unexplainable that dates have such big swings in prices and barley does not. Likewise, it seems inconceivable that changing population may affect dates to a much larger extend than barley prices. This decline in prices of barley (unfortunately we do not have comparable material for dates), we also find back in Egypt (see Table 1). This suggests that whatever

[32] Müller, "Die teuerung in babylon," p. 166f.
[33] Jursa, *Aspects of the Economic History of Babylonia*, pp. 465-466.

happened in Babylon was not a local event and took also place elsewhere in the Mediterranean world.

Figures 1A , 1B, and 1C also show little evidence of substantial inflation between ca. 200BC and AD1800 in terms of silver. Clearly there are some fluctuations like around 300 BC, which may be caused by Alexander the Great flooding the market with Persian silver, and around 1600, due to the influx of Latin-American silver, but the supply of silver had no long-run effect. We do find, though that the price level of Mecca was higher, but this may be caused by the fact that only extreme prices were recorded.[34] That the prices from Mecca were exceptional may also be deduced from Table 2 which shows a mean (and standard deviation) of wheat prices in Mecca to be two to three times as high as elsewhere. Also, we find that between 1400 and 1500 prices in Egypt, Mecca, and Tuscany declined. That this was not the case for Syria may be caused by the insufficient number of price observations: for a period of 115 years we only have 14 observations. This pattern seems to resemble developments in second century BC Babylon and Egypt which showed a common price decline. Yet, on first sight it seems that volatility, and hence market efficiency, is not obviously different between both periods.

How can we analyse these price movements over the time of no less than 23 centuries? One way, as argued in Section 1, is to look at how markets can cope with external shocks. This is often done using a CV, being a relative measure of volatility. The results are reported in Tables 1and 2 below.

Tables 1 and 2 show a great diversity in CVs. It ranges from a high 0.96 for barley in Babylon between 581 and 61 BC to as low as 0.25 for barley in Athens between 385 and 300 BC and 0.28 for barley in Delos. However, for Athens and Delos we have to keep two things

[34] Mortel, Prices in Mecca.'

Table 1
Coefficient of Variation in the Near East and Rome, ca. 581 BC- 72BC

Region	Product	Time	Mean	Std. dev.	CV
Babylon	barley	581-61	13.40	12.91	0.96
		500-220	15.79	14.69	0.93
		200-120	10.11	7.15	0.71
Babylon	dates	570-61	9.21	7.38	0.80
		500-220	12.26	8.33	0.68
		200-120	4.65	3.15	0.68
Egypt	wheat	330-200	24.80	20.96	0.84
		200-120	17.46	4.85	0.28
Athens	wheat	385-300	61.98	36.52	0.59
	barley	385-300	37.58	9.39	0.25
Delos	barley	282-174	33.37	9.45	0.28
Rome	wheat	385-72	16.56	10.80	0.65

Table 2
Coefficient of Variation in the Near East and Italy, ca. 1261BC- AD1800

Region	Product	Time	Mean	Std. Dev.	CV
Egypt	wheat	1277-1420	70.09	50.24	0.72
		1420-1500	50.72	39.90	0.79
	barley	1277-1399	40.57	33.25	0.82
		1420-1490	24.90	14.87	0.60
Iraq	wheat	1008-1248	67.46	59.66	0.88
Mecca	wheat	1308-1400	437.84	334.29	0.76
		1400-1520	329.60	128.68	0.39
Syria	wheat	1320-1400	145.78	79.43	0.54
		1400-1515	152.80	124.06	0.81
Istanbul	wheaten flour	1469-1600	0.63*	0.31*	0.49
	wheat	1656-1800	69.58	29.70	0.43
Tuscany	wheat	1263-1420	45.98	17.45	0.38
		1420-1490	31.64	11.21	0.35
		1550-1800	84.16	26,6	0.32
Modena	wheat	1550-1613	97.55	34.08	0.35
Naples	wheat	1550-1800	60.90	22.30	0.37

*Istanbul is in grammes of silver per kg.

in mind. First, the amount of observations for both regions is very small, creating a downward bias in volatility. Second, in Delos grain was largely imported[35] and was furthermore relatively expensive compared to prices in Egypt.[36] The same applies to Athens, where most of the grains must have been imported. Although it has been argued that intra-annual volatility was large, the few annual observation coupled with a high mean price will have reduced the coefficient of variance. After all, if all imports come from a region with standard deviation x and mean price y, the CV for that region will be x/y. In Delos and Athens, we have the same standard deviation, but the mean will be inflated with the transport costs (t). Hence, the CV for Delos and Athens will be x/(y+t), hence, lower. Indeed, Table 1 shows that the standard deviation in Delos and Athens is not substantially different from the other regions, but the mean prices in both regions are by far the highest for that period.

