LONG-RUN PATTERNS IN MARKET PERFORMANCE AND THE GENESIS OF THE MARKET ECONOMY[1]

MARKETS AROUND THE MEDITERRANEAN FROM NEBUCHADNEZZAR TO NAPOLEON (580 BC AND 1800 AD)

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

Utrecht University

Corresponding author: Peter Foldvari (p.foldvari1@uu.nl)

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ABSTRACT

Price volatility, reflecting the ability of markets to absorb exogenous supply or demand shocks, is an important dimension of economic development. Several studies have pointed out that this increase in market performance, and the accompanying increase in food security, are among the factors that led to increased commercialization in the 18th century. Using a model that captures the supply side determinants of price volatility of markets of basic foodstuffs in pre-industrial societies, we find that the rise in output per hectare, the decline in transaction costs, and the existence of relative small but numerous cities are the main drivers of this increased market performance, ultimately leading to agricultural specialisation. These features were especially common in more developed areas of Europe.

Yet, recent studies suggest that the increase in market performance was not unique for the 18th and 19th centuries. A similar improvement in market performance took place in the early middle ages. Applying our model on the available data for this period, we analyze how market performance, being proxied by price volatility, changed in countries around the Mediterranean between 580 BC and 1800 AD, which caused farmers to send a larger share of their crops to markets giving rise to the genesis of the market economy.

Keywords: market performance, market prices, Mediterranean, economic history, commercialization

JEL codes: D40, E30, N13, N15, O13

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I. INTRODUCTON

Market performance, which is defined as the capacity of the market to absorb unexpected supply or demand shocks, is often seen as a driving force in economic development (e.g. Allen and Unger 1990, Persson 1999, Findlay and O'Rourke 2003, Jacks 2004, Foldvari and van Leeuwen 2011). More stable prices reduce risk and provide additional incentive for farmers to send part of their produce to the market (i.e. commercialization), which was a crucial step in the Agrarian Revolution that is usually seen as a pre-requisite of Industrial Revolution.

A main reason for such a reduction in price volatility (and increase in market performance) is, according to the New Institutional Economics, a reduction in the level of transaction costs, which in its turn is related to the quality of the institutional framework (North, 1982) and which increases the trade potential. There are other, non-trade related, factors that can contribute to decreasing price volatility, like the adoption of new storage technologies and the consumption of a wider variety of goods, but these became significant only after the 19th century. Hence, for the pre-industrial period- the main focus of our research- we will restrict our analysis to the role of trade (e.g. Persson 1999; Studer 2008, Bateman 2012) on increased market performance and its possible effect on increased specialization.

In the next section we start by presenting the model of the main determinants of price volatility (i.e. market performance) of pre-industrial markets of basic foodstuffs. We distinguish three factors that turn out to be important: the size of the market, the transaction costs associated with the trade in the market area, and the level of agricultural productivity. In our model we only focus at supply-side factors since prior to the Industrial revolution and the demographic transition demand shocks played a much less significant role than in a modern society, with just a few notable exceptions like the Black Death in the 14th century Europe. In addition, introducing random demand shocks would not change the qualitative result from the model. In Section 3 we turn to empirical evidence based on a major (and partly new) dataset of prices from a large sample of pre industrial societies, ranging from ancient Babylon via Egypt, Athens and Rome to Medieval and Early Modern Europe to observe the historical change in volatility of main crop prices. We show that markets in Medieval Europe were much more stable in terms of price volatility than those of ancient societies. Yet, we do not find evidence for a similar improvement in market performance for the Middle East (confirming the findings by Söderberg 2006). Combing our model with the data, in Section 4 we find that the difference in development of market performance in the Middle East and Mediterranean Europe can be explained by a reduction in transport and transaction costs that took place in Europe during the Middle Ages. Using our model we estimate the degree of improvement in terms of transport/transaction costs for two regions we have reliable data from: Babylonia in the 3rd century BC and Tuscany in the 16th century AD.

Finally, we address the question what this must have meant for the decision of farmers (and other producers) to sell their produce on the market (i.e. commercialization). We find that, during the phase of transition to subsistence to commercial farming that took place in Europe in the Middle Ages, an improvement in market performance indeed leads to increased commercialization. Since the increase in market performance was mainly riven by increased agricultural output and a reduction in transaction costs, this means these factors were also largely underlying the commercialization process that took place in the early middle ages in Mediterranean Europe. The high levels of price variability in ancient world, and in Medieval Iraq, Egypt and Mecca did, on the other, hand not facilitate such a process of commercialization. This divergence between Medieval Europe and the Middle East is also confirmed by recent research into the level of GDP per capita in these regions (Bolt and Van Zanden 2012).

II. A SUPPLY SIDE SPATIAL MODEL OF CROP PRICE VOLATILIY

II.1 Introduction

In the following we introduce a simple model of grain production and trade in a single centre (single market) framework. For the model we assume a homogenous space, that is, the cost of transportation and agricultural productivity (output per area unit) are about the same everywhere relative to the size of homoscedastic supply shocks. We allow for a spatial correlation of output shocks. The model predicts that regions with multiple smaller centers (cities) should experience lower degree of price volatility than regions with a single dominant center, *ceteris paribus*. Once however one region experiences a reduction in transaction costs and/or its average output grows relative to the magnitude of supply shocks price volatility will decrease and this may even offset the effect of a single big center. This line of thinking leads us to the hypothesis that regions with small degree of centralization (a low degree of urban hierarchy) like medieval Italy experienced less volatile grain prices than Ancient Rome (with its giant capital) or Babylon not only due to smaller transport costs but also due to the more diversified urban structure.

II.2 Price volatility and variance of supply

In order to develop the model, we follow the simplest approach that suffices our needs, so we assume that all population lives in the urban centre and only a single good (Q) is produced. We use the quantity theory of money, where nominal income (or total nominal expenditures) equals the amount of available money (M) and we assume that the velocity of money (v) is constant. If we assume that the nominal income elasticity of demand is constant (c) we obtain the following for the prices:

$$p_t = \frac{M_t^c \bar{v}}{Q_{St}} \quad (1)$$

We can assume that there are shocks in nominal income (or money supply) acting as demand shocks, but this would not add much to the model so we take M as a deterministic process for now. Introducing some random shocks in the money supply would add a source of supply-side shocks but this would not add anything of importance to the model and hence we rather decided not to do that.

The log prices for period t are as follows:

$$\ln p_t = \ln \bar{v} + c \ln M_t - \ln Q_{St} \quad (2)$$

The variance of the log prices can be written as:

$$Var(\ln p_t) = c^2 Var(\ln M_t) + Var(\ln Q_{St}) \quad (3)$$

In order to arrive at the variance of the logarithm of the residual that we use as an indicator of the ability of market in reacting on unexpected shocks, we need to subtract the expected value of prices and then estimate the variance:

$$\ln p_t - E(\ln p_t) = c(\ln M_t - E(\ln M_t)) - \ln Q_{St} - E(\ln Q_{St}) = \ln Q_{St} - E(\ln Q_{St}) \, (4)$$

Where we can get rid of the effect of nominal income simply since we assumed that M is a deterministic process.

$$Var(\ln p_t - E(\ln p_t)) = Var(\ln Q_{St} - E(\ln Q_{St})) \quad (5)$$

That is, with the simplifications introduced in the model, the price volatility is determined by the volatility of supply.

II.3 Determinants of the supply volatility

The next step is to look at the factors affecting the volatility of the supply of agricultural goods in the market. We assume a homogeneous space, where a centre, which serves as the sole market, is surrounded by a market zone (with radius R) that has the same production capability per area unit (q_0) plus a random shock (e_i), the latter are being spatially correlated. Only a single good is produced. The transportation and transaction costs denoted by τ are equal everywhere. We use an iceberg type transportation costs, that is, part of the goods produced is lost during transportation.

The number of production units that supplies to the centre equals the area of the circle with radius R is $N_R = R^2\pi$, and the amount of goods that arrives at the centre from a single producer is $q_{im} = (q_0 + \varepsilon_{im})e^{-\tau m}$ accordingly. The random shock affecting producer i situated on the circumference of radius m is denoted by ε_{im}. The shocks are assumed to have zero mean, they are homoscedastic, and are allowed to be spatially correlated: $\varepsilon_{im} \sim (0, \sigma_\varepsilon^2)$,

$E(\varepsilon_{im}\varepsilon_{jn}) \neq 0, \quad m,n = 0...R, \quad i = 0...2\pi m,$ j=0...$2\pi n$

We can express the amount of total goods that arrives at the centre (Q_s) as follows:

$$Q_s = \int_0^R \int_0^{2\pi m} q_{im} didm = 2\pi q_0 \left(\frac{1 - e^{-\tau R}(1 + R\tau)}{\tau^2} \right) + \int_0^R \int_0^{2\pi m} \varepsilon_{im} e^{-\tau m} didm \quad (6)$$

Since the random shocks have zero mean and are uncorrelated with the effect of distance, the expected value of the total supply is:

$$E(Q_s) = 2\pi q_0 \left(\frac{1 - e^{-\tau R}(1 + R\tau)}{\tau^2} \right) \quad (7)$$

As $\lim_{\tau \to 0+} \left(\frac{1 - e^{-\tau R}(1 + R\tau)}{\tau^2} \right) = \frac{1}{2} R^2$, in the absence of transportation costs, the expected value of total supply simplifies into $E(Q_s) = \pi q_0 R^2$ as expected.

