The purchasing power of silver and market efficiency from a Babylonian perspective

Staple crops and silver from antiquity until the industrial revolution

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Abstract

Silver has been an important means of exchange and storage of wealth since the third millennium BC until the 19th century AD and even today silver plays its part. Even though silver nowadays has lost its function as a means of exchange, it still functions as storage of wealth as can be shown by its substantial price rise during the recent economic crisis. When we think of silver as money, we think instinctively of coins. Yet silver was used as money long before the invention of coinage. In 7th century Asia Minor and in the Middle East (Mesopotamia) coinage was used on a massive scale only at the conquest by Alexander the Great. Silver can only keep its trustworthiness when it is pure and the purity has always been a major concern, before as well as after the invention of coinage. This invention did not help the guarantee of coinage, as states always (especially in times of crisis and scarcity of silver) were tempted either to reduce the weight of the coins (which was impossible before the invention of coinage) and its purity. This uncertainty evidently influenced the utility of this means of exchange and finally it was abolished as such in the 19th century. But how did this affect the amount of staple products that could be bought for a unit of silver?

In this paper we test the purchasing power of silver from antiquity until the industrial revolution. We find (unsurprisingly) that an increase in silver leads to a price increase. However, prices will increase faster for staple goods than for luxury and industrial goods. We find that purchasing power from antiquity to ca. 1500 was remarkably equal with the exception of Delos, Athens, and Babylon between ca. 200-100 BC. Whereas the former two were import economies, Babylon was characterized by a favourable climatic situation and a lack of inflow of silver. This changed after the 16th/17th century when the inflow of silver caused a decline in purchasing power of silver in all regions. Relating this to market efficiency, we find that, after 1700, the higher the market efficiency, the lower the purchasing power. We explain this by a flow of silver to the new commercial and economic centers and, partly, by higher elasticity of industrial products, increasing the effect of silver on agricultural prices.

I. The purchasing power of silver in Mesopotamian perception

During a siege of Samaria in Israel by king Ben-Hadad of Aram (840s BC), an extreme famine broke out in the city so serious that contemporary reports claimed that women ate their own children. The prophet Elisha predicted: "Hear the word of the LORD: thus says the LORD, Tomorrow about this time a seah of fine flour shall be sold for a shekel, and two seahs of barley for a shekel, at the gate of Samaria."[1] This is apparently a very low price in view of the siege, but it is still high in view of Babylonian parallels. The text actually mentions the purchasing power of the (Israelite) shekel (how much grain can be bought for one shekel instead of, what is common today, the amount of shekel per unit of grain) instead of price. whih was a common practice in the Near East to indicate the value of bulk goods. We see this in all kinds of document. Hence we can in these cases better speak of "exchange values" or "equivalents" than of prices.

We can find the same in the royal inscriptions of Assyrian and Babylonian kings, where they claim that economic conditions under their reigns were extremely favourable. The Assyrian king Assurbanipal claims in one of his Annals that in his time "the grain (*še-am*) waxed five cubits tall [in its luxuriant g]rowth, an ear grew to [five]-sixth of a cubit in length" and that "10 homers (variant 12) of barley (ŠE.PAD.MEŠ) for one (var. 2) [shekel]" was the value of exchange.[2] Much more elaborate is Nabonidus in his partly preserved Basalt stela from Babylon, also called the "tariff stela" which we quote here[3]:

1. My good deeds he (some god; Sin? Marduk?) beheld with joy,
2. and he gave me length of days. At the word of the god Sin (moon god),
3. the king of the gods, Adad released the rain,

[1] II Kings 7:1-2. The shekel in Israel weighed about 11 grammes and the seah was about 7.3 litres.
[2] A.C. Piepkorn, *The Inscriptions of Assurbanipal*, p. 28-31, Annals edition B, Col. I 29 and 36, resp. editions D and B. One Assyrian homer (*imēru,* 'donkey('s load)) is 100 *qa* (litres). Cf. Hawkins 1986.
[3] Schaudig 2001: 530-2.

4. and Ea opened his springs; wealth,

5. prosperity and abundance he established in my land.

6. One kor (*kurru*), 1 bushel (*pānu*), 1 seah (*sūtu*) (= 234 litres) of grain (was sold) for one shekel of silver; one kor, two bushel and three seah (= 270 l.) of dates

7. for one shekel of silver; one (bushel?), 30 qa (66 l.) of sesame oil for one shekel of silver;

8. [x +?] 18 *qa* (litres) of fine oil for one shekel of silver; five minas (5 pounds) of wool

9. for one shekel of silver; one mina of /tin?\ for one shekel of silver.

10. Wine, the quality beer of the mountain, which in my country does not exist,

11. 18? litres of wine for one shekel of silver was the exchange value (KI.LAM) current in my land.

12. [Full]ness and abundance in my land he established.

These values are indeed favourable. In Babylonia since time immemorial there was an ideal or iconic purchasing power of the shekel. The shekel (8.33 grams of silver) could buy one kor (*kurru* =180 litres) of grain or dates and constituted a one month salary. Reality was often different, as the Babylonians also well knew, and one can better perceive the boasts of the kings when they claim that in their time people could buy 1000 litres of barley in the time of Assurbanipal or somewhat more modest 234 litres of barley and 270 litres of dates in Nabonidus' reign. These exchange values have hardly value as they are from propaganda texts, but it must be said that in Nabonidus' reign even higher equivalents are attested (Jursa 2010: 445).

Interest in the purchasing power of silver is also attested in the inscriptions of Sargon II (722-705 BC). In this period copper, bronze and silver were used as money, but before 712 BC copper was preponderant. In 712 Sargon II conquered Carchemish. After that campaign, silver replaced copper as the main currency and silver is measured in the mina of Carchemish

(Postgate 1979: 18, Müller 1997: 120; Radner 1999: 129). Sargon II plundered so much booty in that campaign that he boasted that from that time on the exchange value (*mahīru*) of silver was to equal that of bronze (Annals from Khorsabad 232–4 =Fuchs 1994: 130 ff.). A modern economist would perhaps doubt whether that is really so good.

Besides political interest, there also existed scientific interest in the purchasing power of the shekel in Babylonia. It is attested in four types of text: the chronicles, the astronomical diaries, omens and the commodity price lists. In the first place there is an entire chronicle dedicated to market prices (ABC 23). It records exchange values of the shekel from before the time of Hammurabi (18th century BC) until probably the time of Nabu-šuma-iškun (c. 760-748 BC). It seems as though the compiler collected random prices from this period he could find. It is perhaps no coincidence that it run until Nabu-šuma-iškun, the predecessor of Nabonassar (747-734), with whom the Neo-Babylonian chronicle series and possibly also the notation of celestial phenomena like eclipses start.[4] We do not know what the sources were for the chroniclers. If the earliest astronomical diaries are older than Nabonassar, these documents may have been the source, but we gather that the chronicler precisely wanted to redress the lack of data before that time and tried to find information in whatever source he found: royal inscriptions, price documents and some stray recordings. In chronicles occasionally exchange values are mentioned as well, as in the so-called Diadochi chronicle concerning the wars after Alexander's death (ABC 10 = BCHP 3, r. 29': "barley: 6 litres; dates [n litres]". The chronicle reports warfare between the armies of Seleucus and Antigonus for that year, 309/8 BC, in and around the city of Babylon and understandably these prices belong to the highest ever recorded.