The second remarkable outlier is the CV of 0.96 for Babylon in Table 1. However, at a closer look, we find that the CV for the over-all period in Babylon is actually higher than that of each of the sub-periods. This is strange given that the CVs are supposedly indicative of market efficiency and it is unexplainable that average market efficiency between 581 and 61BC is lower than the average of each of the sub periods. What is also remarkable is that the CV for the later period in Babylon (largely covering the Parthian period) is clearly not higher, perhaps even lower, than the earlier period. This is also remarkable since the Parthian period is generally considered a period of great shocks to the economy caused by hunger and warfare.

Yet, with the exception of Delos, Athens, and for certain periods in Babylon, all CV's are between ca. 0.3 and 0.9 with no clearly discernable pattern. The only possible inference one might possibly make is that the CV's drop slightly after 1500, even though this may be caused by the changing regional focus. Given that the CV is considered indicative of market

[35] Reger, *Regionalism and change*, p. 83-116.
[36] Von Reden, 'Price fluctuations.' p. 12.

efficiency, this suggests the existence of long-run stability of market efficiency between ca. 600 BC and AD1500. With possibly a small increase of efficiency (a decrease in the CV) between 1500 and 1800. Yet, as can also be seen from Tables 1 and 2, the CV does fluctuate a lot, suggesting that either market efficiency is episodic, with periods of increasing or decreasing efficiency, or the CV of prices is an impaired indicator of market efficiency.

Foldvari and Van Leeuwen argue that in order to analyse to what extent these factors may reduce the effect of unexpected demand and supply shocks such as wars and plague epidemics, one must first remove all other effects.[37] The appropriate way to measure market efficiency is thus to look at the residual variance after modelling the movement of prices. The unconditional variance of prices (and the CV) may be very different across countries and time, but does not necessarily reflect differences in market efficiency. After all, in China there are regions with one, two, or even three rice harvests a year. A failed harvest in a region with only one harvest has of course a massively different effect on price volatility than a harvest failure in a region with three harvests a year even though this does not say much about market efficiency. Likewise, Földvári and Van Leeuwen showed that a trend in the prices, for example caused by inflation, may inflate the CV. Since the longer the period, the more likely a trend, CVs calculated over longer time periods are almost always higher than over short time periods which is, as we discussed above, what we found in Table 1 for Babylon.

In order to remove this spurious component of volatility (i.e. country- and time specific demand and supply related factors and the trend), Foldvari and Van Leeuwen use a conditional heteroscedasticity model, in which the variance of the residual term [=variance around the conditional expected value of the prices] is modelled, thereby filtering out the effect of the trend. The residual variance therefore captures, in a correctly specified model, only the effect of unexpected shocks. Hence, the lower the residual variance, the better markets can cope with shocks.[38]

Unfortunately, since this method requires quite some data, we can only report these results for a set of regions which are given in Table 3. This Table presents some marked changes compared to Tables 1 and 2. A first interesting finding is that market efficiency for Babylon for both barley and dates for the entire period is inbetween that of each of its sub-periods as one may expect. This suggests that this measure of market efficiency is more accurate than simply using CV's. Second, we find a clear increase in market efficiency (thus a

Table 3

standard error of the regression on first differences (log prices)

		barley	Dates	Wheat	rice
Babylon	300-60 BC	0.54	0.41		
Babylon	300-200BC	0.64	0.32		
Babylon	200-120 BC	0.45	0.48		
Egypt	AD1277-1420	0.61		0.57	
	AD1420-1500	0.52		0.63	
Mecca	AD1290-1420			0.50	
Syria	AD1300-1500			0.35	
Istanbul	AD1469-1650			0.30*	0.24
	AD1656-1800			0.19	
Florence	AD1338-1377			0.36	
	AD1525-1615			0.58	
Tuscany	AD1287-1420			0.32	
	AD1420-1490			0.28	
	AD1490-1650			0.29	
	AD1550-1800			0.21	
Modena	AD1550-1613			0.21	
Naples	AD1550-1800			0.25	

Source: This paper
*wheaten flour

38 *Ibidem.*

decrease in conditional volatility) between Babylonian times and the late medieval period for Turkey and Syria and the Western part of the Empire. The same is not true, though for Egypt, Mecca, and Iraq where market efficiency remained about the same between 500BC and 1500 AD. Indeed, whereas in Babylonian times the average indicator according to Table 3 is around 0.48, in the late medieval period it declined in Italy to around 0.32 and around 1800 to 0.24 (thus market efficiency increased). A similar decrease took place in Syria and Turkey. Yet, in Egypt and Mecca this does not seem to be happening. In sum, after filtering out country, time, and regional specific factors influencing volatility, we find that conditional price volatility is decreasing in the Northwestern part of the Near East and the Western Empire, and, hence, market efficiency is increasing.