If we keep R, τ and q_0 fixed, the variance of the supply depend only on the variance of the sum of the supply shocks times the effect of transportation costs, expressed as the integral: $\int_0^R \int_0^{2\pi m} \varepsilon_{im} e^{-\tau m} didm$. The variance of the supply in the center is accordingly:

$$Var(Q_s) = \int_0^R \int_0^R \int_0^{2\pi n} \int_0^{2\pi m} \left(\varepsilon_{im} e^{-\tau m}\right)\left(\varepsilon_{jn} e^{-\tau n}\right) didjdmdn = \pi^2 R^4 E\left(\varepsilon_{jn}\varepsilon_{im} e^{-\tau n} e^{-\tau m}\right) \quad (8)$$

We can make use of the assumption that the distance effect is independent of the shocks.

$$Var(Q_s) = \pi^2 R^4 E\left(e^{-\tau m} e^{-\tau n}\right) E\left(\varepsilon_{im}\varepsilon_{jn}\right) = \pi^2 R^4 \frac{4e^{-2\tau R}(1-e^{\tau R}+R\tau)^2}{R^4\tau^2} \pi^2 R^4 E\left(Cov(\varepsilon_{im}\varepsilon_{jn})\right) \quad (9)$$

Since $E\left(\varepsilon_{im}^2\right) = E\left(\varepsilon_{jn}^2\right) = \sigma_\varepsilon^2$ due to the homoscedasticity we assumed about the shocks, we only need to have an assumption about the expected value of the covariances. For the linear correlation between the production of any two points in the market radius we assume that:

$$\rho(\varepsilon_{im}, \varepsilon_{jn}) = e^{-d_{imjn}} = \frac{Cov(\varepsilon_{im}, \varepsilon_{jn})}{\sigma_\varepsilon^2} \quad (10)$$

from which we can express the covariance as follows:

$$Cov(\varepsilon_{im}, \varepsilon_{jn}) = e^{-d_{imjn}} \sigma_\varepsilon^2 \quad (11)$$

$$\text{and } E\left(Cov(\varepsilon_{im}, \varepsilon_{jn})\right) = E\left(e^{-d_{imjn}}\right)\sigma_\varepsilon^2 \quad (12)$$

The expected value of the distance between two points in a circle with radius R can be approximated as:[2]

[2] The approximation is based on a Monte Carlo simulation with 100000 randomly chosen points on a circle for 10000 different values for the radius (between 0.001 and 10). The formula has been established with a linear regression with R-squared above 0.9999. The relationship is basically deterministic. An analytic solution to the

$$\bar{d}_{ij} = 0.7249R \quad (13)$$

Using the same Monte Carlo technique used above, we estimate the mean of the correlation coefficient between two producer and fitted the following polynomial to the data:

$$\left(E(e^{-d_{ij}})\right)^{-1} | R) = 1.004 + 0.707R + 0.209R^2 + 0.011R^3 - 0.001R^4 + 0.00005R^5 \quad (14)$$

With N=10000 and R^2=0.9998.

The variance of supply at the centre can be estimated using (14), (12) and (9).

II.4 Simulating the model

From the model it follows that price volatility (i.e. market performance) is determined by output volatility in combination with the level of transaction costs and the size of the economic area around the centre. We carried out a simulation using assumptions regarding the key parameters of the model. The results are reported in Figure 1, which shows, on the horizontal axis, the radius of the market and on the vertical axis the CV of supply.

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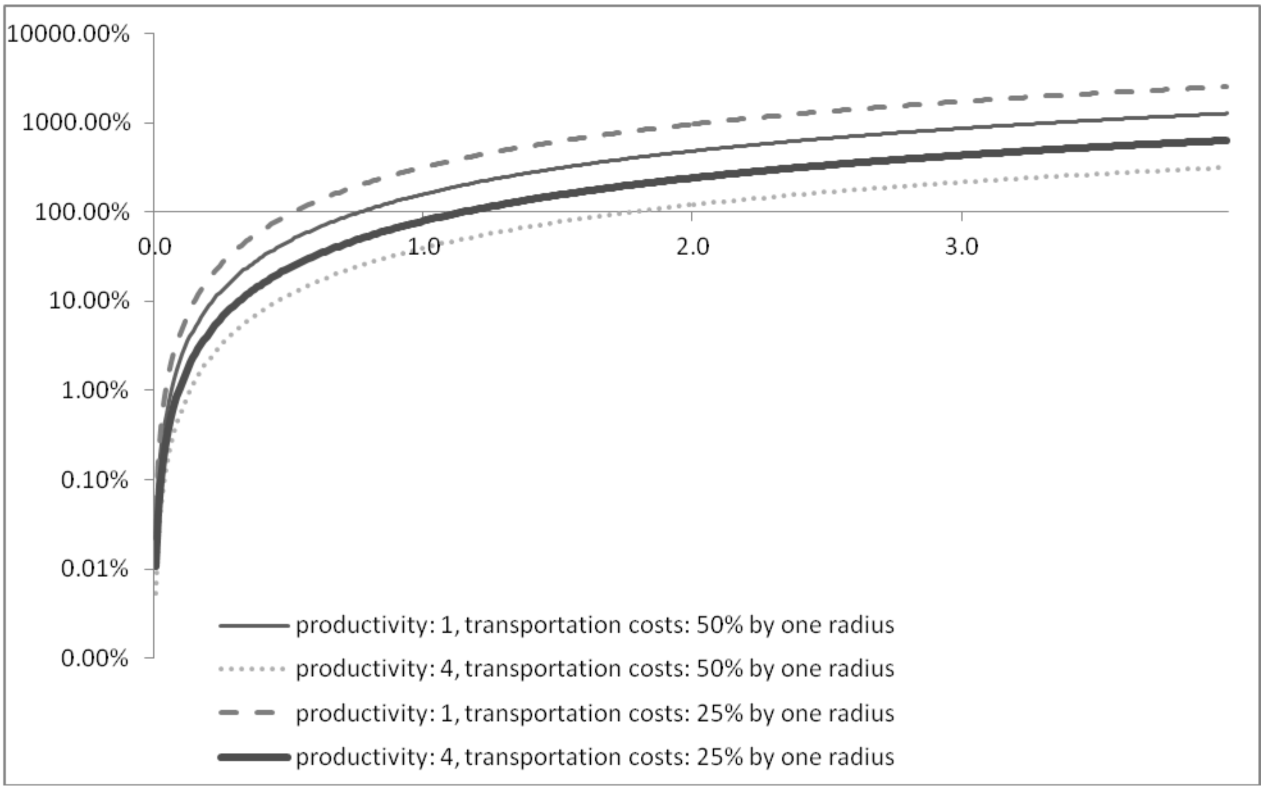
quadruple integral $\bar{d}_{ij} = \int_0^R \int_0^R \int_0^{2\pi} \int_0^{2\pi} \sqrt{\left(r_1 \cos\alpha - r_2 \cos\beta\right)^2 + \left(r_1 \sin\alpha - r_2 \sin\beta\right)^2}\, dr_1 dr_2 d\alpha d\beta$ would simply be too difficult.