The exchange values in the astronomical diaries need not much commentary as they are discussed elsewhere (see for example the contribution of Van der Spek 2011, this

[4] It may well be that the chronicle stems from a much later period, possibly the Achaemenid period.

workshop). The commodity price lists (actually lists of exchange values of silver) can be compared to the "Chronicle of the Market Values" just mentioned. It shows specific interest in prices and in much greater detail than the chronicle. It contains tablets with records concerning every month of a certain year as if to show intra-annual developments and one tablet records the equivalents of dates of month VIII, usually seen as the harvest month of this fruit. The interesting thing is, that it is not always 1 shekel that is taken as point of reference, but also 2 shekels or even a mina (60 shekels).

Finally there are the omens. The heart of Babylonian scholarship was divination. All these collections of data served the science of prediction. And in the omen collections we see the result. Every omen consists of a *protasis*, in which a certain phenomenon is described (e.g. "if the sun is surrounded by a halo"), followed by an *apodosis*, in which the consequences are indicated (e.g. "the next day rain will fall") – which is by the way a sound observation, which cannot be said of most omens. But there are also omens which have *apodoses* relating to KI.LAM, *mahīru*, "exchange value." In good omens the KI.LAM is of course good, and in bad omens it is bad. Unfortunately most of the editors of these omens did not understand the gist of these omens, and they translated the word with "business", "trade" or even "economy", so that an *apodosis* could sound as "the economy will be booming". But that is too modern. Like the composer of chronicles, price lists and astronomical diaries, these astrologers or other diviners had interest in the vicissitudes of seemingly unpredictable prices. Hence, when the KI.LAM is good, this means that one gets much volume for one shekel of silver. The examples can be taken from the Chicago Assyrian Dictionary s.v. *mahīru* 2 c) where the references in omen collections are discussed, but in all cases the translation is wrong. We shall give a few examples of good omens first. 1. *Māt šarri ša sunqu īmuru* KI.LAM *napša immar*, "the king's country that has experienced hard times, will experience good business" (CAD), must be "the king's country that has experienced famine, will enjoy abundant exchange values (i.e. abundant grain for one shekel, hence low prices)". Evidently in times of famine prices are high, but the good omen is that they will become low. This need not be caused by business, but for instance by the end of a siege or a good harvest. 2. DU_6+DU KI.LAM *napaš Nisaba*, "upswing of business, abundance of cereals"(CAD) must be "increase of exchange value, abundance of cereals", evidently so, when there is abundance of grain (Nisaba is the goddess of grain), you will get much grain for a shekel. 3. *Ebūru iššir* KI.LAM SIG_5 GAR-*an*, "the crop will prosper, business will be good" (CAD), must be "the crop will prosper, the exchange value will be good." 4. KI.LAM GI.NA, "business will remain stable" (CAD), must be "the exchange value will remain stable", hence stable prices, which can be seen as a good omen. 5. KI.LAM *ke-e-nu*, understandably not translated by the CAD, since it does not mean obviously "just business", but "fair exchange value", in our words "fair price." Then a few examples of bad omens. 6. KI.LAM TUR-*ir mēništu ibašši*, "Business will be reduced, there will be scarcity" (CAD), must be "the exchange value will decrease, there will be scarcity." Evidently in times of scarcity you do not get much grain for your shekel. And all the other comparable examples, where we see translations like "diminishing markets", one should read "diminishing exchange values", hence rising prices. Of special interest is this omen, perhaps more difficult to interpret: KI.LAM *ina* KUR ŠUB *kaspu ul ibašši*, "business will collapse in the country, there will be no silver." This translation seems reasonable: when there is no silver, there can be no trade. But actually this is not true: when there is no silver, one can turn to trade by barter. But when there is no silver, it is impossible to establish the exchange value of silver. So the translation must be: "the exchange value (of the shekel) will be annihilated, (because) there will be no silver." We shall stop here, but this short overview already shows that the study of omens is an important source for the study of economic mentality. The main interest of the scholars was the purchasing power of the shekel and what we would term the level of the prices.

II. Defining the problem

What we want to do in this paper is to share the Babylonians' interest in the purchasing power of silver, though not for divinatory purposes. We want to look how the volumes and flows of silver impacted its purchasing power from Babylonian times, with a limited supply of silver, to the Industrial Revolution when silver had become much more abundant. We will consider the following points:

1. It is a well-known phenomenon and an increasing supply of silver usually leads to inflation. But the reverse is also true. When silver is scarce it will be expensive, and for this scarce and expensive silver you can buy more that is prices are low. Does this impact all products the same? And, even though, as shown in the previous Section, low prices are usually seen as sign of prosperity, if they are low due to a shortage of silver is this necessarily a sign of prosperity?

2. If silver is a commodity it will go to those regions, where one gets the best exchanges for it, in other words, where the purchasing power of silver is highest. In a well integrated market you expect that traders will buy wool in Babylonia rather than in Egypt, when you can buy with your shekel of silver twice as much in Babylonia than in Egypt, taking transport costs into account. If this does not happen, it is an indication of bad market integration. In principle it does not work differently for grain than for silver.

3. One might ask if a high purchasing power of silver is good for market integration or not. In other words: is scarcity of silver detrimental for international trade and leads supply of more silver to better trade and better exchange of goods?

4. Does the level of the purchasing power of silver influence volatility of prices?

We shall study these 4 questions by looking at two periods and regions. Firstly the Mediterranean world in the Hellenistic period up to the early modern period, where we can compare prices in Babylonia, Egypt, Delos and to a few other regions and secondly in pre-industrial Europe after the Black Death.

Answering above questions is not easy because of lack of data. Therefore, we start in the next Section to set up a model that allows us to analyse the role of an increase (or decrease) in the supply of silver in the prices of different products. This model thus establishes the relation between the price level of a staple crop and the growth of the amount of silver in the economy. We also show that the growth of silver may have a different effect on the price of different products. Then we move on to comparing purchasing powers in Section 4. We find that Babylon differed from the rest of the Mediterranean between ca. 200 and 100 BC. This may be due to lack of silver in that period. Therefore, adapting the model as discussed in Section 3, adapting our earlier specified model, we calculate the amount of silver in the Babylonian economy in Section 5. Section 6 discusses the early modern period. The remarkable finding is that there is a reversal of fortune around the 18th century. We end with a brief conclusion.

III. The model

In order to say something about the purchasing power of silver, we first have to analyse how an increase in the amount of silver leads to a rise in prices. This can be done using a simple model in which we equalize developments in the goods and money markets.

For the market of goods we assume that there are two goods, a staple food (indexed as F) and the rest (R), which can be seen as a combination of all other goods in the market. In case of a dual crop economy, like Babylon, where most of the expenditure consisted of barley and dates, we can simply think of F and R as barley and dates. In such a market, the demand and supply are defined as follows (i=F, R):

$$Q_i^S = a_i e^{u_i} \quad (1) \text{, where } u_i \sim NID(0,\sigma_{u_i}^2) \qquad (1)$$

where Q_i^S is the supply shock, a_i is the average production. We assume that all production is offered for sale on the market. For the demand side we get:

$$Q_i^D = b_i Y^{\alpha_i} P_i^{\beta_i} P_j^{\gamma_i} e^{v_i} \text{ i=(F, R), j=(R, F) (2) } v_i \sim NID(0,\sigma_{v_i}^2) \qquad (2)$$

where Q_i^D is the demand shock, b_i is an intercept, Y denotes income (for simplicity we use nominal income, but this should be no problem since α_i is the income elasticity of demand when all prices are fixed). P_i and P_j denote the price of the product expressed in silver for which we define the demand and the price of the alternative good respectively. The Greek letters are elasticities: α_F is the income elasticity of product F while β_F and γ_F are its price and cross-price elasticities. The price elasticity shows the effect of price change of product F on the demand for F, while the cross-price elasticity shows the effect of price changes of the alternative good on the demand of F.