This finding of slightly increasing market efficiency over time for the Western part of the Empire as opposed to Iraq and Egypt is confirmed by estimates of national income. Existing estimates show at best a small increase in per capita GDP for the area of current day Iraq between ca. 500BC and AD1500. For Mesopotamia, located in what is nowadays Iraq, Foldvari and Van Leeuwen (2010) calculated about 600 1990 GK dollars in the around 500 BC. This may be linked to estimates from Pamuk and Schatzmiller for Southern Iraq around AD720 of 656 GK dollars and around 1220 of 640 GK dollars. Likewise, for Egypt it increased from580 to 780 GK dollars between 300 and AD1500. This is on the whole lower than the figures for Italy that show an increase in per capita GDP from 1,000 to 1,400 GK dollars between ca. 300 and AD1400.[39] This was no exception since England showed a strong increase between 1300 and 1500, largely caused by the decline in population during the Black Death.

The findings thus far seem to suggest that market efficiency, defined as the capability of the market to handle unexpected shocks, increased slightly between 500 BC and AD1500

[39] See also Scheidel and Friesen, "The size of the economy,"; Lo Cascio and Malanima, "'GDP in Pre-Modern Agrarian Economies (1-1820 AD)."

for the Roman Empire and the Norhwestern regions of the Near East. The question remains, though, what is causing this development. Unfortunately, no solid quantitative evidence is available at the moment. Therefore, we will only supply some tentative answers based on the literature in the next Section.

IV

The question that remains is why market efficiency increased between 500 BC and AD1500. Given the lack of data and the fact that we cover about 2000 years for a large area, any answers we provide must necessarily be provisional. Yet, we think it is important to make a first attempt here based on the existing literature.

As pointed out by Foldvari and Van Leeuwen (2011a), there are four broad reasons for increasing market efficiency: temporal spatial risk reduction (trade), change in consumption patterns, technological development, and temporal risk reduction (storage).[40] All these broad factors reduce price volatility and, hence, cause, in terms of Table 3, the "standard error of the regression on first differences" to go down, i.e. market efficiency to go up.

The most often quoted factor is technology which may increase agricultural output and make yields more stable. One way of looking at this is to view output per worker which should rise together with technological change. Looking at per capita GDP, we find at best a marginal increase between Babylonian times and 1500 for Iraq (Foldvari and Van leeuwen (2010); Pamuk and Schatzmiller).[41] This is not true for the Western part of the empire though, where there was a through around AD700, but where per capita output in AD1000 was considerably above that of AD1.

This finding of a lack of increase in labour productivity in the Near East (and in the West up to the 7th century) is in agreement with the lack of technological development found

[40] Foldvari and Van Leeuwen, "What can price volatility tell us".
[41] Foldvari and Van Leeuwen, "Comparing per capita income in the Hellenistic World".

in both regions (e.g. Finley 1965).[42] It is important though not to treat the Near East as a homogeneous region: in Iraq and Egypt agricultural production took place with the help of irrigation systems while in Turkey and Syria dry-land agriculture dominated. This had a serious effect on technological progress since the irrigation system was complex, difficult to maintain, and required structurally different agricultural technologies. Hence, this system, basically unaltered, continued during the centuries after the fall of the Byzantine Empire without many changes.

Yet, whereas during Byzantine rule (up to ca. 7th century) old traditions of soil conservation and irrigation were maintained, this changed during the Caliphate. As pointed out by Ashtor, little evidence exists of technological innovations in that period.[43] The muslim rulers just took over the systems from their predecessors. Many existing inventions, such as the water-wheel were often badly maintained. It was even stated that, because of bad dyke maintenance, the area in Iraq under swamps became larger during the Abbasid Caliphate (AD750-1258).[44] He also states that the tax burden discouraged investments in agriculture. The same applied to Muslim law: a landowner whose estate is not directly threatened by a burst dyke or canal was not obliged to contribute to the repair.

Indeed, whereas there are reports that during Seleucid and Byzantine rule the dry lands were ploughed with iron ploughs[45], in the early Middle Ages wooden ploughs were used.[46] This contradicts strongly with Europe where there is plenty of evidence of technical developments from the 9th century onwards. Examples are the introduction of the wheeled plough, introduced around the 5th century and largely used on sanded soils. Also the introduction of the horse to pull the plough was a great improvement. This was possible because improvement in harnessing (a stiff collar over the shoulders over the animals that let

[42] Finlay, "Technical innovation and economic progress".
[43] Ashtor, *A social and economic history of the Near East*, p. 46-47.
[44] Idem, p. 48.
[45] Van der Spek, "How to measure prosperity."
[46] Ashtor, *A social and economic history of the Near East*, p. 49.

them breath freely) which spread through Europe between the 10th and 12th century. In Near East buffaloes were put in front of the plough as before. Other developments were the scythe which was introduced in the 12th and 13th centuries, and the flail for threshing which remained in use until the 19th century.[47] Also the change from two-course to three course rotation improved output considerably. This development could not take place in the Near East which had a different crop structure due to its irrigation agriculture.