FIGURE I

SIMULATION OF THE RELATIONSHIP BETWEEN COEFFICIENT OF VARIATION OF AGRICULTURAL SUPPLY AND THE SIZE OF THE URBAN CENTRE



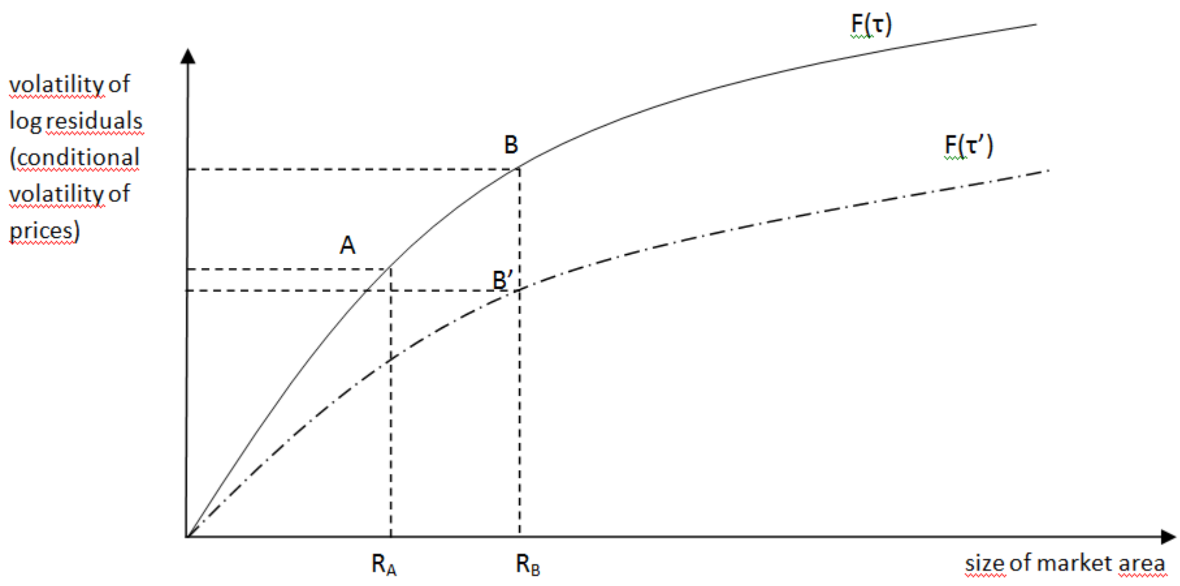
Note: we assumed in all cases that the standard deviation of the production is 30% of unit production, that is, σ_ε^2=0.09. If a productivity increase causes the standard deviation of the supply shocks to grow proportionally, productivity improvement will have no impact on the CV of the supply.

It demonstrates that if the radius of the economic area around city increases, the CV will increase quite rapidly initially and moderately after about 2R. However, this increase of the CV is faster the higher the transportation (or transaction) costs. Hence, from Figure 1 it follows that economies with a number of smaller centers (cities) had smaller price volatility than economies with a single or a few large dominant centers. The effect of the market size (or urban dominance of big cities) can be counterbalanced by reduction in transaction/transport costs or improvements in the level of agricultural productivity.

In the Figure 2 below, we show this mechanism. Let us assume we have two economies: A has smaller market zone than B. If they face the same transportation costs and have the same agricultural productivity, they are both along the same curve F(τ). In this case smaller market size means less conditional volatility. If B experiences a decrease in transaction costs (or its productivity increases relative to the size of production shocks) its

FIGURE II

THE RELATIONSHIP BETWEEN MARKET SIZE, TRANSATION COSTS, AND RESIDUAL VOLATILITY OF GRAIN PRICES



curve representing the relationship between price volatility and market size will shift become less steep (F(τ‘)). That is, even with the same market size as before its conditional price volatility will be lower than in A.

This finding applies to regions with multiple smaller centers (cities) and a single dominant center as well. Given a certain level of urbanization, a number of smaller centers with lower degree of city hierarchy (for example, Northern Italy in the Middle Ages) will have lower residual price volatility than one big city, assuming there is no difference in transportation costs and agricultural productivity.

III. THE DATA

In order to test the predictions from above model, namely that market performance is driven by output, a decrease in urban primacy, and a reduction in transaction costs, we need first and foremost to have information on the price volatility of markets (i.e. on market performance) in the past. Therefore we present, for the first time, price series of staple crops for a very long time period – between the first price data available for ancient Mesopotamia until 1800. Fortunately, one of the first complex societies, ancient Babylon, knew well developed markets of which detailed price information is available in the clay tables of various dynasties in Mesopotamia between ca 580 and ca 60 BC. The datasets available for other ancient societies (Athens, Egypt, Rome) are much smaller and more problematic. Only during the Middle Ages (after about 1200) do we find datasets similar in quality and scope; these European and Middle Eastern datasets for the period 1200-1800 are the end point of our sample. These have been studied intensively by economic historians, and therefore can be used as a standard to compare ancient markets with.[3] Economic historians focusing on ancient economies have also studied the functioning of markets in Mesopotamia and the Roman Empire (e.g. Temin 2002, Erdkamp 2005, Romero et al. 2010). These studies are however not really comparable with

[3] But in spite of the abundance of sources for the post 1200 period, there is still considerable debate about the performance of European markets between 1200 and 1800, about (for example) the question if their volatility fell over the long run and if market integration increased similarly; Some authors emphasize the connection between increasing market efficiency of markets and the gradual process of growth in the early modern period; others have stressed the presence of well working markets already in the medieval world (E.g. Masschaele1993, Galloway 2000, Clark 2002).

each other, because they use different methods and approaches and do not systematically try to explain the causes of volatility. This paper aims to fill this gap, by applying the same methodology to the available data, and measure the performance of markets in a systematic way.

As explained already, market performance is measured here through the volatility of the price series. 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 common to use the Coefficient of Variance (CV) (e.g. Persson 1999, Söderberg 2004, 2006, Ó Gráda 2005) or the standard deviation of the log prices. Still these approaches are not applicable on non-stationary series. The CV is based on the implicit assumption that the mean and the standard deviation of the prices are finite and do not depend on time, which is obviously not true one the series are non-stationary (Foldvari and Van Leeuwen 2011). For this reason we rather report the standard deviation of the first-difference of log prices.

In this paper we focus on the prices of the main staple crops of the societies concerned (wheat and barley). The region we study are the countries bordering the Mediterranean, because they are (among the) oldest civilizations of the world dominating the western part of the Eurasian Continent until the 17th or 18th centuries. The Middle East was the cradle of city life, and probably the first region of the world with active markets. It saw the flowering of ancient societies in Egypt, Greece and Italy, the continuation of city life in (amongst others) Byzantium and Constantinople, and the re-emergence of urban society in Italy after about 1000. Another reason for concentrating on the region bordering the Mediterranean is that these regions had similar climate and crops. This makes it possible to eliminate differences in climatic conditions from the analysis, since asymmetrical climatic shocks could theoretically lead to diverging price volatilities.[4]

In the data appendix we discuss the various datasets that we collected. One problem should be briefly discussed here, however. Some authors, in the tradition of Finley (1973), have doubted whether the prices from antique societies can indeed be considered as “real” market prices. Yet, as pointed out by Von Reden, the Egyptian, Athenian, and Delian prices exhibit relatively strong seasonal variation and imports increased during periods of high prices, which can be taken as evidence in favor of prices determined by market forces (Von Reden 2008). The same is argued for Babylon by a variety of authors like Temin (2002), Foldvari and Van Leeuwen (2013), and Romero et al. (2010). Van der Spek (in press) 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.’ Similar arguments suggesting a working market has been used for the Roman Empire by Rathbone (2011) and, from the perspective of active trade relations, by Kessler and Temin (2005).

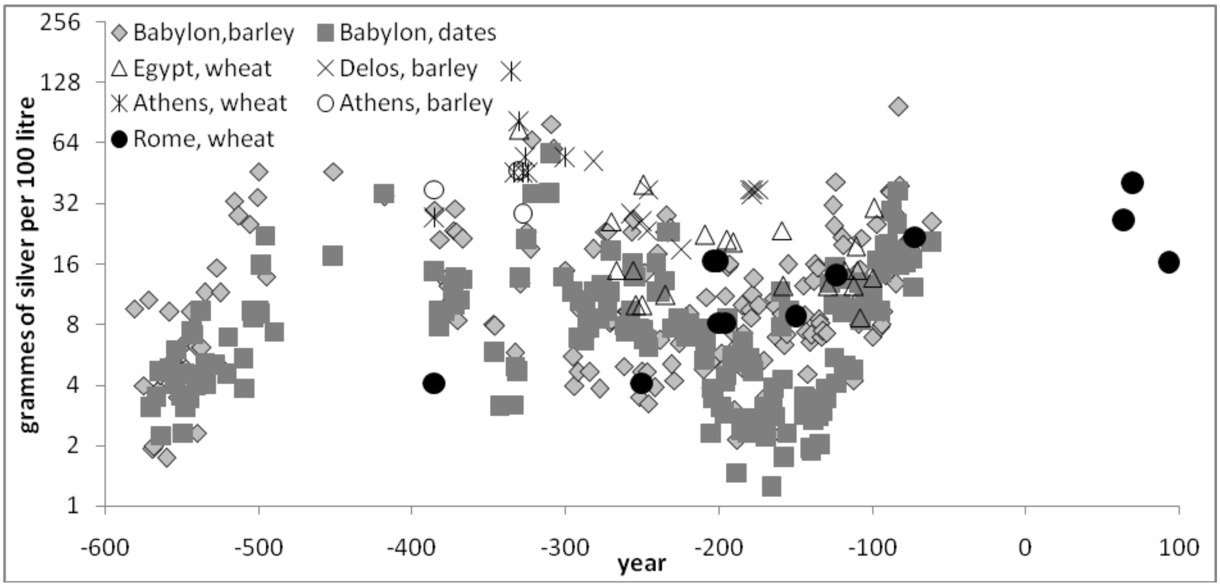
Finally, in order to make them comparable, all price series were converted into grams of silver per 100 liters for the graphs. A visual examination of the main series collected for this study yields already a few interesting features of these price series (Figures 3A-3C). The