If we want to know the equilibrium price, we have to set demand and supply equal:

$$P_i = \left(\frac{a_i}{b_i}\right)^{\frac{1}{\beta_i}} Y^{-\frac{\alpha_i}{\beta_i}} P_j^{-\frac{\gamma_i}{\beta_i}} e^{\frac{u_i - v_i}{\beta_i}} \quad (3) \quad (i=F, R \text{ and } j=R, F)$$

Since P_F and P_R are in a simultaneous relationship in order to arrive at P_F we need to substitute the equilibrium price P_R into the formula for P_F. This yields two reduced form equations for both products:

$$P_F = \left(\frac{a_F}{b_F}\right)^{\frac{\beta_F}{\beta_F\beta_R - \gamma_F\gamma_R}} \left(\frac{a_R}{b_R}\right)^{-\frac{\gamma_F}{\beta_F\beta_R - \gamma_F\gamma_R}} Y^{\frac{\gamma_F\alpha_R - \alpha_F\beta_R}{\beta_F\beta_R - \gamma_F\gamma_R}} e^{\frac{\beta_R(u_F - v_F) - \gamma_F(u_R - v_R)}{\beta_F\beta_R - \gamma_F\gamma_R}} \qquad (4)$$

$$P_R = \left(\frac{a_R}{b_R}\right)^{\frac{\beta_R}{\beta_R\beta_F - \gamma_R\gamma_F}} \left(\frac{a_F}{b_F}\right)^{-\frac{\gamma_R}{\beta_R\beta_F - \gamma_R\gamma_F}} Y^{\frac{\gamma_R\alpha_F - \alpha_R\beta_F}{\beta_R\beta_F - \gamma_R\gamma_F}} e^{\frac{\beta_F(u_R - v_R) - \gamma_R(u_F - v_F)}{\beta_R\beta_F - \gamma_R\gamma_F}} \qquad (5)$$

As we can observe, the price of the other good is eliminated from the right-hand side of the equations; the price of each product now depends on the production of that product, the production of the other product, the income, an error, and the various elasticities.

Let's now look at the monetary side of the economy. We start by assuming that the quantity theory of the money holds:

$$Y = M\overline{v} \quad (6)$$

where *Y* is the nominal value of all goods in the economy that are traded for silver (we assume that this equals total nominal income), *M* is the amount of silver, and *v* is the velocity of money, which we take as constant.[5]

Combing the good- and monetary side of the economy, we can substitute (6) into (4) and (5) to obtain a relationship between the quantity of silver and the price of the two goods:

$$P_F = \left(\frac{a_F}{b_F}\right)^{\frac{\beta_F}{\beta_F\beta_R-\gamma_F\gamma_R}} \left(\frac{a_R}{b_R}\right)^{-\frac{\gamma_F}{\beta_F\beta_R-\gamma_F\gamma_R}} \overline{v}^{\frac{\gamma_F\alpha_R-\alpha_F\beta_R}{\beta_F\beta_R-\gamma_F\gamma_R}} M^{\frac{\gamma_F\alpha_R-\alpha_F\beta_R}{\beta_F\beta_R-\gamma_F\gamma_R}} e^{\frac{\beta_R(u_F-v_F)-\gamma_F(u_R-v_R)}{\beta_F\beta_R-\gamma_F\gamma_R}} \quad (7)$$

$$P_R = \left(\frac{a_R}{b_R}\right)^{\frac{\beta_R}{\beta_R\beta_F-\gamma_R\gamma_F}} \left(\frac{a_F}{b_F}\right)^{-\frac{\gamma_R}{\beta_R\beta_F-\gamma_R\gamma_F}} \overline{v}^{\frac{\gamma_R\alpha_F-\alpha_R\beta_F}{\beta_R\beta_F-\gamma_R\gamma_F}} M^{\frac{\gamma_R\alpha_F-\alpha_R\beta_F}{\beta_R\beta_F-\gamma_R\gamma_F}} e^{\frac{\beta_F(u_R-v_R)-\gamma_R(u_F-v_F)}{\beta_R\beta_F-\gamma_R\gamma_F}} \quad (8)$$

In this simple model, the price of the two goods will depend only on the amount of silver in circulation in the long-run, since the demand and supply shocks have zero mean. This makes it possible to rewrite equation 7 and 8 as:

$$\Delta \ln P_{F,t} = \ln P_{F,t} - \ln P_{F,t-1} = \frac{\gamma_F\alpha_R - \alpha_F\beta_R}{\beta_F\beta_R - \gamma_F\gamma_R}\Delta \ln M_t \quad (9)$$

$$\Delta \ln P_{R,t} == \frac{\gamma_R\alpha_F - \alpha_R\beta_F}{\beta_R\beta_F - \gamma_R\gamma_F}\Delta \ln M_t \quad (10)$$

[5] For example Mayhew (1995, 240) has argued that the velocity of money is nothing more than how hard the money supply has to work. He argues that, if anything, the velocity of money decreased between ca. 1300 and 1700 in England.

We can assume that the income elasticities and the cross-price elasticities (the alphas and the gammas) are positive, meaning that both products are normal goods, and they are substitutes, and the own price elasticities (the betas) are negative, hence the increase of silver in circulation will have a positive effect on the price of a good, if $\beta_F \beta_R > \gamma_F \gamma_R$. If we assume that both goods are staple crops, we can safely argue, following Allen (2000,14), that the cross price elasticity (gamma) is a small but positive number (ca. 0.1) while the own price elasticity (beta) is around -0.6. Hence, $\beta_F \beta_R > \gamma_F \gamma_R$ holds and the growth in money supply is positively related with the growth in prices.

Another interesting observation in equation (9) and (10) is that the effect of the growth of silver does not necessarily have to be the same for all products. This all depends on the elasticities of the products. There are several possible combinations but, simplifying, one might say that when the own price and income elasticities are bigger in absolute value than that of the other product, the effect of a change in silver in on the price becomes smaller. Since the price of a product is also dependent on the elasticity of other products, if the elasticity of product *R* goes up, both the effect of an increase in silver on the price of product *R* and *F* goes down, but lesser so than for product F. To phrase it differently: if we assume, as has been done for Babylon, that barley is more a luxury good (with thus a higher income elasticity than dates), an increase in silver will increase the prices of barley less than for dates.

IV. Comparing purchasing powers in different regions and over time

We can apply this model on the differential purchasing power of silver in different regions and time periods. Unfortunately, as outlined in the introductory paper, we do not know for sure whether in the Hellenistic period the shekel was a real weight measure of 8.33 grammes of silver or did actually represent 2 drachmas. In other words, were the coins weighed or counted?[6] If the later is true, the silver content and weight of the "shekel" was reduced over time. There is some evidence that the latter is the case. One of the commodity price lists is extremely helpful in this issue, Slotsky/Wallenfels 2009, p. 83-97, text 6 r. 12'- 15'. It gives two distinct exchange values of barley (for two shekels of silver) for month III 175 SEB = 27 May – 25 June 137 BC: 2 *pan* 2 *sut* (= 84 litres) in staters of Demetrius and 2 *pan* (= 72 litres) in staters of Arsaces.[7] Slotsky and Wallenfels make the interesting observation (2010: 94, n. 65): "The increased purchasing power (+6%) of the Demetrius staters is almost identical to the greater average weight of silver tetradrachms minted at Seleucia on the Tigris by Demetrius II (+6.7%) over those of Mithradates." In other words a shekel of Demetrius was valued higher than a shekel of Mithradates, because its weight was higher. The document refers to the time shortly after the abortive attempt of Demetrius in 138 BC to reconquer Babylonia from the Parthians. In his short reign a few months he apparently was able to introduce new coins, which had a higher weight than the Parthian coins.