That being said, it is clear that in the Near East agriculture used to be far more productive in ancient times than in the West. As pointed out by Van der Spek (2006) and Jursa (2010), output was very high in Babylonian times, largely caused by the introduction of the seeder plough which deposited the grain seeds in the furrows, the distance being carefully measured.[48] The seed-yield ratio is estimated at as high as 1:24 and even though technological development stagnated afterwards, the remarkable fertility of the earth remained. Ashtor points at a seed yield ratio of 1: 10 whereas in Carolingian times (9th century) in Western Europe it was rather 1:2.5.[49] However, whereas it declined substantially in the Near East, in Western Europe it rose to 1:4 in the fourteenth century, to 1:6 in the sixteenth century. Yet, whereas there was an increase in yields in the west, in the east it declined or, at best, remained stable.

This increase in Western agriculture as opposed to the Near East can also be seen by estimates of agricultural productivity. In the Near East agricultural productivity must have declined almost continuously from the 6th century onwards as shown by a continuous decrease in tax revenue from the 6th century onwards. The authorities tried to make up for this by increasing the tax rates, which caused large scale flight from the land. As pointed out by Ashtor, “the flight from the land was a major phenomenon of agrarian life in Upper

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[47] Idem, p. 49.
[48] Van der Spek, “How to measure prosperity”; Jursa, *Aspects of the Economic History of Babylonia*, p. 49.
[49] Ashtor, *A social and economic history of the Near East*, p. 50.

Mesopotamia".[50] The same happened in Egypt as well. All in all, lower crop yields combined with lower tax incomes suggests in general a deterioration of agricultural output in the Near East. This contrasts sharply with the evidence for the Western part of the Mediterranean after ca. AD1000. Before that time, agricultural output most likely had stagnated. However, after that period, there was a considerably growth up to the late 14th century after which stagnation occurred. Persson estimated a growth of agricultural productivity of 0.15-0.2% growth per annum between AD1000 and 1300 in Tuscany.[51] This corresponds to the growth found by Broadberry et al (2011) for the period 1270-1700 in England[52] but seems a bit overestimated given the many changes that took place in England between 1300 and 1700 which are not recorded for early medieval Tuscany. Federico and Malanima arrive at an estimate of 0.05% per capita per annum growth between the 10th and 14th centuries.[53] This growth indeed was partly because of increasing land and capital (particularly livestock) per capita, which increased.[54] Only from the mid14th century onwards, we see a declining/stagnating trend in agriculture.

These findings clearly suggest that per capita output in the Western part was higher in the 14th century, possibly aggravated by the Black Death, than around AD1. Standard economic theory says that necessity goods like wheat have an income elasticity between 0 and 1, i.e. when income increases with 1 unit, the demand for those goods increases with less than 1 unit (i.e Engels law). This means that with increasing income, the share of that good in the total budget declines. In addition, when income grows, the income elasticity of demand declines (see for example Clark Huberman and Lindert who argue that income elasticity is higher for the poor in 19th century England).[55] This means that an even smaller proportion is spent on

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[50] Idem, p. 67.
[51] Persson, "Labour productivity in medieval agriculture", p. 139.
[52] Broadberry et al. "British economic growth, 1300-1850", Table 8.
[53] Federico and malanima, "Progress, Decline, Growth", p. 450.
[54] Idem, p. 451.
[55] Clark, Huberman and Lindert, "A British Food Puzzle."

that necessity product and more on what was previously considered luxury products (i.e. products with a higher income elasticity) with increasing incomes. For the West this means a shift to goods that produce more expensive kcalories. Indeed, as shown by Federico and Malanima, consumption of meat products in Italy started to increase, which provide relatively expensive kcalories. Equally, in England after the Black Death we notice and increase in the consumption of ale, which also provides expensive kcalories.[56] For the Near East, with no comparable increase in per capita output, no such consumption change must have taken place. This does not, however, mean that there was no change in consumption at all. It is argued that due to the lesser salinization of the soil, wheat became grown in more abundant quantities in Iraq compared to Babylonian times.[57] This can also be deduced from the fact that we actually have wheat prices in the 9th century as compared to the centuries BC. This, no doubt, meant that people increased the share of wheat consumed in Iraq. However, since wheat is also a necessity good, and given that this process only took place in Iraq rather than in Syria and Egypt, this will hardly have changed the variability of prices.

