Comparing per capita income in the Hellenistic world: the case of Mesopotamia[1]

Peter Foldvari (University of Debrecen) and Bas van Leeuwen (Utrecht University/ Free University/Warwick University)

5 July 2010

In the past literature, GDP growth between ca. 1 CE and the late middel ages was considered non-existent or even declining. Recently, with a revived interest in historical national accounting, the late medieval figures have been revised upward largely because of ioncreased shares of manufacturing and pasture. Leaving Ancient GDPs unaltered would thus imply an increased economic growth in the first milennium. Yet, together with the increased attention for the late medieval period, also present estimates for the Ancient period have been revised upwards, essentially leaving the changes in economic development over time unaltered. The focus so far has been on Italy though, which as is argued in the literatire, was quite unrepresentative with a high share in manufacturing during the period around 1 CE. We therefore estimate a new per capita income for an agrarian society in the medeterranean: Mesopotamia. At the same time, we try to explain why its per capita income deviates from that of Rome by looking at the two main reasons for higher income identeified in the literature: manufacuring and pasture.

[1] This paper is part of the project *'On the efficiency of markets for agricultural products in pre-industrial societies: The case of Babylonia c. 400 – c. 60 BC'* funded by the Netherlands Organisation for Scientific Research (NWO).

1. INTRODUCTION

Scientific interest has significantly grown in a comparative research on the standards of living and income per capita of pre-industrial societies. Where previously no surprises were thought to be found, mostly due to an overly simplified view on the Malthusian trap, now significant differences and previously unbelievably high income levels are found.[2] Where people in ancient societies were thought to have completely different ideas on economy and society than ours (see the substantivist-modernist debate), now working markets and the effects of exogenous shocks are found (see Temin, 2002).

Two main conclusions can be drawn from this new branch of quantitative studies. First, it seems that per capita income in both 1 CE and 1000 CE were significantly higher than the ca. 500 GK dollars estimated by Maddison (2003). Lo Cascio and Malanima (2009) revise Maddisons's estimates for the Roman Empire to find that the per capita income was around 1000 G-K USD at 1990 prices (Maddison estimated 570 dollar), and for Italy they arrive at an even higher per capita income of 1400 G-K dollars.

Second, the relative position of the Ancient economies relative to medieval economies remains stable: per capita GDP during the first millennium CE seems to have declined in Italy (Maddison, 2007; Lo Cascio and Malanima, 2009). This finding is in need of explanation though. What we know about the income in Ancient economies is based on estimates for mainly Rome, while medieval economies, besides Italy, are represented by Holland, Spain, and England. Obviously, these economies are significantly different in terms of economic structure and this may have a relation with the observed evolution of income. The only regions for which we can observe the income for the whole period is Italy. As mentioned earlier Lo Cascio and Malanima (2009) find that Italian per capita income decreased after the fall of the Empire. This process is above question especially since it is backed by anthropometric evidence. Angel (1984) claims that heights in the Eastern Mediterranean reach their maximum between ca. 200 BCE and 120 CE, a level only seen again after 1500. Such a dramatic decrease in the per capita value added can most likely be a result of a decline in the manufacturing sector, partly as a result of the loss of export markets, and partly due to the contraction of the local market. This is found by Scheidel (2007) as well, who uses the

[2] Several studies have been done for Medieval Europe including Holland, Italy, Spain, between ca. 1000 AD and 1800 (Álvarez-Nogal and Prados de la Escosura, 2009; Malanima, 2009; Van Zanden and Van Leeuwen, 2009; Broadberry *et al.,* 2009), while studies on the Ancient period include the Roman Empire (i.e. Scheidel, 2009; Lo Cascio and Malanima, 2009), Athens (Amemiya, 2007), and Mesopotamia (Bedford, 2007).

number of shipwrecks in the Mediterranean as a proxy of commercial activities and finds that the number of shipwrecks decreases from the 1st century CE on. Yet, this should not be necessarily true for other European economies. The ones more focussed on self subsistence might have been much less affected by the dissolution of the West Roman Empire. Once income is measured in some monetary unit (or through a single product like wheat) one cannot dismiss the possible effect of agricultural structure on these estimates. For example, England around 1300 had a far lower share of manufacturing than Italy, but the pastoral sector was significant enough to increase the per capita income close to the Italian level. The underlying reason can simply be that the same amount of nutritional value is produced with more resources in pasturage than when produced by arable cultivation (Broadberry and Campbell, 2009).

This is why not only it is important to look at the development of GDP, but also at its underlying structure. Since both Rome and Athens had significant manufacturing, we need an estimate for a society more dependent upon arable agriculture like Mesopotamia. This is our objective in this paper. Mesopotamia was a largely agricultural economy with a low share of pasture, low trade, and a relatively low urbanisation.[3] Assuming that either pasture or labour productivity outside agriculture is the source of different GDP estimates, Mesopotamia should have a lower income per capita than Italy/Roman Empire or Athens. Without doubt, the share of pastoral sector increased in Mesopotamia over time and probably so did wool processing manufactures so in later periods a growth in per capita income is possible.