It thus appears that the shekel was referring to coins (at least at that time) rather than pure silver and that the share of silver in the coins (and their weight) changed over time. Fortunately we do have some information on the size and silver contents of the coins. We know that until Alexander the Great the uncoined silver usually consisted of 87.5% silver (1/8th alloy)[8]. The coinage introduced in Asia by Alexander the Great shows in general a silver content well above 90%. It was not until the first century that serious and systematic debasements of silver coinage took place in Syria and Egypt.[9] Weight is another story. The

[6] We assume that the shekel as mentioned in the astronomical diaries did not relate to pure unalloyed silver, but on the silver as it appeared on the market, hence including the alloy.
[7] All Parthian kings had the throne name Arsaces.
[8] For a detailed discussion of the silver see Jursa 2010: 474-490, discussing previous literature, in particular Vargyas 2001: 13-51.
[9] Mørkholm 1991: 5.

silver tetradrachm at the time of Alexander the Great was about 17.28 gr. and was slightly reduced to 17.20 by 300 BC.[10]

About 172 (reign of Antiochus IV) the weight of tetradrachms from Antioch was reduced to 16.80 grams and this remained the standard in the second century. By c. 105 BC it was reduced to 16.30 gr.[11] A similar decline is attested for the Parthian coins. Under the reign of Mithradates I (165-138/2[?]) the purity remained well over 90%, but under his successors it declined to about 88% under Mithradates II (121-91) and to about 75% in the mid first century BC. The weight of the coins also declined. The silver tetradrachms minted at Seleucia on the Tigris by Mithradates have 6.7% less weight than the Seleucid ones minted by Demetrius II, who temporarily occupied Babylon in 138 BC.[12] In sum, we can get the following silver value of the shekel:

Table 1: silver content of the shekel

	Grammes of silver/shekel
<-331	7.29
-250	7.25
-200	6.42
-150	7.04
-120	6.97
-100	6.79
-80	6.53
-60	6.29

Source: http://parthia.com/parthia_stats_gordus.htm; Mørkholm 1991: 5; Le Rider & De Callataÿ 2006: 29-31.

In this table the reduction of silver content and weight are both incorporated.

[10] In Babylon, however, for a short period tetradrachms were struck at a lighter weight. Satrap Mazaios in Alexander's time and Seleucus I struck coins (lion staters) which better conformed to the local shekel standard (cf. Houghton, Lorber 2002: 44). Somewhat mysterious is the remark in a number of texts that payments were in shekels to be paid in staters "according to the rate/counting of Babylon" (*manûtu ša Babili*). Tim Doty (1977: 77) suggests that it "may refer to a rate of exchange fixed at Babylon between the Babylonian units of payments (minas and shekels of silver) and the Greek coins in which the payment was actually made. It is just possible that it may refer to coins struck at the Seleucid mint at Babylon."

[11] Mørkholm 1991: 6.

[12] Slotsky / Wallenfels 2009: 94, n. 65.

The purchasing power is reported in Table 2. Up to ca. 1200 AD the purchasing power looks to be more or less constant, circling around 5 litres per gramme of silver. Clearly, there

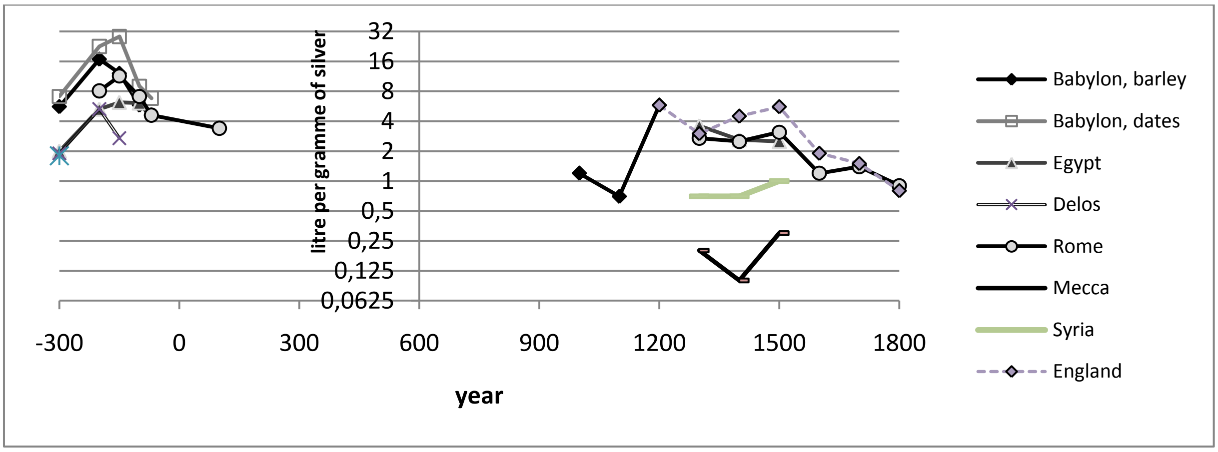
Table 2: litre of grain per gramme of silver in the Euro-Mediterranean region, ca. 300 BC-AD 1800

	liter wheat per gramme silver									
	Babylon		Egypt	Delos	Athens	Rome	Florence	Mecca	Syria	England
	barley	dates	wheat	barley	wheat	wheat	wheat	wheat	wheat	
-300	5.6	7.1	2.0	1.9	1.8					
-200	16.8	22.6	5.3	5.3		8.1				
-150	12.1	28.5	6.2	2.7		11.4				
-100	5.8	9.0	6.1			7.1				
-70	4.6	6.8				4.6				
100						3.4				
1000	1.2									
1100	0.7									
1200	5.8									5.8
1300			3.6			2.7	1.9	0.2	0.7	3.0
1400			2.6			2.5	4.4	0.1	0.7	4.5
1500			2.5			3.1	3.4	0.3	1.0	5.6
1600						1.2	1.1			1.9
1700						1.4				1.5
1800						0.9				0.8

Source: Vargyas (2001); Von Reden (in press); Van der Spek (in press); Rathbone (in press).

are some deviations from this general pattern. First, in Delos and Athens the purchasing power seems to be lower on average. One suggestion may be the high transport costs: both Athens and Delos depended strongly on imported grains. This means that transport costs came on top of the price, hence lowering the purchasing power of silver in terms of grains. Second, between AD 100-1200 it seems that purchasing power on average was also lower, even

Figure 1: log 2 litre of grain per gramme of silver in the Euro-Mediterranean region, ca. 300 BC-AD 1800



Source: Table 2

though this is hard to prove. Nevertheless, Scheidel (2010) also found that grain wages were considerably lower in those periods. Third, it seems that in Babylon between ca. 200 and 130 BC the purchasing power was considerably higher than average even though also in Rome and Egypt purchasing power seems to show some upward trend in this period.