[4] Two agricultural systems can be distinguished: in Mesopotamia and Egypt agriculture was based on floods and irrigation, which produced higher yields (per hectare and per amount of seed) than in continental Europe and probably led to a more stable agricultural output as well since the input of water could to some extent be controlled. Moreover, in Babylon a system of dual crops – barley and dates – came into existence; the fact that harvests of those crops were spread over the year, should also have stabilized prices (this is demonstrated by the fact that during the harvest of dates also barley prices tended to fall - see Foldvari and Van Leeuwen 2009). The rest of the regions were characterized by rain fed agriculture, with only one harvest per year. One can thus expect hence that this difference in the type of agriculture may lead to a lower volatility of prices in Babylon.

data are concentrated in two periods: between 600 BC and 150 AD, and after about 1000 AD. There is a large gap in between – there is hardly any evidence on price formation in this part of the world between the fall of the Roman Empire and the High Middle Ages (only a few Egyptian and Iraqi prices partially fill the gap). This gap coincides with a break in trend: after 1200 prices are much higher than during ancient times (implying that the relative price of silver went down). The Babylonian prices are more or less stable in the very long run, although a brief period of inflation occurred after the conquest by Alexander the Great in 334 BC, which lead to the bringing into circulation of huge hoards of silver (Figure 3A). Their variability is large, however. Prices in Delos and Athens are on average higher than in Babylon or Egypt, probably because both were dependent on large-scale imports of grains from overseas (Reger, 1994). Price information about the Roman Empire is quite limited, however, in particular in view of the size and complexity of this society.

FIGURE IIIA

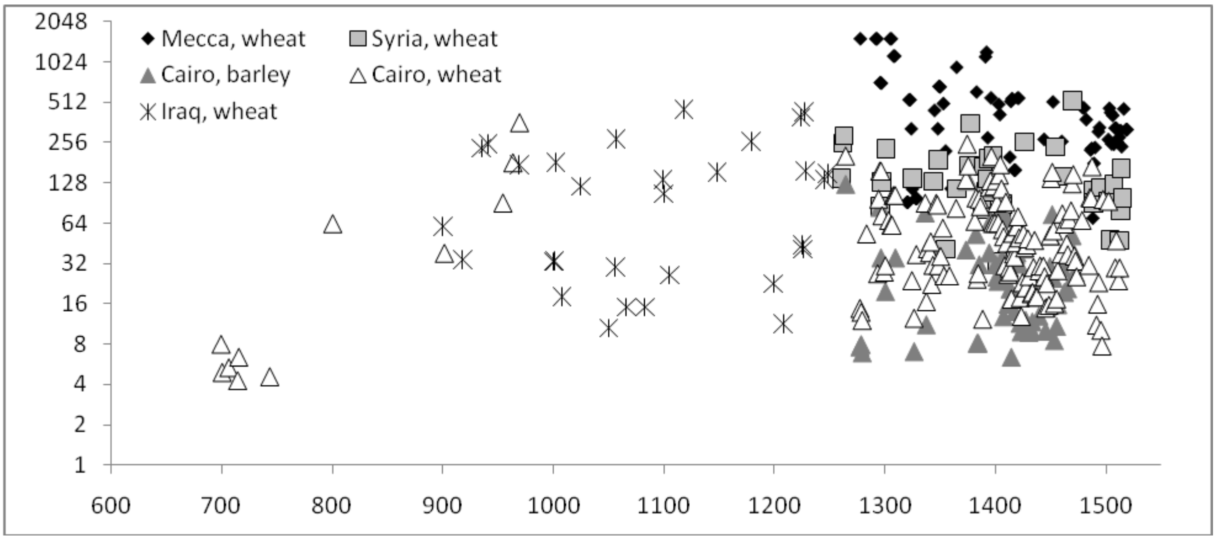
GRAIN PRICES IN VARIOUS ANCIENT SOCIETIES IN GRAMMES OF SILVER PER HECTOLITER (LOG 2 SCALE), 600BC-100AD



Source: Jursa (2010); Slotsky (1997); Slotsky and Wallenfels (2009); Vargyas (2001); Von Reden (2008); Van der Spek (2010); Rathbone (2011)

FIGURE IIIB

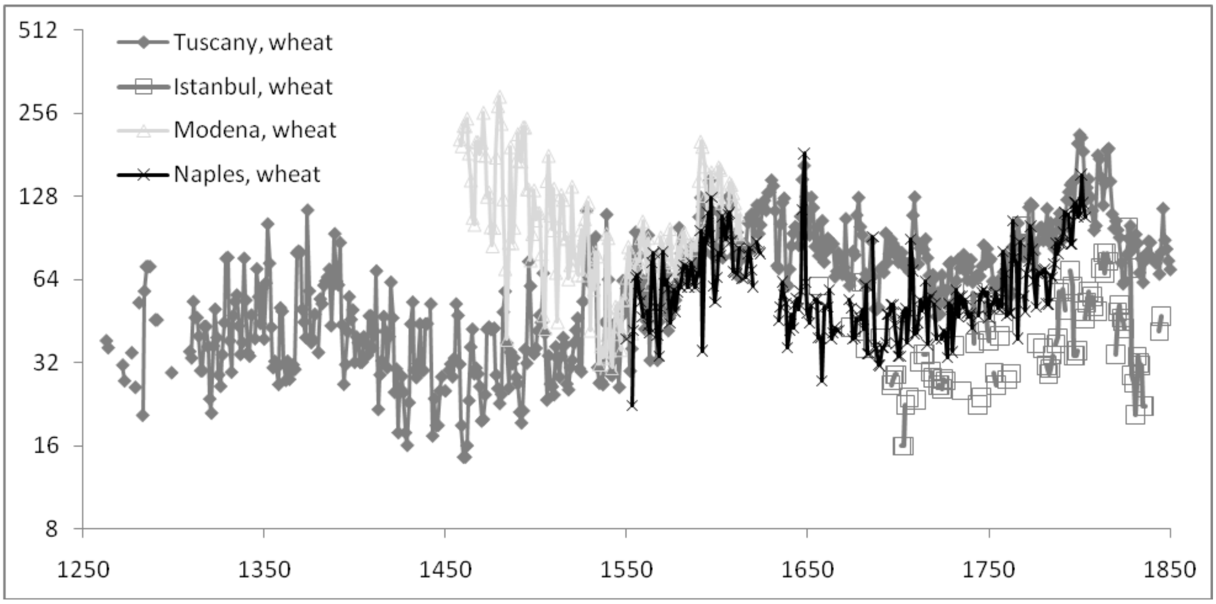
GRAIN PRICES IN THE MIDDLE EAST DURING THE MIDDLE AGES IN GRAMMES OF SILVER PER HECTOLITER (LOG 2 SCALE), 1250AD-1550AD



Source: Ashtor (1969); Mortel (1989); Pamuk (2004); Schatzmiller, (2011)

FIGURE IIIC

GRAIN PRICES IN EUROPE DURING THE MIDDLE AGES IN GRAMMES OF SILVER PER HECTOLITER (LOG 2 SCALE), 1550AD-1800AD



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

Figures 3B and 3C present the large datasets available for the Medieval and Early Modern period. In the Middle East, the prices of Mecca stand out as being very high – again probably due to the dependence on large-scale imports (but this time via caravan routes and probably not via the sea). This may also be caused by the fact that only extreme prices were recorded (Mortel 1989). Price information about the Middle East becomes much richer after 1200, and for many Western European cities we have annual (and sometimes monthly) price data from the 13th century onwards.

IV. DECOMPOSING CHANGES IN MARKET PERFORMANCE OVER TIME

The price volatility estimates (standard deviation of the first-difference of the log prices) are reported in Tables 1 and 2.

TABLE I

STANDARD DEVIATION OF THE 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	1277-1420AD	0.61		0.57	
	1420-1500AD	0.52		0.63	
Mecca	1290-1420AD			0.50	
Syria	1300-1500AD			0.35	
Istanbul	1469-1650AD			0.30*	0.24
	1656-1800AD			0.19	
Tuscany	1287-1420AD			0.32	
	1420-1490AD			0.28	
	1490-1650AD			0.29	
	1550-1800AD			0.21	
Modena	1550-1613AD			0.21	
Naples	1550-1800AD			0.25	

Source: Jursa (2010); Slotsky (1997); Slotsky and Wallenfels (2009); Vargyas (2001); Von Reden (2008); Van der Spek (2010); Rathbone (2011), Romano (1965); Ashtor (1969); Bassini (1974); Malanima (1976); Mortel (1989); Pamuk (2004).*wheaten flour

In Table 1 we find that price volatility in ancient markets were of comparable level at about 0.5 with Egypt and Mecca during the Middle Ages. In Western Europe (after 1200) and in Istanbul markets we find lower volatility and Syria now presents itself as an intermediate case. For Tuscany we find lower volatility with a decline during the early modern period in line with the findings for Europe between 1200 and 1800 (Persson, 1999). That this was a general European pattern is shown by the results of the same analysis performed on the very rich data which are available for Europe between 1360 and 1800 (see Table 2). The variance is consistently low (compared with the results for Ancient economies), and Italy in the late Medieval Period is a bit of a high outlier here. The decline of the variance between the 15th century and the 18th century points to continuing improvements in the functioning of markets in this period.