However, consumption and technological development are not the only factors able to smooth price volatility; a third factor may be trade. According to Wickham (p. 718), in the 12th century, the Mediterranean was full of ships, many of them carrying bulk goods.[58] The same applies for the period around AD 1. The evidence of shipwrecks indeed shows a rise in trade between ca. 200 BC and AD200. For Babylon, being separated from the rest of the Mediterranean, this meant of course that it was largely trade in precious goods rather than bulk products like grain.[59] However, between AD200 and 1200 the development was different in East and West. Whereas the West suffered from a decline in trading activities due to the

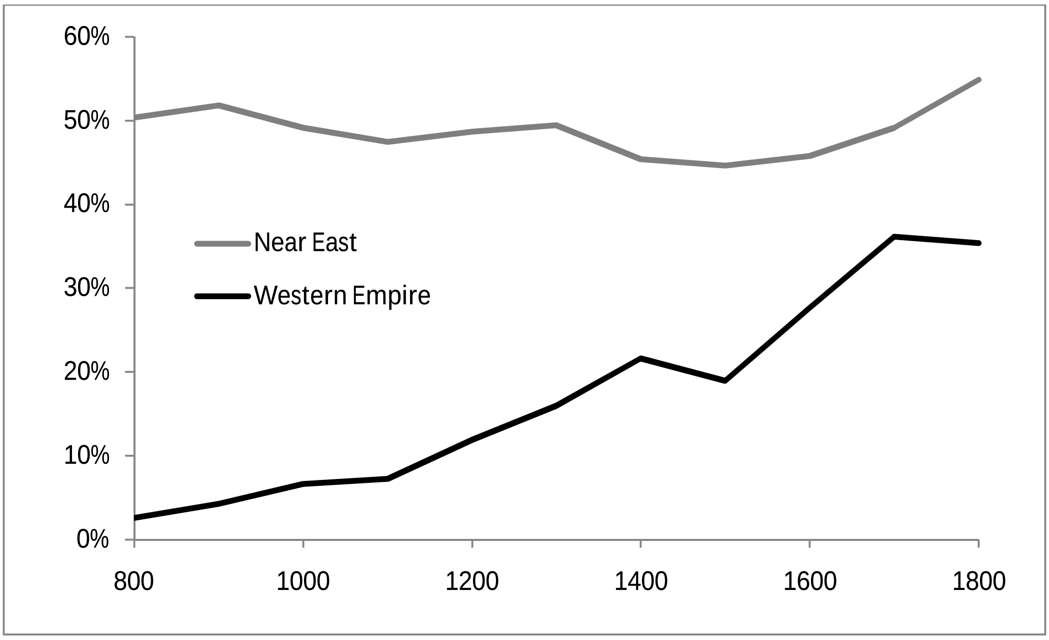
[56] Overton and Campbell, "Production et productivité," Table XII. For an extensive discussion on consumption also see Dyer, *Standards of living in the later middel ages*.
[57] Jacobson and Adams, *Salt and silt.*
[58] Wickham, *Framing the early Middle Ages*, p. 718.
[59]Jursa, *Aspects of the Economic History of Babylonia*, p. 224; Van der Spek and Van Leeuwen, "Quantifying the Integration of the Babylonian economy."

fall of the Western Roman Empire, in the Near East, where the Byzantine Empire lasted several centuries longer, there was a remarkable continuity of trade.[60] Or, as argued by Wickham, "a multiplicity of routes continued to characterize the late empire in the East."[61] This does not mean, however, that completely no trade between East and west occurred. Pirenne, for example, argued that from the 7th century onwards trade was negligible.[62] McCormick, in his famous work on the origins of the European economy, although stating that communication decreased until the mid-8th century, found that after that period communications between the Arab World and the West were on the increase again.[63] Yet, this must largely have been trade in more luxury products and cloth.

Unfortunately, little direct evidence on the relation between trade and market efficiency

Figure 2

Hierarchy of cities in the (former) Western Roman Empire and the Near East, ca. AD800-1800.



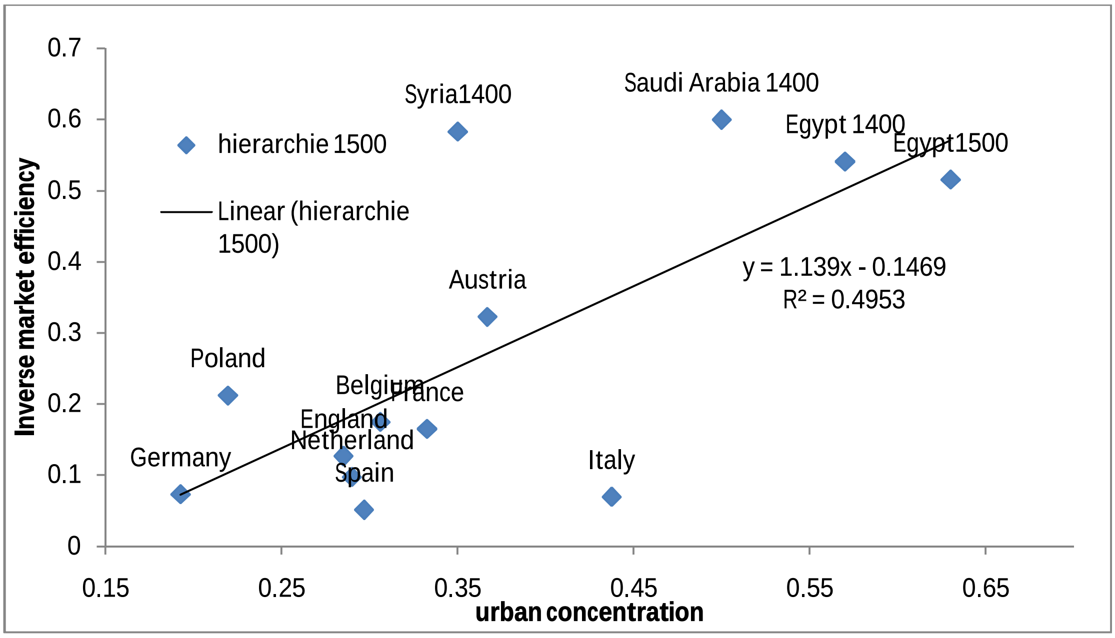
[60] Lopez, "The Trade of medieval Europe," p. 307.
[61] Wickham, *Framing the Early Middle Ages*, p. 714.
[62] Pirenne, *Mohammed and Charlemagne.*
[63] McCormick, *The origins of the European Economy*, p. 436.