For the period after ca. 1300, estimates are reported in Table 3. We reported the purchasing power of silver for three periods: 1360-1550 (before the influx of silver), 1650-1800, and 1800-1900. For the first two periods we also reported the rank of each city which allows us to see if the rank changed between the first and the second period with the influx of Spanish silver. For the third period we do not provide ranks, since we have too many missing observations. The most remarkable finding is that there is a clear reduction in purchasing power between 1360-1550 and 1650-1800 period and a further decrease after 1800. This is

Table 3: litre of grain per gramme of silver in Europe, ca. 1360BC-AD 1900

land	plaats	1360-1550	rank 1360-1550	1650-1800	Rank1650-1800	1800-1900
Poland	Krakow	21.78	1	8.27	1	
Austria	Vienna	6.29	2	2.41	3	1.16
Germany	Frankfurt	6.21	3	1.16	18	0.34
France	Strasbourg	5.59	4	1.99	5	1.08
UK	England	4.76	5	1.41	11	0.86
Germany	Wurzburg	4.69	6	2.03	4	
France	Toulouse	4.41	7	1.68	9	
UK	Exeter	4.18	8	1.27	16	0.58
France	Tours	4.14	9	1.35	15	0.91
Germany	Munich	3.84	10	1.96	6	
Netherlands	Amsterdam	3.28	11	1.69	8	1.11
Netherlands	Utrecht	3.28	12	1.64	10	
France	Douai	3.27	13	3.08	2	
France	Valence	3.24	14	0.96	20	
Spain	Madrid	3.22	15	1.40	12	
Spain	New Castile	3.22	16	1.40	13	
France	Paris	2.92	17	1.37	14	1.07
France	Grenoble	2.75	18	1.76	7	1.26
Netherlands	Leiden	2.30	19	1.26	17	
Spain	Barcelona	2.14	20	1.09	19	0.59

Source: Allen-Unger dataset on grain prices (http://www.gcpdb.info/)

true for all regions. Probably the main decrease must have taken place in the 17th century given there is no statistically significant difference in purchasing power in the pre-1200 period and the 1360-1550 period.

In sum, we found that the purchasing power is more or less constant up to the 16th century and declining afterwards. There are a few examples, though with different purchasing powers be it lower (Delos and Athens) or higher (Babylon between 200 and 100 BC). After the 16th century the purchasing power declined with no apparent pattern: all countries exhibited an about equal decline in purchasing power of silver. The question is how these patterns can be explained. In the next section we discuss Antiquity and in section 6 we discuss the early modern period.

V. The amount of silver in the Babylonian economy in a Mediterranean perspective

Let us start with the purchasing power in antiquity. Not much difference apparently existed between Rome, Egypt and, in general, Babylon. Only Athens and Delos a bit higher, possibly because imports made unit value of wheat higher.

Egypt is a special case as from late 3rd to late 2nd century BC payments were actually made in bronze coins and not in silver. It seems that the Ptolemaic coinage decree, which ordered that foreign coins (tetradrachms 17.20 – 16.80 g.) had to be converted into the Ptolemaic tetradrachm (14.3 g. by 295 BC) at the rate 1:1 (cf. Von Reden 2007: 43-8). Obviously this was done to reach an increase of silver and gold influx, but the reverse was apparently the case. The silver shortage became so severe that actual payments were done in bronze coinage, which were subject to a growing inflation, at least in bronze coinage.[13] Von Reden (in press) argues that in the official silver standard the prices remained remarkably stable, but this may be misleading. Actually it is difficult to establish the purchasing power of silver, as it was out of circulation. Bad money had driven out good money.[14] At the return of the silver in currency about 130 BC, the purchasing power of silver is not much deviating from the earlier periods.

When we look at the same period in Babylon we see that, as outlined in the previous Section, the purchasing power of silver for foodstuffs is very high, especially in the second century. The figures may be somewhat biased by a few extreme outliers, as can be seen in the table below. In these years one shekel of silver (containing perhaps c.10 % alloy) could buy the following amount of barley (in litres):

[13] Von Reden (in press), "Price Fluctuations in Babylonia, Egypt and the Mediterranean World, third to first centuries BC."
[14] Von Reden interprets the coinage decree as a response to Gresham's law (Von Reden 2007: 43), but it did not help.

Table 4: litre of barley per shekel in Babylon, ca. 190 to 164 BC

Julian month	*Year BC*	*Litres of barley per shekel*
May/June	190	288
October/November	190	270
October/November	188	390
August/September	166	372
Beginning of October	165	354 (?)
End of October	165	378,5
April	164	96

These prices are extremely low, when you know that an ideal exchange value was 180 litres and 120 litres was the midpoint in the Hellenistic period. They also show that prices could suddenly rise (April 164).

Several of the jumps in prices have been attributed to changing amount of silver in circulation. For example, Pirngruber in his paper (this conference) suggests that the low prices (hence high buying power of silver) of 190-188 are due to the enormous war effort of Antiochus III against Rome and the subsequent defeat with the required indemnities to the Romans and the low prices of 166-165 to the outrageous festivities of Antiochus IV at Daphne in 166 BC. The sudden high price can be explained by the arrival of Antiochus IV with his army, ready for a campaign into Iran (Van der Spek 1997/8: 173-4; Antiochus died in December, however. His corps was brought to Babylon or Seleucia. Cf. Pirngruber – this colloquium). So it seems that the fact that a lot of silver left the country led to a high purchasing power of the silver that was left in Babylonia. Indeed, this flight of silver from Babylon can also be attested differently: if we look at the distribution of coins, especially to the coins issued in Seleucia on the Tigris, we see that most of the coins ended up in Syria and Asia Minor (Van der Spek 2004; Pirngruber, this workshop).

It is difficult to estimate the amount of silver in circulation in Babylonia. There are estimates for the quantity of coins struck in the Hellenistic period in general. F. de Callataÿ (1993; 2005) calculated that in the Hellenistic Greek world c. 3,000 tons of silver and 300 tons of gold were in circulation. In total value this amounts to 6,000 tons of silver, if the silver: gold ratio is conveniently set at 1:10. Leandre Villaronga calculated 200 tons of silver coinage having been struck in the Iberian peninsula and Georges Depeyrot arrived at 1000 tons of *denarii* for the Roman republican period (first half of the first century BC). Another major result was the conclusion that 1000 tons of silver (out of 3000) was brought to Rome in the course of the conquering process (De Callataÿ 2005: 73-4). De Callataÿ adduces estimates of Richard Duncan-Jones (1994: 170) of a production of c. 880 tons of coined gold and c. 5,766 tons of coined silver. These figures can further be compared by estimates for later Antiquity, the Middle Ages and Early modern times (Depeyrot 1991; 1995-6) [*non vidi*].

But we can go one step further for Babylon. We can use the model as outlined in Section 3 to make estimates iof the trend of silver in circulation over time using an unobserved component model (see for example Commandeur-Koopman (2007)). In our model, the underlying trend of price movements is affected primarily by the amount of money. This allows us to estimate the development of the amount of money over time in Babylon using the price information. The state-space method is not sensitive to the presence of missing data, so it is an especially useful tool in historical data analysis.

For the available six commodity price series (barley, dates, cuscuta, sesame, cress, and wool) we found the local level model the most applicable. The state-space representation is the following:

$$\begin{aligned} \ln P_t &= \mu_t + \varepsilon_t \\ \mu_t &= \mu_{t-1} + \xi_t \end{aligned} \quad (11)$$

where the first equation is called the observation or signal equation, while the second is the state equation. Both ε and ξ are normally and independently distributed random variables

Table 5: state space model of the 6 products in Babylon

	Barley	cress	dates	cuscuta	sesame	wool
no of obs	535	359	484	324	388	335
R-squared	0.787	0.751	0.737	0.866	0.797	0.855
normality stat	186.68	426.65	724.35	146.6	434.5	314.9
normality p-value	**2.9E-41**	**2.26E-93**	**5.1E-158**	**1.47E-32**	**4.46E-95**	**4.17E-69**
Homosc. test	0.88018	2.011	2.29	0.672	3.06	0.763
Homosc. test p-value	**0.799623**	**0.000107**	**1.6E-07**	**0.978068**	**5.72E-10**	**0.918287**
Durbin Watson	2.12	1.94	1.87	1.91	2.03	1.92
q	24	24	24	24	24	24
r(1) (ACF at lag 1)	-0.062	0.032	0.067	0.043	-0.016	0.04
r(q) (ACF at lag q)	0.027	-0.0006	-0.021	-0.0104	-0.035	0.007
critical value of the ACF at 5%	0.086468	0.105556	0.090909	0.111111	0.101535	0.109272
Q(q)	80.34	85.64	240.12	65.07	154.81	31.89
Q p-value	**5.37E-08**	**7.5E-09**	**1.49E-37**	**1.19E-05**	**4.21E-21**	**0.129744**
state vector at the end						
level	**3.42**	**5.19**	**3.06**	**1.73**	**5.12**	**0.28**
level p-value	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
variance of level component	**0.024**	**0.024**	**0.023**	**0.016**	**0.022**	**0.008**
p-value of seasonal effects	**0.000**	**0.791**	**0.434**	**0.454**	**0.729**	**0.943**