TABLE II

STANDARD DEVIATION OF THE FIRST DIFFERENCES OF LOG PRICES IN EUROPE,

1360/1550-1650/1800[5]

	1360-1550	1650-1800
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
Netherlands	0.29	0.22
England	0.29	0.23
Poland	0.22	0.24
Germany	0.19	0.23

Source: Allen - Unger Global Commodity Prices Database (downloaded from http://www.gcpdb.info/)

[5] Note: 1500: Austria: Stiftklosterneuber, Vienna; Belgium: Louvain, Mons; England: Chester, England, Exeter, Southern England; Douai, Grenoble, Le Quesnoy, Mauberge, Montelimar, Nancy, Paris, Strasbour, Toulouse, Tours, Valence, Valenciennes, Vienne, Voiron; Germany: Frankfurt, Munich, Wurzburg; Italy: Arezzo, Bari, Florence, Sansepolcro; Netherlands: Amsterdam, Leiden, Utrecht; Poland: Krakow, Wroclaw; Spain: Aragon, Barcelona, Madrid, New Castile, Old Castlile, Valencia, Valladolid. For 1700: Austria: St Polten and Vienna; Belgium: Antwerp; France: Aix, Angers, Arles, Avignon, Beziers, Chateu Gonier, Douai, Draguignan, France, Grenoble, Marseilles, Paris, Rennes, Strasbourg, Toulouse, Tours, Valence; Germany: Augsburg, Cologne, Dresden, Frankfurt, Holstein, Leipzig, Munich, Weyer, Wurzburg; Italy: Ancona, Bassano, Brescia, Milan, Naples, Pesaro, Pisa, Senigallia, Siena; Netherlands: Amsterdam, Arnhem, Leiden, Rotterdam, Utrecht; Poland: Danzig, Gdansk, Krakow, Poland, Warsaw; England: Southern England; Spain: Barcelona, Bilbao, Cervera, Madrid, New Castile.

How to explain the big decline in price volatility that seems to have occurred in the western Mediterranean between 100 and 1200 AD? Following the model presented in section 2, we discuss three possible factors that could systematically affect the volatility of crop prices.

The first is the productivity of the agricultural system. As pointed out by Van der Spek (2006) and Jursa (2010, 49), productivity was very high in Babylonian times. 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 (1976, 50) points at a seed yield ratio of 1: 10 for early Medieval Middle East, whereas in Carolingian times in Western Europe it was rather 1:2.5. The yield ratio's of the main cereals in Italy and southern France were estimated at 3 to 5, the yield per hectare at 6-10 hl (Slicher van Bath, 1963; Van Zanden, 1998, p. 69). Moreover, Babylon had the advantage of two harvests per year (barley in summer, dates in autumn), which increased productivity and helped stabilize prices. Based on our model the productivity differences, ceteris paribus, should have contributed to a lower price volatility in Babylon than in Europe. If we look not only at the level but also on the trend of agricultural productivity the picture becomes much more favorable for Europe, since agricultural productivity was slowly increasing in Medieval Europe. Persson (1991) estimated a growth of agricultural productivity of 0.15-0.2% growth per annum between 1000 and 1300 AD in Tuscany; Federico and Malanima (1994) arrive at a less optimistic estimate of 0.05% per capita per annum growth between the 10th and 14th centuries. Improving agricultural technologies in the medieval Europe, hence, can explain the observed downward trend in agricultural price volatility observes in Table 1.

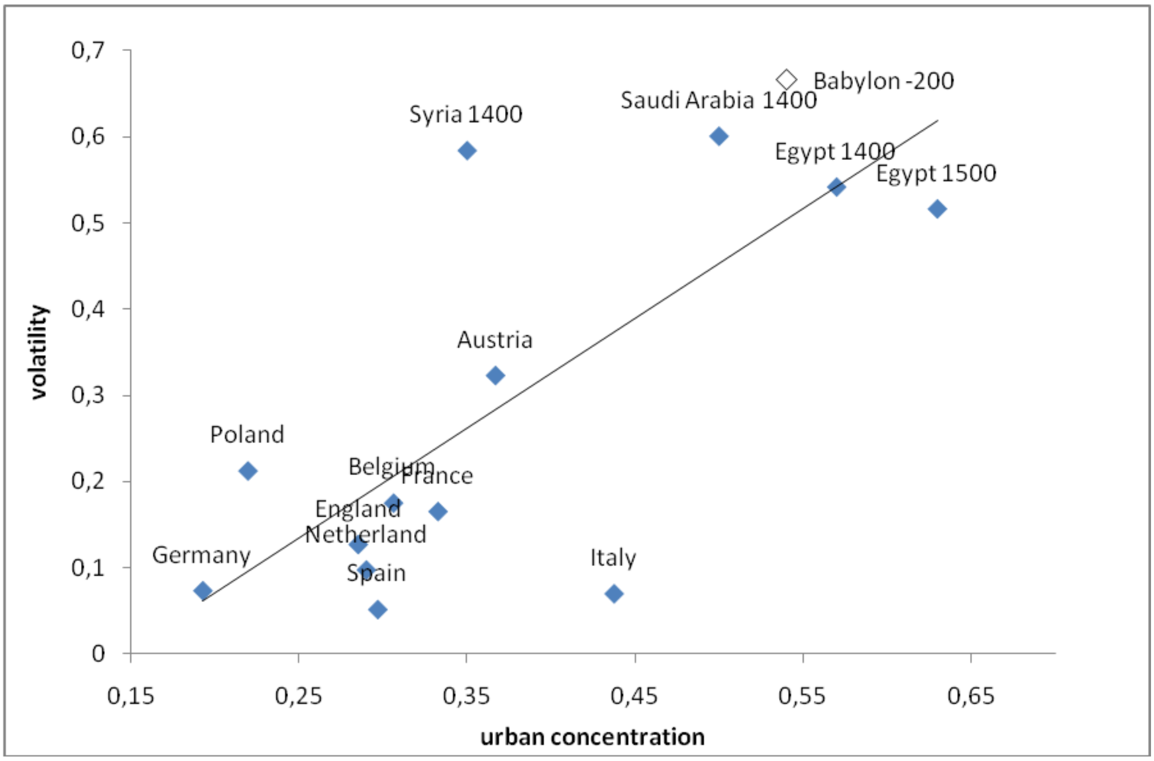
The second factor isolated in the model, the structure of the urban system, is more helpful in explaining the patterns found. For this we rely heavily on Bosker et.al. (2012), which compares the evolution and the structure of the urban system in the Middle East and

Western Europe between 800 and 1800. They show that the urban system of the Middle East was quite different from that of Western Europe: the first was characterized by a very high level of urban primacy, in which the largest (capital) city dominated the urban system, whereas the European urban system (after 1000) was much more balanced. The level or urban primacy, defined as the share of the urban population living in the largest city, was between 15 and 30% in the Middle East (with giant cities such as Baghdad and Cairo), whereas in Western Europe it varied between 5 and 13%. This is linked to the different political economy of the states and the cities concerned: cities of the Middle East were closely tied to the success of their empires, and it was in particular the capital cities that dominated the urban system. In medieval Europe, urbanization was a different phenomenon, based on productive activities (such as trade, finance and the production of textiles); in particular the balanced structure of the Italian urban system – with its many small and medium sized city-states – is a good example of this structure (Bosker et.al. 2012). In ancient societies we find analogues: Classical Greece clearly had an urban system with certain similarities to what we find in Medieval Europe, as had classical Italy, before the rise of Rome to world power. In Mesopotamia the process of early state formation consisted of the consolidation of bonds between more or less independent city-states, but when our data start to flow (during the reign of Nebuchadnezzar 605-562 BC) this process has resulted in a highly centralized state dominated by the capital city of Babylon; its total population is estimated at about 200,000 to 300,000, or as large as the next ten largest cities taken together (Bairoch, 1988: 27; also Van der Spek, 2008). Similarly, for Egypt our oldest data refer to the Hellenistic period, when the country was strongly unified and Alexandria (with perhaps as much as 300,000 inhabitants) was the capital city. Summing up, with the exception of Athens and Delos (and early Rome), the ancient markets that are included in our sample are typical 'urban primates' and therefore more closely resemble the cities in Medieval Middle East than those of Western Europe. This helps to explain the rather poor performance of their markets.