exist.[64] Fortunately, recently a dataset on the population size of cities above 10,000 persons between AD800 and 1800 has become available (Bosker, Buringh, and Van Zanden). We can use this dataset to calculate a concentration index, defined as the no. of people in the biggest city divided by the people in all other cities above 10,000 people[65]. We find, plotted in figure 2, that concentration remains almost constant at 50% between 800 and 1800 in the Near East, while it increased markedly from ca. 5 to 35% in the Western part of the Empire.

But how does this help us explaining changing market efficiency through trade? One could argue that the hierarchy of such cities is an important determinant of trade. After all, the

Figure 3

Market efficiency versus urban concentration around AD1500



Note: the lower the value, the higher market efficiency

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[64] This pattern can also be found in the general trend of economic complexity of the several regions of the Roman Empire as presented by Ward-Perkins. He graphs the economic complexity, measured largely from archaeological finds, of the several regions of the former Roman Empire between 300 and 700 AD. Even though this is, of course, broader than just trade as it also includes the change of craftsman skills, it also is a strong indicator of trade between the different regions. Basically, the figure shows that in the Western part of the Empire (i.e. Italy) there was a strong decline in economic complexity between ca. 400 and 600 AD followed by a small recuperation while in the Levant the level remained about constant. In sum, as pointed out by Wickham, trade possible hardly changed in the Near East between ca. 200 BC and 1500 AD while in the West it was about equal in 1500AD and 1 AD, with a dip around 700. Ward-Perkins, *The Fall of Rome*, p. 122.

[65] We include all cities that were at some point in time above 10,000 people between 800 and 1800AD. If those cities have in a certain year no observations (because they have less than 10,000 inhabitants), we assume that they count for 5,000.

more hierarchical a country is (i.e. the more one city dominates), the higher transport costs will be and, hence, the lower total trade and market efficiency will be. More localized markets, on the other hand, will increase trade (see Figure 3). Indeed we find that a lower concentration means a higher market efficiency around 1500 for which we have most data on market efficiency. This point has also been forcefully brought forward by Lopez, who argued that in the sixth and seventh centuries the "formerly tight network of laborious cities and well-cultivated fields was changing to a sparse pattern of virtually self-sufficient large estates surrounded by no man's land."[66] Local markets sprouted and became increasingly abundant after the 8th century. It is therefore clear that, in the 10th-15th century Iraq and Egypt, cocnentration was high and market efficiency low while the reverse is true for most Western countries.

This leaves the question why concentration in the West in Figure 2 is increasing, but market efficiency did increase as well. The argument may be found in declining transaction costs. If transaction costs (including travel) are high, as was the case during the problematic years of the early Middle Ages, it was better to have multiple market centers. People could bring their products to the most local city for a local price as was the case in 9th century Italy. However, whereas during Roman times transport costs were high[67], in the period after ca. AD900 we see that there is an increasingly reduction of transaction costs in the Western countries due to new modes of transport, reduced tariffs etc. This is forcefully brought forward by McCormick who, based on the duration of embassies between Constantinople and the West, shows that the travel lasted about 2.5 months shorter in the ninth than in the 8th

[66] Lopez, "The Trade of medieval Europe," p. 306.
[67] Idem, p. 307.

century.[68] This means that it became cheaper to have just one market instead of maintaining all kinds of local markets. Hence, trade became better when concentration increased.

The final factor is storage. Foldvari and Van Leeuwen (this workshop) have modelled that storage reduces conditional volatility and, hence, increases market efficiency.[69] This would leave us the question as to whether storage exists and increases over time. Wrigley (1987) and Nielsen (1997) have argued that in case of storage alone prices start to exhibit autocorrelation.[70] Hence, under this hypothesis we should only test whether price series are non-random, i.e. the price of last year is not the best price estimate of this year. Of course, as pointed out by Persson (1999), almost all price series, even those like butter which is essentially non-storable show autocorrelation.[71] This implies that simply looking for autocorrelation is not going to give much evidence on storage.