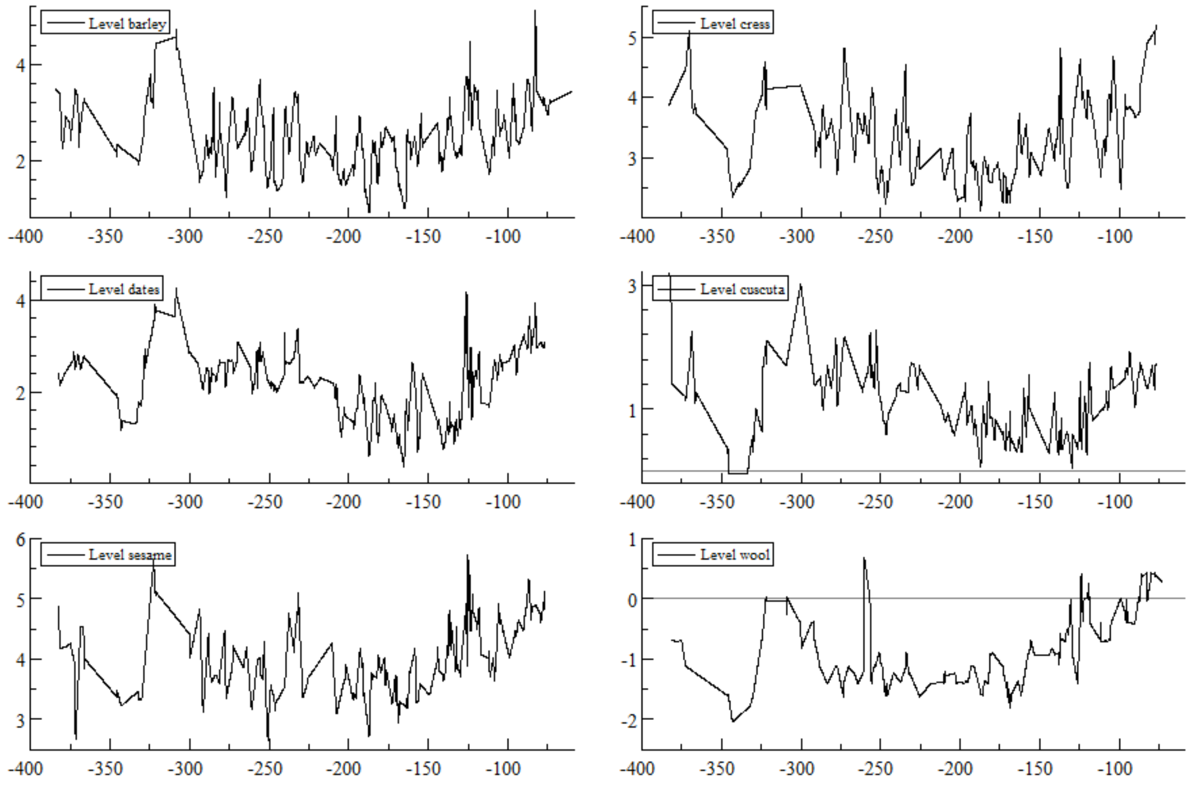
(disturbances).[15] The results from the estimation are given in Table 5.[16]

The estimates of the smoothed states (levels) are the following:

[15] In state space methodology, unlike in classical regression analysis, the unknown parameters to estimate are the disturbances. It is possible to find an equivalence between an ARIMA(0,1,1) model and the local level model described as (10), so the stationarity of the price series is not a requirement in state space modelling. Another great advantage of state space modelling is that it is not sensitive to missing data. The reason lies in the estimation method: the state (μ_t) is estimated by a Kalman-filter based on all past information. If the next observation is not available, the Kalman-filter can fill in the missing value simply by forecasting it form the past observations. Also we can separate the seasonal effects (in all cases deterministic seasonal effects proved sufficient, showing that the relative effect of seasonality remained the same over the whole period).

[16] Unfortunately, even the best fitting basic model did not result in a residual with the expected properties: the normality is always rejected at 1% (which is less of a problem), but in case of cress, dates, and sesame even the homoscedasticity can be rejected. Also, even though none of the statistics finds a first order autocorrelation (DW, r(1)) and not even at higher lag (r(q)), the Ljung-Box test (Q-test) rejects the null hypothesis at 1% that none of the first 24 ACF parameters are different from zero. Still as we chose the best fitting model, a further improvement is not possible. We did not experiment with removing outliers (that may be responsible for the above mentioned problems) since we did not wish to affect the trend by any selective choices of outliers.

Figure 2: local level component of lnprices



The estimated levels (μ) differ by product. This is, however, to be expected as equation (9) and (10) already show that the effect of silver on the change in prices may be different for each product.

After having interpolated the price series of the six products in Babylon, we have to calculate an index of the amount of coins in circulation. As shown by equation (9) and (10), the growth of *M* is a common component in all equations with changing prices. Therefore, in order to estimate *M*, we apply a fixed effect panel specification as follows:

$$\mu_{it} = c + \eta_i + \gamma_t + u_{it} \quad (12)$$

where η_i are the good specific effects (dummies for each crop) and γ_t are year dummies. Based on (9), it is straightforward that:

$$\gamma_t = \phi_i \ln M_t \quad (13)$$

where

$$\phi_i = \frac{\gamma_i \alpha_j - \alpha_i \beta_j}{\beta_i \beta_j - \gamma_i \gamma_j} \quad (14)$$

In order words, the price of each product depends on the value of *M*, but the coefficient differs by product. Unfortunately, it is not possible to estimate product specific time dummies (it would require NxT regressors). However, if we add dummies for all six products, the year dummies in a fixed effect regression will capture the common trend in all products, i.e. the weighted average of the phi. This, however, only works when the relation between the growth of *M* and the growth of average prices is exactly 1 (this would mean that equation 13