We can test this hypothesis more systematically by comparing, for the 15th and 16th century (for which we have the best data) the relationship between the volatility of grain prices and the degree of urban concentration (Figure 4). We indeed find that a positive relationship between urban concentration (defined as the share of the largest city in the total

FIGURE IV

MARKET VOLATILITY VERSUS URBAN CONCENTRATION AROUND 1500AD



Sources: Figure 1B and 1C; Allen - Unger Global Commodity Prices Database (downloaded from http://www.gcpdb.info/)

urban population) and market instability around 1500, confirming the expectations based on our model.

The third factor is transport and transaction costs. While Italian cities had access to waterways, Middle Eastern primate cities such as Baghdad and Damascus were typically situated in the middle of their territory and therefore without access to sea transport (Bosker et.al. 2012). These differences are also related to the modes of transport linking the two urban systems. Cities in the Arab world were mainly connected by caravan routes using camels as 'ship of the desert'. This was initially an efficient solution, but there were not many possibilities for further improvements, which can serve as a partial explanation why we cannot observe an improvement in price volatility in the Medieval Middle East compared to the Antiquity. Cities in Medieval Europe were dependent on transport overseas, which did change dramatically in productivity (due to a broad range of changes in ship design, in infrastructure and institutional setting). This was, according to Bosker et.al. (2012), an important reason why the European urban system was much more dynamic than that of the Middle East. At the same time, there are reasons to believe that transaction costs were much lower in Western Europe than they used to be in ancient Babylon or Egypt. First and foremost because of a different political economy in which commercial interests dominated political decision making in the Italian city republics (and in many other European communes), resulting in well protected property rights and relatively high levels of trust (Greif, 2006; Van Zanden, 2009). The literature on this is extensive and cannot be dealt with in detail here; we restrict ourselves to trying to quantify this effect on the basis of what we know about the decline of price volatility.

Using our model with some historical information on 3rd century BC Babylon and 16th century Tuscany, we can arrive at some estimates of the improvement of transaction costs over time. According to Table 1 price volatility in Seleucid Babylon was about 0.64, while it was 0.35 in Tuscany around 1500. We know that the size of the market in Tuscany was about the half of Babylon, implying that the radius was about 70.7% of the Babylonian market. As discussed in section 3, the Babylonian agriculture was significantly more productive per acre than the Tuscan. For this reason we assume that the former had three times much output per area unit than the latter. The final factor we need is the volatility of output per hectare. Even though very little historical evidence exists on this, we can arrive at plausible guesstimates. Tuscan productivity might be proxied using information on contemporary England which can be considered comparable and which suggest a volatility equal to on average 25% of the mean.[6] For Babylon Van Leeuwen, Foldvari and Pirngruber (2011) estimated that output volatility per acre was about 50% of that of England.

Table 5 below reports the results of this exercise. The size of the market area of a Tuscanian city is assumed to be about half of that of Babylon: choosing a market radius of 4 units for Babylon hence translates into a radius of 2.82 for Tuscany. The fourth row gives the volatility in output per acre. The transaction costs were now chosen in such a way that the predicted volatility resembled the actual values from Table 1. We find that the transaction costs in Tuscany must have been between 15% and 22.5% per radius if Tuscany had an agricultural output of 50% or 33% of that of Babylon (we estimated two scenarios). In Babylon, the transaction costs were in the order of 30% loss of goods per radius.[7] In other words, this comparison of the two economies suggests that we have to assume a decline of about 33% to 50% of the transaction costs between ancient Mesopotamia and Medieval Tuscany to explain the strong decline of the crop price volatility found in Table 1.

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[6] We calculated the output per acre on demesnes in Norfolk and Suffolk between 1270 and 1340 The data are obtained from Bruce M. S. Campbell (2007).

[7] Jursa (2010, 150) gives transport costs in the order of magnitude of 20% for only 2/3 of the radius, meaning close to 30% for the full radius of the Babylonian market.

TABLE V

DECOMPOSITION OF THE DIFFERENCE IN MARKET VOLATILITY BETWEEN SELEUCID BABYLON AND A MEDIEVAL CITY IN TUSCANY

	Babylon	Tuscany (1)	Tuscany (2)
output per area unit	1	0.5	0,333
std dev of output per area unit	12% of the mean output	25% of the mean output	25% of the mean output
τ	0.357 (30% per radius)	0.163 (15% per radius)	0.255 (22.5% per radius)
radius of market zone	4	2.82	2.309
predicted CV of prices	**0.64**	**0.33**	**0.36**
observed residual std dev. of log prices	0.71	0.35	

IV. FROM SUBSISTENCE FARMING TO COMMERCIAL FARMING IN EARLY MEDIEVAL EUROPE: A MODEL

Our finding of an increase in market performance (i.e. a reduction in price volatility) already in the early middle ages due to a reduction in transaction costs and a rise in agricultural output, has important consequences for the rise of commercial agriculture. After all, the increased reliance of farmers, due to lower transaction costs and higher output, on commercial agriculture, i.e. producing for the market, and to be less reliant on subsistence farming, was an important part of the European modernization process during the early modern Europe (e.g. Eschelback Gregson 1993; Koepke and Baten 2008). Yet, as seen in the previous section, we also found a process of lower transaction costs and higher output already in the early middle ages. Hence, the question arises if this also led to increased commercialization already a thousand years earlier.

Recently several authors have indeed tried to make the argument that a process of commercialization existed in the early medieval period (e.g. Britnell and Campbell 1995). Especially McCormick (2001,18, 618) shows that in the early medieval Mediterranean basin commercialization increased markedly, while it rather declined in the Middle East in the same period. The reasons for these changes in commercialization are less clear. Sometimes it is brought as related to population size (Dyer 2005), to factor markets (Campbell 2009), or to wars and other conflicts (McCormick 2001), yet many take it simply as given. Nevertheless, its effect has been argued to be great, determining many of the later (i.e. early modern) developments that we consider crucial in the transformation to sustained per capita income growth such as the consumer revolution and occupational specialization (Dyer 2005).

Hence, it is important to determine if, and why, commercialization started during the early medieval period when market performance increased (i.e. price volatility declined). Therefore, in the following we present simple model that identifies the most important market and cost related factors that affected the change of survival strategy (subsistence versus commercialization) in agriculture.[8] We assume that a farmer can engage either in subsistence (denoted by u) farming where the income follows a normal distribution

$$y_s \sim N(\mu_s, \sigma_s^2) \, (15)$$

or produces cash crops with revenue

$$y_c = pq_c \, (16)$$

where p denotes the price, and price is assumed to be a normal random variable.

$$p \sim N(\mu_p, \sigma_p^2) \quad (17)^9$$

We assume that the agent is price taker, so q_s and p are not correlated. If the farmer followed a mixed strategy in which share w (0≤w≤1) of the total revenue is from specialization and 1-w is from subsistence farming then the expected value of his total revenue would equal:

$$\mu = (1-w)\mu_s + w\mu_p\mu_c \, (18)$$

and the standard deviation of his income would equal:

$$\sigma^2 = (1-w)^2\sigma_s^2 + w^2\sigma_c^2 + 2(1-w)w\sigma_{sc} \, (19)$$

For the revenue from cash crops we assume that with unit resources more output can be produced, but since these should be transported to the market some transaction costs occur:

$$q_c = \beta y_s = (1+\gamma)e^{-\tau d} y_s \, (20)$$

with

$$\gamma \geq 0, \tau \geq 0, d \geq 0 \; ,$$

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[8] We do not include any bureaucratic measures in our model, though. Obviously, if the state demanded taxes paid in money, farmers were forced to offer a share of their produces for sale even when it would not have been profitable.

[9] Since the output from subsistence farming has no market price, we assigned unit price to it.

where γ, τ, and d denote the productivity bonus of commercial farming, the transport costs and the distance from the market respectively. Using above assumptions the variance of y_c is as follows:

$$\sigma_c^2 = Var(p \cdot q_c) = \beta^2 \sigma_s^2 (\sigma_p^2 + \mu_p^2) + \mu_s^2 \sigma_p^2 \quad (21)$$

and the covariance of the two revenues are: $\sigma_{sc} = Cov(y_s, y_c) = \beta \mu_p \sigma_s^2 > 0$. In other words, due to the common shocks in agricultural production the revenues from the two activities are positively correlated.