The problem is that storage as such has never been completely modelled other than saying that when costs of storage outweigh the benefits there will be no profit maximizing storage.[72] However, such as model does not say anything about the autocorrelation properties of the series, nor about any non-profit maximizing storage, i.e. the convenience yield. However, Foldvari and van Leeuwen (2011b) combined both sorts of storage and modelled their effects on the autocorrelation of the price series. They found that, within a reasonable interval of risk aversion parameter and if supply shocks are larger in magnitude than demand shocks, the existence of storage is reduces relative price fluctuations.[73] In other words, the existence of storage (both profit maximizing and the convenience yield, reduces the volatility of the series and, hence, also reduces the unexplained volatility. They also show that profit maximizing

[68] McCormick, *Origins of the European economy,* p. 473.
[69] Foldvari and Van Leeuwen, "Risk aversion and storage in pre-industrial economies".
[70] Wrigley, *People, Cities and Wealth*; Nielsen, "English government intervention in early modern grain markets."
[71] Persson, *Grain markets in Europe*, p. 61.
[72] See for example McCloskey and Nash, "Corn at Interest."
[73] Relative price fluctuation is defined as the log difference of prices: $\ln p_t - \ln p_{t-1}$.

storage does not necessarily increase autocorrelation in the differences of the price series. They do, however, find that the convenience yield does increase this autocorrelation.[74]

Above discussion leads to the conclusion that any autocorrelation of the differences of the price series most likely indicates the existence of a convenience yield. And since a convenience yield by definition has to be combined with the existence of storage, also of storage. Foldvari and van Leeuwen (2011b) show that Babylon did hardly show any evidence for the existence of a convenience yield, while they did found evidence from ca. 1400 onwards both for the Western Empire and the Near East. Since the convenience yield by definition is coupled with profit maximizing storage (after all without storage there would be no convenience yield), this also implies an increase of storage over time.

In sum, even though above discussion makes clear we cannot be very specific, we do find some common trends in factors determining market efficiency. Clearly, the Western part of the empire was much more dynamic than the Near East. Whereas technology, consumption, and trade in the western empire contributed considerably to a decline in price volatility, the Near East remained almost stable (or even declined a little) during the period of 2000 years. Storage, however, as proxied by the convenience yield, seems to have increased in both regions, hence decreasing unexplained price volatility, i.e. increasing market efficiency. It can therefore thus also be no surprise that in the West, even after 1500, market efficiency kept increasing while the same was not true in the Near east.

[74] This finding can be rephrased as follows: without storage, the inter-harvest (interannual) growth rate of prices is not predicatble on basis of past prices, which is basically tantamount with the weak form of market efficiency. This does not seem to change if there is storage as long as the representative agent has only revenue (and/or consumption) in his/her utility. Once convenience yield is incorporated in the model (via storage entering the utility function), the growth rate of prices start to depend on past prices and become predictable.

V

So far, we find that technological development, trade, consumption and storage all improved up to 1500 in the Western part and, to a lesser extent in the dry-farming areas of the Near East causing market efficiency to increase. We also found in Table 3 that this increase continued after 1500. But what was driving this increase? It is easy to see that all factors that were at work before 1500 continued afterwards: technological development increased, as did trade and consumption. However, contrary to the period prior to 1500, these factors had a different regional impact.

To see this, let us look at Table 4. It is important to note that although almost all countries experienced an increase in market efficiency (thus a decrease in unexplained volatility), the relative ranking changed. Where for example Italy around 1500 was relatively inefficient compared to the other Western European regions, in 1700 it ranked to the top. Likewise Germany, which had ranked to the top in 1500, in 1700

Table 4

standard error of the regression of first differences (log prices), 1500-1700

	1500	1700
Italy	0.44	0.19
Austria	0.37	0.23
France	0.33	0.23
Belgium	0.31	0.20
Spain	0.30	0.30
Netherland	0.29	0.22
England	0.29	0.23
Poland	0.22	0.24
Germany	0.19	0.23