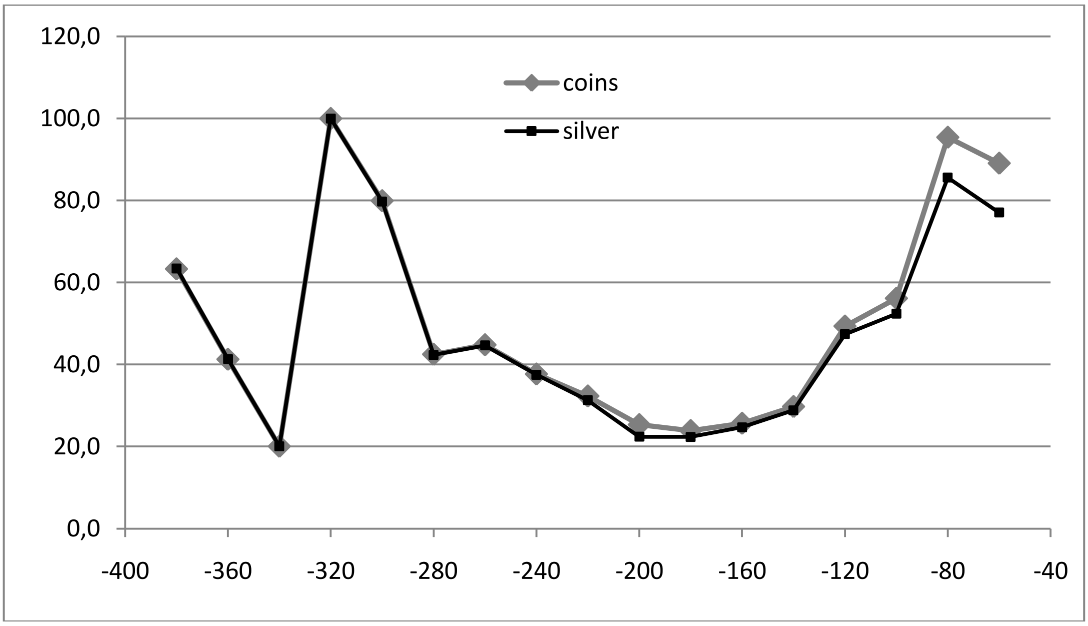
Table 6: panel regression

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.083584	0.009054	230.1272	0.0000
Fixed Effects (Cross)				
BAR--C	0.406250			
DAT--C	0.125000			
CRES--C	1.281250			
MUS--C	-0.968750			
SES--C	1.843750			
WOOL--C	-3.093750			
R-squared	0.958189	Mean dependent var		2.083584
Adjusted R-squared	0.949204	S.D. dependent var		1.733010
S.E. of regression	0.390586	Akaike info criterion		1.117116
Sum squared resid	233.5650	Schwarz criterion		2.097517
Log likelihood	-709.4765	Hannan-Quinn criter.		1.478412
F-statistic	106.6444	Durbin-Watson stat		0.282563
Prob(F-statistic)	0.000000			

Note: time dummies are not reported

simplifies to $\gamma_t = lnM_t$). This is an acceptable assumption if we assume the neutrality of money in the long-run, i.e. a monetary expansion should increase only the prices with a factor of one in relative terms (that is the elasticity of average price with respect to *M* is one). Indeed, some experimenting with plausible elasticities for several products seems to result in an average value of 1. Therefore, the time dummies will be unbiased estimators of lnM. The regression is reported in Table 6. A unit root test confirms that the residuals from this regression are stationary, so we do not have a spurious regression here. Once we take the exponential of the year dummies (not reported here), we obtain the estimates of the amount of money in circulation (Figure 3). This only shows the money in

Figure 3: Index of money and silver in circulation, ca. 385-64BC (330BC=100).



circulation, not the silver in Babylon. The pattern does not look implausible: a large increase in coins when Alexander the Great entered Babylon in 331 BC and opened the Persian treasury and pumped almost 5000 tonnes of silver in the market. Apparently, though, the amount of coins had reduced around to average levels around 295 BC, which lends support to Aperghis' claim that a lot of coins moved away from Babylon with the soldiers. Only after 180 BC we see a gradual increase in the number of coins again, which can be explained by a lesser silver content and, hence, increasing prices (more coins needed to be paid for the same amount of grain).

As pointed out in Section IV (Table 1) though, the silver content changed slightly over time as did (to a limited extent) the weight of the coins. Therefore, we have to multiply the numbers from Table 1 with those for coins as reported in Figure 3 to get an index of silver in circulation in Babylon (also reported in Figure 3).

We indeed find that the opening of the Treasure led to a great increase of silver which, however, soon moved out of Babylon. Up to 124 BC, however, the amount of silver in circulation remained almost stable and only increased afterwards. It is thus clear that silver became scarcer in Babylon between ca. 200 and 140 BC. As far as we know, the scarcity of silver did not lead to the introduction of a bronze standard in Babylonia (perhaps temporarily only in 274 BC). It also did –probably- not lead to an influx of silver which one would expect in an integrated market. The low prices and the high purchasing power of silver and the remaining volatility seem not to be corrected by market integration. Factors are inadvertent policy of the state (expenditure abroad for armies and luxury), good and bad harvests and perhaps climate. The low prices were certainly determined by local factors like good weather and water supply. The diary of Augustus/September 169 BC adds: "very good barley". Nevertheless the economy of Babylonia remained open enough to be in line with the rest of the world and could retain the silver standard. The difference with Egypt in this respect is remarkable and may be a point of discussion at the colloquium.

The rise of Rome contributed to a drain of silver to the west, due to Roman successes in wars with the accompanying booty and tribute, but also the growth of the city of Rome. As mentioned above, an estimated total of 1000 tons of silver was brought to Rome, i.e. 1/3 of the total silver production. Rathbone observes that Roman warfare in the Eastern Mediterranean is probably the best explanation for the high wheat prices attested on Delos in 190, 178, 174 and 169 BC, because the *publicani*, who made it their base, stayed there between the wars (Rathbone, in press). By the late second century the price of wheat at Rome had doubled. Probably the price had been rising through the second century, maybe with a spurt due to the coinage reform of 141/0 BC. Its basic cause was probably the massively increased monetary wealth of Rome and Italy from the profits of imperial expansion and also increased monetization (Rathbone, in press). The expansion of Rome must have contributed to a greater connectivity in the Mediterranean world.

VI. Silver in the late medieval and early modern period.

For the period after antiquity, the purchasing power is difficult to analyse because the streams of silver become bigger. Roughly, one may say that the purchasing power remained stable until ca. 1600 and declined afterwards when the Spanish silver overflowed the European markets. However, the ranking of each region remained the same. This suggests that silver flows did spread across Europe such that every country managed to reduce the purchasing power of silver.

How can we test this? We do have little data on trade before 1800, even though Persson (1999) and Jacks et al. (2011) have shown the markets to be relatively integrated. Fortunately, we can use the method proposed by Földvári and Van Leeuwen (2011) who calculated market efficiency by filtering out the expected volatility. Hence creating a measure of how markets react to unexpected shocks. They define the underlying reasons for increasing market efficiency as storage, trade, technology and consumption. Hence, flows of silver by trade are included in this measure.

Below two figures report the results. In 1360-1550 we do not find a significant trend in the data: no matter the level of market efficiency, the purchasing power remained almost the same everywhere. This is also the same in antiquity where, as we already concluded, purchasing power was not significantly different from the period 1360-1550.[17] However, this

[17] Pairwise correlation is either -0.34 (0.02 p-value) or -0.14 (0.34 p-value), depending on Poland.