We assume that the farmer seeks to maximize the expected value of the following utility:

$$U(y) = \ln\left(y - l\right) (22)$$

, in other words, he wishes to choose w so that

$$E(U(y = \mu)) = \ln\left(\mu - l\right) - \frac{\sigma^2}{2\left(\mu - l\right)^2} + O \, (23)$$

is the maximum possible.[10]

With this setup this problem becomes a standard Markowitz portfolio choice problem with two risky assets. The optimal choice of w is at which the slope of the indifference curve in the mean-standard deviation plane equals the slope of the portfolio frontier, or in other words, w is increased to the point that the utility gain from the increased expected revenue equals the reduction in utility as a result of growing standard deviation. Formally:

$$\frac{\partial E(U)}{\partial \mu} \frac{\partial \mu}{\partial w} = -\frac{\partial E(U)}{\partial \sigma} \frac{\partial \sigma}{\partial w} \quad (24)$$

[10] O denotes the rest of the terms from the Taylor-series approximation. Obviously, if the revenues were normally distributed, the third moment would equal zero. We use a second-order Taylor approximation here, as it is generally found to be accurate (see Hlawitschka 1994).

where $\frac{\partial E(U)}{\partial \sigma} < 0$ since risk is a harmful good.[11]

FIGURE V

OPTIMAL CHOICE OF A MIXED STRATEGY OF SUBSISTENCE FARMING AND COMMERCIAL FARMING

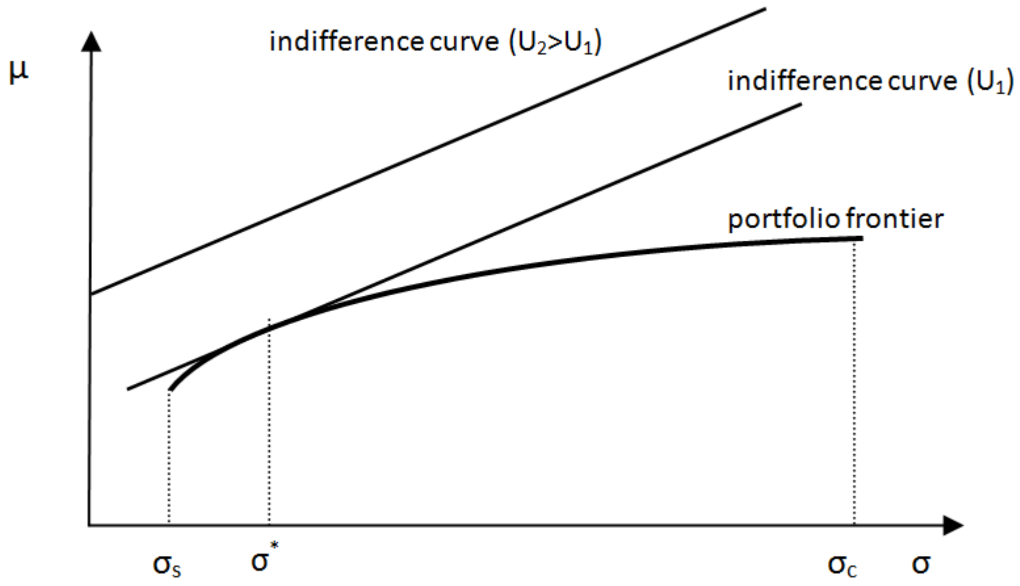

Figure 5 visualizes the mechanism of choice. The optimal choice of w is where the indifference curve touches the portfolio frontier, i.e. where their slopes are equal. At this point the standard deviation of the portfolio is σ^*. If the slope of the indifference curve exceed that of the portfolio frontier the optimal choice will be at w=0 (subsistence farming), i.e. only subsistence farming will occur if the revenue from cash crops is simply not high enough to

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[11] The slope of the indifference curve is: $m_I = \frac{\sigma(\mu - l)}{(\mu - l)^2 + \sigma^2} \geq 0$ if $(\mu - l) \geq 0$,

while the slope of the portfolio frontier can be expressed as: $m_{pf} = \frac{\sigma(\mu_p \mu_c - \mu_s)}{w\sigma_c^2 + (w-1)\sigma_s^2 + (1-2w)\sigma_{sc}}$.

compensate for the higher risk involved.[12] If the indifference curve`s slope is less than that of the portfolio frontier, the optimal choice will be w=1 (pure commercial farming). In other words, a farmer will send all his produce to the market when the returns from commercial farming outweigh the risk sufficiently enough.

Obviously if the parameters are so that a corner solution is chosen changes in the parameters will not have any impact on w. This is different for any intermediate case, which is the case we are discussing for the early Middle Ages, with a mixed strategy where part of the produce is brought to the market and part is used for subsistence. In such a phase, factors like transport costs, productivity or price volatility play a role in the individual`s choice.

Even though a closed form solution of the optimal w in the transitory phase is possible to achieve, it is far too complex and lengthy to offer any insight. Therefore, instead we present simulation results of different scenarios. In Figure 6 we report the simulated effect of a reduction in price volatility. Since lower price volatility ceteris paribus increases the slope of

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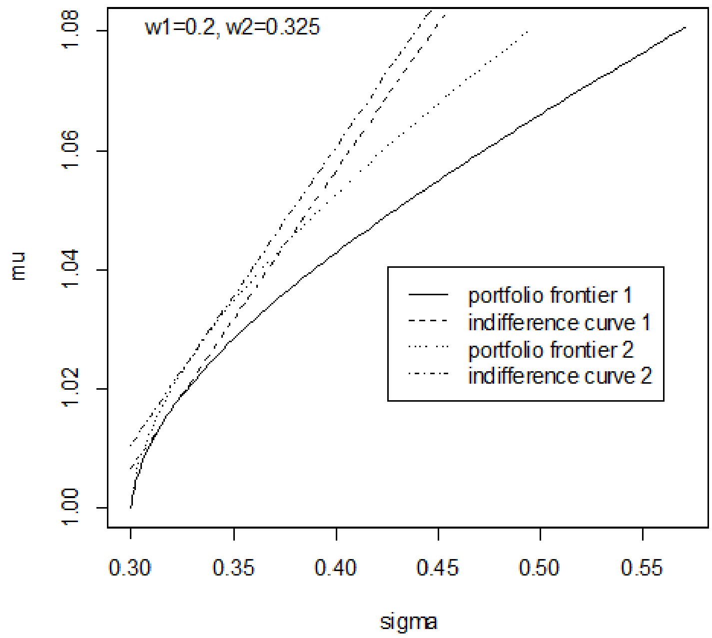
[12] This is the case as long as $\mu_p(1+\gamma)e^{-\tau d} \leq 1$. Obviously if $\mu_p\mu_c - \mu_s = \left(\mu_p(1+\gamma)e^{-\tau d} - 1\right)\mu_s \leq 0$, that is $\mu_p(1+\gamma)e^{-\tau d} \leq 1$ the portfolio frontier will be either a horizontal line or a negative sloped curve, while the indifference curve retains its positive slope, and there will always be a corner solution with w=0. Once this is not the case, there will be a w>0 solution as follows. Under w=0 the slope of the portfolio frontier is: $m_{pf|w=0} = \frac{\mu_s}{\sigma_s}$, and the slope of the indifference curve at w=0 is: $m_{I|w=0} = \frac{\sigma_s\left(\mu_s - l\right)}{\left(\mu_s - l\right)^2 + \sigma_s^2}$. As long as $m_{pf|w=0} \leq m_{I|w=0}$ the farmer will prefer a corner solution with w=0, which requires that $\frac{l}{\sigma_s} \leq \frac{x_{|w=0}}{1+x_{|w=0}} - x_{|w=0} = \frac{-x_{|w=0}^2}{1+x_{|w=0}}$ where $x_{|w=0} = \frac{\mu_s - l}{\sigma_s}$. This condition obviously never holds for any positive value of l. This means that as long as $\mu_p(1+\gamma)e^{-\tau d} \leq 1$ and l is a positive number or zero, the optimal choice of w will exceed zero.

the portfolio frontier, more than that of the indifference curve the new optimum will be at a higher value of w.

FIGURE VI

THE EFFECT OF A REDUCTION IN PRICE VOLATILITY ON COMMERCIALIZATION

(BASELINE CASE IS DENOTED BY 1)



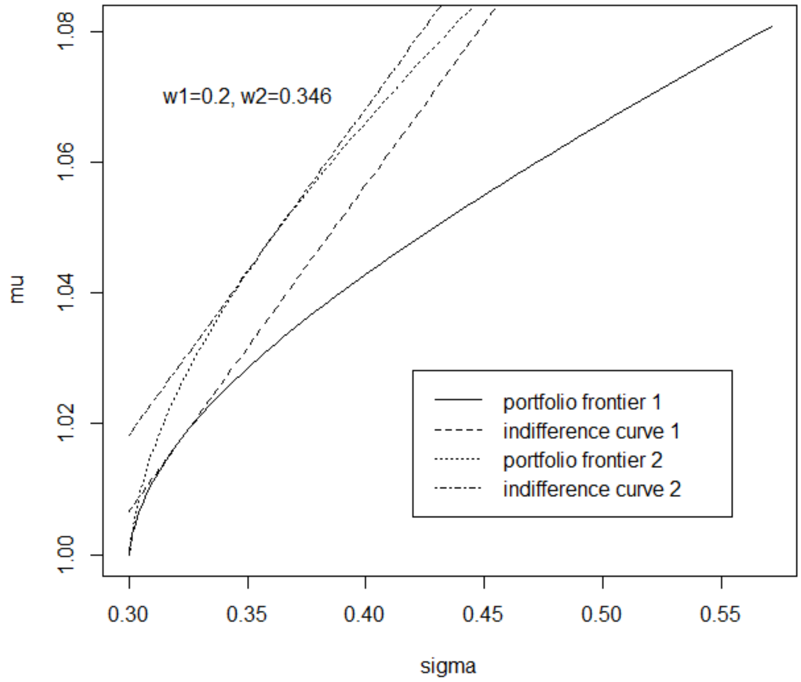
Note: standard deviation of price is reduced from 0.5 (case 1) to 0.4 (case 2)

Similarly, a reduction in transport costs increase the returns from commercial farming more than the volatility of revenue and will also lead to increase in the share of cash-cropping (Figure 7).