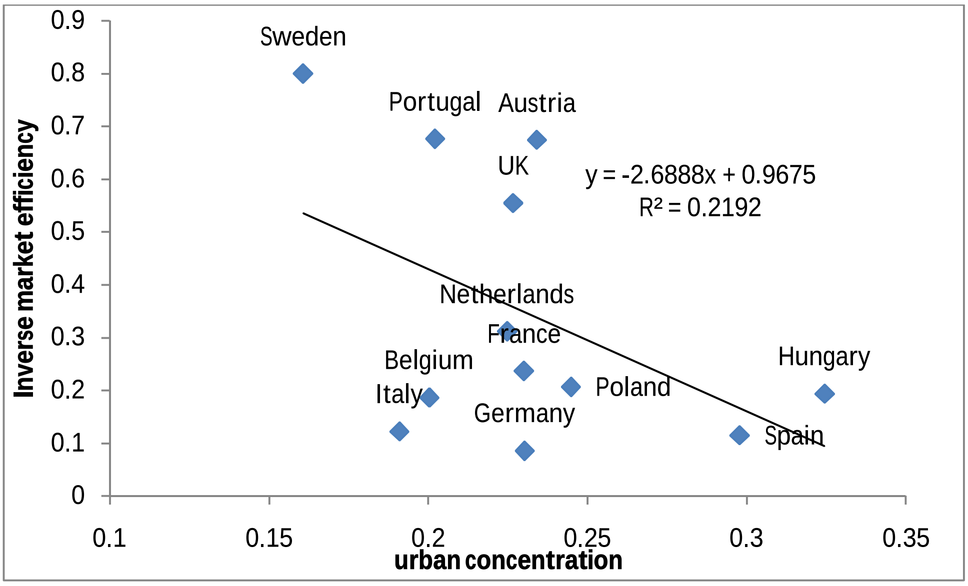
ranked at almost the bottom. If we calculate a correlation, we find -0.38, suggesting that those countries that had a relatively high level of market efficiency in 1500 ranked at the bottom around 1700. This clearly suggests a remarkable turnaround: factors that made countries rank relatively high in terms of market efficiency around 1500 were holding them back around 1700.

Very little evidence can be found in storage, technology, or even consumption since these all spread fairly rapidly over the continent. Yet, as argued in the previous Section, concentration of urbanisation mattered. In the early middle ages, with high transaction costs, a multicentre market system was beneficial to increase trade and, hence, reduce volatility and increase market efficiency. But in that period there still is no countrywide national market. If transaction costs really start to drop, forces of agglomerations will become dominant and a single, or just few, regional markets will gain dominance. This process, which culminates in the 19th century, has abundantly been described in the literature on globalisation.

This pattern can be found back in Figure 4. Here we find that for the period around

Figure 4

Market efficiency versus urban concentration around AD1700



1700 a higher urban concentration means a higher market efficiency. The existence of one (or a few) dominant cities will thus increase trade and, hence, market efficiency. This is exactly the opposite from Figure 3 which shows that as late as 1500 a lower urban concentration (i.e. more local markets) was beneficial for trade.

In sum, before ca. 1600, higher transaction and transport costs meant that in order to increase trade, one needed more local markets and, hence, a lower urban concentration. Afterwards, when transport costs declined dramatically, the existence of one (or a few) dominant cities increased trade within a country. This meant that the Western Roman regions could profit from their low levels of concentration after the fall of the Roman Empire. Their slowly increasing level of concentration kept pace with falling transport costs. Yet, in the Near East, their continuously high level of concentration was obstructing any significant level of trade. Lowering transport costs, however, made urban concentration increasingly important to stimulate trade after 1500. Since the relative ranking of countries by level of urban concentration remains almost identical over time, this means that the ranking of countries in terms of market efficiency switched: countries with relatively low levels of market efficiency increased their efficiency levels much faster than those countries with lower levels of urban concentration and higher levels of market efficiency.

VI

In this paper we analyze market efficiency in the Near East, the Roman Empire and their successor states between ca. 500BC and AD1500. Looking at the coefficient of variance (CV) we find no discernable patter. Yet, after correcting for expected price shocks such as originating from agricultural structure, we find that in the long-run unexpected volatility decreases over time, hence market efficiency increases, in both the Western Europe and the dry-land agricultures in the Near East. Yet, in regions with irrigation agriculture such as Egypt and Iraq, no significant increase in market efficiency took place until ca. 1500. Consequently, around 1500 Italy and Turkey had surpassed Iraq and Egypt, but were still behind countries like the Netherlands and England. Yet, between 1500 and ca. 1700 we find a reversal: whereas all countries increased their market efficiency, the increase in Italy was considerably faster than in, for example England or Holland.

We also try to give a preliminary explanation. Whereas technological change and, hence, productivity growth was stronger in the dry areas of the Near East and the Western Empire, the situation in Iraq and Egypt remained the same or declined since the same technologies could not be applied. Likewise, consumption diversified since less and less of the household budget was spent on the same staple crops. The same applies to trade, where we find that the high concentration figures initially worked counterproductive for trade in Iraq and Egypt since transport costs were too high. In the West, however, lower concentration further trade, and the lowering of transport and transaction costs since the mid-9th century made further concentration possible while increasing trade at the same time. However, in the Near East, with virtually constant concentration, no such increase could take place. Finally, for storage we find that the autocorrelation of price differences increases, i.e. storage increases, which also smoothes price volatility.

After 1500 this pattern changes: transport costs reduced further, which means that concentration becomes increasingly important for increased trade, and, hence, higher market efficiency. Counties like Austria and Belgium, which had a relatively high concentration, turned from relatively inefficient to relatively efficient markets.

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