Figure 4: Market efficiency versus litres of wheat per gramme of silver, 1360-1550

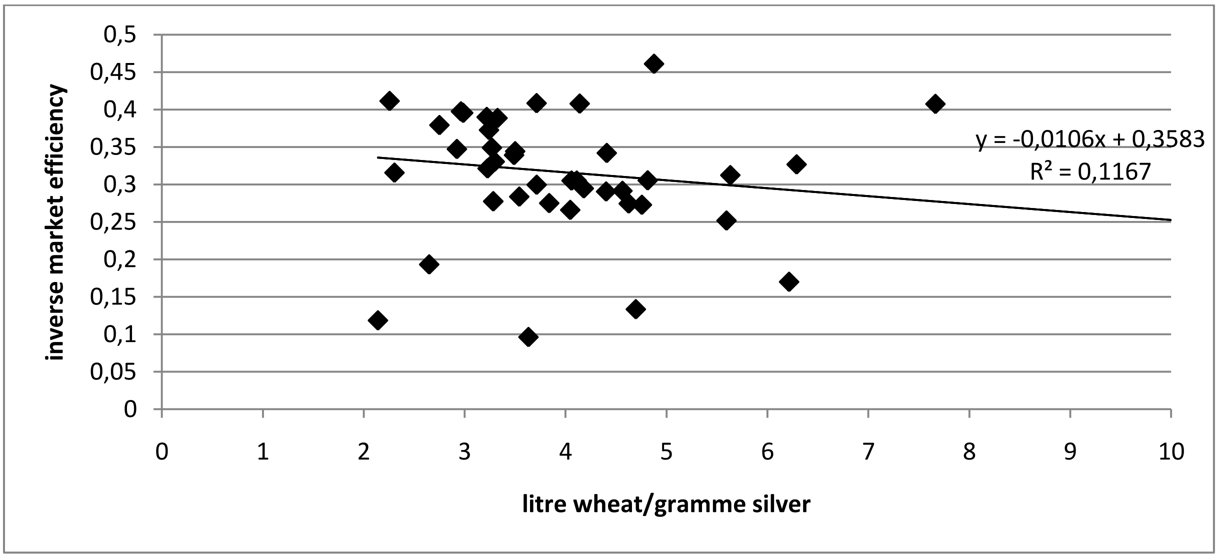
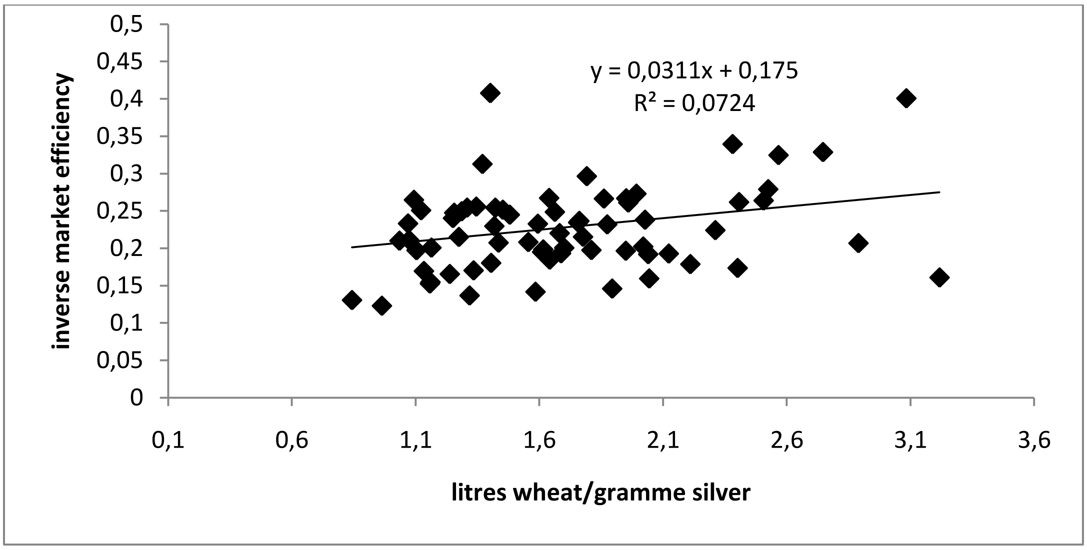


Figure 5: Market efficiency versus litres wheat per gramme of silver, 1650-1800



changed after 1650. Figure 5 clearly shows a positive correlation of 0.27 (0.02 p-value), i.e. the higher the market efficiency, the lower the purchasing power. How can we explain this?

It is first important to look at which countries had a relatively high market efficiency (and low purchasing power) after 1650. The countries were Sweden, Portugal, and Italy. On the other end of the spectrum we have England, Denmark and Spain with a low market efficiency and high purchasing power. Most other countries are in between.

This division seems to be indicative of income and increased international trade. Indeed, for the pre-1700 period, trade could take place also in luxurious goods. Hence, purchasing power was less dependent on staple goods. This changed after ca. 1650 (see O'Rourke and Williamson 2002) when the first wave of globalization set in. Van Leeuwen Foldvari and Van Zanden (this workshop) found that the richer (industrial) countries after 1650 had generally the less efficient markets. Indeed, they less and less produced their own staple crops. This suggests that the poorer, often more agricultural based, countries had more efficient staple production. Indeed, it can hardly be a surprise that the Polish market (which produced grain) was at least as good in coping with unexpected shocks as was the Dutch one (which imported grain from Poland). However, for Holland it not only meant a higher share of imported staples and thus a relatively higher price (and lower purchasing power) because of added transaction costs, but also flowed silver more to those countries with a larger industrial sector (exports industrial products). The latter situation caused an increase in silver in circulation in those economies which (according to section 3), increased the price of staples and reduced the purchasing power of silver.

Consequently, those countries with less efficient markets for staples (the industrial countries) after 1600 saw their purchasing power decline faster than the non-industrial countries, causing a negative relationship between market efficiency and purchasing power. There is one offsetting effect though. If there is more silver available, then, as shown in section 2, it will also be distributed unevenly over the different goods. Given the standard assumption on elasticities of industrial products (higher income and own price elasticity), the input of silver will lower the prices of industrial products and staple products (but more of industrial products). Hence, for staples, we expect prices in industrial countries for staples to rise slower due to the input of silver than without industrial goods (hence, the purchasing power would be higher). Obviously, the over-all purchasing power is lower in those countries with lower market efficiency, hence the inflow of silver was bigger than the offsetting effect of increasing elasticities of industrial products.

VI. Conclusion

It is interesting to look at the purchasing power of silver for staple products from Antiquity till the industrial revolution since it may tell us something about the flows and uses of silver. We developed a model in which we show that an increase in silver may lead to different degree of price rises for different products. Then, we compared the purchasing power for several regions. We found no substantial difference in antiquity, except for Athens and Delos, which were dependent on imports. Another exception is Babylon around 200-100 BC.

Several authors have argued that there had been a drain in silver from Babylon in that period. We applied our model to calculate the amount of silver in Babylon and find no shift between 200 and 100 BC. Hence, the drain in silver of that period may be at least partially responsible for the increased purchasing power. Likewise, the increase in silver after 140 BC may explain the rise in prices. The fact that the goods have different elasticities accounts for the fact that dates showed a stronger decline in prices than barley as argued in Section 3.

For the later period, we do see a general reduction in purchasing power after ca. 1600. This may be caused by the influx in silver. Testing for market efficiency, we find that only after 1600 there is a negative relation between market efficiency and purchasing power: the higher the market efficiency, the lower the purchasing power. Higher market efficiency was largely in poorer, agricultural regions, which explains the higher purchasing power of staples. Furthermore, in industrial countries was a bigger inflow of silver due to exports of industrial products. Third, the elasticities are generally higher for industrial goods, suggesting a lower effect of silver on the price of staple goods as well (and hence a higher purchasing power). However, the inflow of silver must have been much bigger as to offset this effect.

In sum, we found that the (lack of) silver had a profound impact on the purchasing power. 2nd century Babylon and 17th century Europe are cases in point. Second, the flows of silver were at best hampered in Antiquity as we could see by the high purchasing power in Babylon and the lack of silver in Egypt. This may partly be caused by the focus on trade in luxury products as opposed to staples that dominated up to the 16th century. Yet, despite the lack of flows of silver, the economies were relatively persistent in their purchasing power. Third, when comparing our series with indicators of market efficiency, we find that a high purchasing power has no relation with market efficiency before ca. 1650. However, after ca. 1650 a high level of market efficiency corresponds with a higher purchasing power. This is caused partly by increasing trade in staples, which, fourthly, also decreases price volatility (see for example Jacks et al, 2011).

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