FIGURE VII

THE EFFECT OF A REDUCTION IN TRANSPORT COST ON COMMERCIALIZATION

(BASELINE CASE IS DENOTED BY 1)

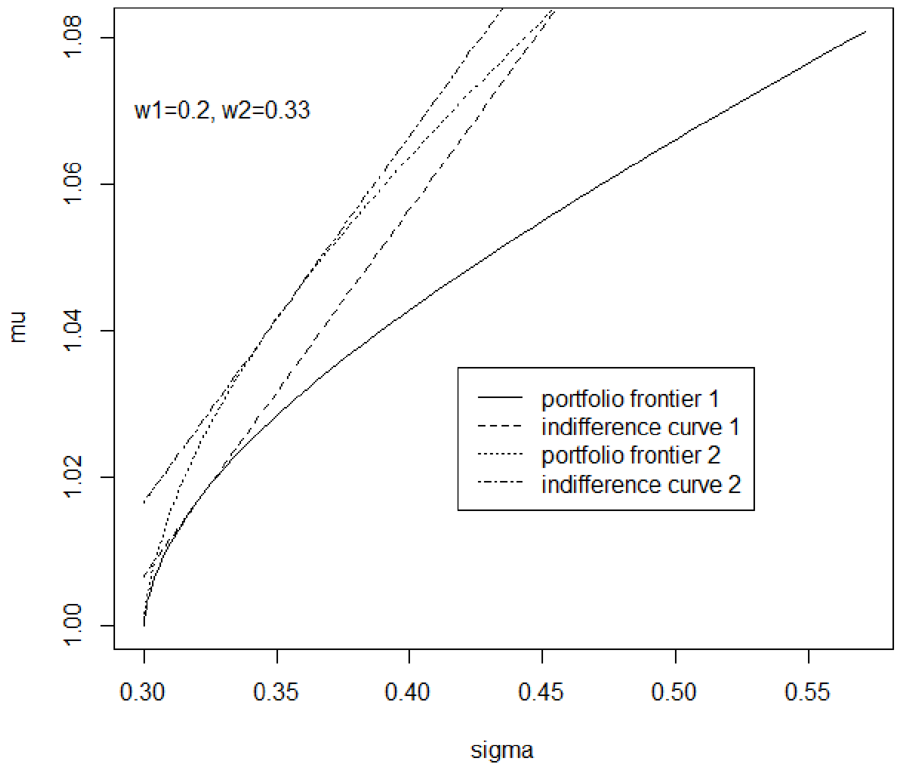


Note: the parameter τ is reduced from 0.2 (case 1) to 0.15 (case 2)

Finally, in Figure 8, we report the simulated effect of an increase in the productivity bonus of producing for the market, *ceteris paribus*. Not surprisingly, we find an increase in the optimal value of w.

FIGURE VIII

THE EFFECT OF AN INCREASE IN THE PRODUCTIVITY OF CASH CROPS ON COMMERCIALIZATION (BASELINE CASE IS DENOTED BY 1)



Note: the parameter γ is increased from 0.1 (case 1) to 0.15 (case 2)

We can thus conclude that, besides possible other factors, especially the changes in transport costs, agricultural productivity, and price volatility that we found in early medieval Europe played an important role in the transition to commercial agriculture. This is also stressed by McCormick (2001) who shows that transportation and communication costs went down considerably in Europe as opposed to the Middle East. Likewise agricultural productivity, which increased spectacularly in Europe (e.g Slicher van Bath 1963, Erdkamp 2005), actually declined in the Middle East (Ashtor 1976). Consequently, the Middle East did not undergo a similar transition to commercialized agriculture. This, in turn, might also have had its effects on later growth pattern of these two regions. Indeed, several authors, such as Abu-Lughod (1989) and Dyer (2005) have argued that the differential development in commercialization in the early medieval period, affected also developments in later centuries including the consumer revolution and the world system (e.g. Wallerstein 1974).

V. CONCLUSION

The availability of historical market prices suggests that working markets existed in the antiquity. The majority view holds that the next big step in the evolution of the markets of basic foodstuffs took place during the 18th and 19th century when price volatility declined due to a combination of trade, changing consumption patterns, increased output, and technological development. This decrease in volatility, in this line of thought, also made a process of commercialization possible in which farmers sold an increasing share of their produce to the market.

However, much less is known what happened before the 19th century. Recently several datasets on prices of basic foodstuffs became available that enabling researchers to compare market performance over the very long run, from the first Babylonian sources of market prices 2600 years ago (the age of Nebuchadnezzar) to that of Napoleon at about 1800. This paper, to our knowledge, is the first to present a systematic comparison of such datasets, focused on markets in the Mediterranean region. We find that markets in Medieval Europe were significantly less volatile than markets of ancient societies such as Babylon, and also less volatile than markets in Medieval Egypt, Arabia and Iraq thus suggesting a significant improvement in the working of markets in Europe in the early medieval period.

Using a model to analyze the main determinants of this increase in market performance, we find that especially the reduction in transaction costs and the increase in agricultural output contributed to this decline in price volatility in early medieval Europe. In the Middle East, which did not undergo similar changes, market performance stayed basically unaltered.

This increase in market performance in Europe in the early medieval period also suggests an increasing degree of commercialization. By extending our market performance model with commercialization, we are able to show that a lowering of transaction costs, combined with higher per capita output and lower price volatility, all contributed to a change in the production structure with a higher proportion of goods being sold on the market already in the early medieval period. Obviously, this rise in commercialization did not occur in the Middle East which did not witness improvements in output, price volatility, or transaction costs.

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Data Appendix

Babylon: for the period between 600 and 500 BC the data are taken from Jursa (2010, pp. 443-457). 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 the prices on dummies referring to place, year, and month as suggested by Clark (2004). 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 (Slotsky, 1997; Vargyas, 2001; Slotsky and Wallenfels, 2009; Van der Spek, 2010). These data are based on the Astronomical Diaries. These diaries are best described by Hunger and Pingree (1999, 141) as 'record(s) of observed phenomena carefully chosen from the realms of the celestial, the atmospheric, and the terrestrial.'[13] 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 400-50 BC on a monthly, or even daily basis. However, many observations are missing. Still, out of a possible 4079 months, we still have observations for 512 months.[14] 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 (2008) reports prices for Egypt between ca. 300 and 90 BC. These data

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[13] The name 'Diary' was coined by Abraham Sachs on the basis of the colophon-title *naṣāru* (EN.NUN) *šá ginê*, 'regular observation'.

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

are largely representative for the more densely Greek dominated parts of the country. As Von Reden 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), and Athens. Furthermore, we use data for the second great Empire in this region, Rome, from Rathbone (2011). For the later periods from ca. 1200 onwards we have data from Iraq, Egypt, Syria and Istanbul (Ashtor, 1969; Mortel, 1989, Pamuk, 2004). The earlier estimates are normally taken from contemporary economic historians, often reporting extreme prices, while the Istanbul data refer to retail prices (Pamuk, 2004, 452). 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 (Coniglio, 1952; Romano, 1965; Basini, 1974; Malanima, 1976; Pamuk, 2004).

Three problems should be mentioned. First, some authors have doubted whether the prices from antiquity are "real" market prices. We deal with this problem in the paper. The second problem is that not all prices are of the same crop. 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 to salt than barley, wheat was slowly replaced by barley in Babylon.[15] 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 (forthcoming), the price difference 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. Also Von Reden (2008, 12) argues that wheat prices in Athens are around

[15] Jacobson and Adams (1958); Artzy and Hillel (1988). However, for a critique see Powell (1985).

20-30% higher than barley prices, a difference not unlike the one found in Egypt (Von Reden, 2008, 15). Since barley is the preferred grain in Babylon, however, Van der Spek and Van Leeuwen (in press) argue that its price must be closer to that of wheat. Hence, since barley was the main foodstuff in Babylon 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 converted 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 1000 AD this contains a problem because gold coins entered into circulation and some prices are expressed in terms of gold. Therefore, where necessary, we follow Söderberg (2004; 2006) and use the Cairo bimetallic standard for Near East up to 1500. Although this is 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 1200 AD, 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. In all cases, this transformation did of course not affect the estimated volatility of the price series.

The data after 1400 are taken from the Allen-Unger dataset and are given in grammes of silver per litre per annum.