In this paper we use the production approach for Ancient Mesopotamia, cross-checked by the other two approaches (income and expenditure approaches) to arrive at some point estimates of the GDP per capita. In the next section, we will discuss the construction of Mesopotamian income. In Section 3, we then move on to analysing the development of per capita income over the period ca. 400 to 50 BCE. Section 4 then discusses the comparability with other regions. We end with a brief conclusion.

2. CALCULATING MESOPOTAMIAN GDP

Several efforts have been made to "guesstimate" income levels in ancient societies (Hopkins, 1980; Goldsmith, 1984; Maddison, 2003; Milanovic, 2006; Temin, 2006; Scheidel, 2009).

[3] Bairoch (1988, 26.) estimated an urbanization ratio 5% for the region around Ur in 2300 BCE. He assumes that Babylon had a population of 200-300 thousand. If we take the average of his estimate and assume that the nine other major cities had a population of 30 thousand each, and we accept the population estimate of Aperghis (2009) of 4.65 million we arrive at an urbanization rate of 11.2%.

Most of them are based on a feasible version of the expenditure method of GDP estimation. When the expenditure method is used, GDP is usually divided into consumption, investment/savings, public expenditure and, in case of open economies, net exports. Due to the lack of reliable and detailed information on these, however, one needs to rely on some assumptions regarding the minimum consumption that is needed for the population to survive, usually expressed in caloric value, and this is converted into some money or grain equivalent. This gives the minimum value of the consumption. Another set of assumptions is needed about the extent of the rest of the equation.[4]

These methods, rough as they may be, have the likable property that they cross check the GDP with the probable kcaloric consumption per capita. Hence, unless they increase per capita consumption with a certain percentage, they can be seen as some sort of minimum estimates. This is exactly what is done by Bedford (2007, 327). He estimates some sort of minimum per capita GDP for Mesopotamia based on the average price of barley and a minimum consumption per head. Relying on the expenditure side alone yields only a minimum estimate. Therefore, it is important to include GDP estimates from the income side as well as the output side. Since all three methods should result in the same figure for per capita income, this means that each of the underlying data and assumptions in the estimates must be consistent with all others, or else there will be a discrepancy in the outcomes of the three methods.

We start with defining the geographical scope of our estimates. This study focuses on the area of Mesopotamia. This is wider than just Babylonia, covering about what is present day Iraq for the period between roughly 400 and 60 BCE. This period is chosen mainly because of its abundance in price data, while for the earlier period, although less abundant in price data, we have information on wages and even consumption that are important for calculating GDP. There is much discussion about the size of the population. For example, Maddison (2003) sets the population at one million. However, this seems to be an obvious understatement. As Aperghis (2004) shows, tax revenue from agriculture was so high that taxes must have been enormous if really just 1 million people had lived there. In addition, since the area cultivated necessary to support a person in an Ancient society is set between 0.5 and 1 hectare (i.e. Pastor, 1997; Aperghis, 2004), one million people would amount to a minimum of 1 million hectares, only 2.3% of the total area. In the 1950s, with a population of around 4.8 million people, around 10% of the land was effectively used, and it is possible that

[4] Goldsmith assumes 8% for the share of public expenditure in GDP for Rome, while Maddison revised this to 13%.

around 200 BC even more land was available for cultivation (Van der Spek 2008). Hence, if a population of 1 million were true, much fertile land would have been underutilized. Indeed, Aperghis (2004, 36-40) collected available archaeological evidence and arrives to a far higher population in total. Using data mainly from Adams (1981), and Adams and Nissen (1972) he calculated for several survey regions population densities and projected that to the entire regions. In this way, he arrived at estimates for the central Euphrates flood plain of ca. 750,000, for Southern Babylonia, Nippur region, the Diyala region east of Baghdad, the Seleukeia-Tigres area, the South-eastern corner of the Mesopotamian plain, all ca. half a million. Also for the Eastern Bank of the Tigris and Northern Mesopotamia there is evidence that they were fertile and well populated. Adding all data up, Aperghis (2004, 40) arrives at a population estimate of between 4 and 5 million. We have to stress, though, that our GDP figures are not very sensitive to the actual population. Clearly, the total output numbers are related to the population, but since we compare that method with the income and expenditure approach, this will not bias our per capita estimates. The same goes for the rest of our estimates. Therefore, we follow Aperghis (2009) and set the population of Mesopotamia in 400 BCE at 4.65 million.

We can use Aperghis' (2009) results to arrive at a GDP per capita estimate with the production approach. He estimates that the total agricultural output around 300-400 BCE was around 10,000 talents annually (of which 10% being pasture). This number needs to be reduced by the value of intermediate inputs, which is assumed to be 20% of the gross output (based on the 1841 input output table for England [Horrell, Humphries and Weal 1994]). Furthermore we need to make some assumptions regarding the non-agricultural sectors. Since Aperghis (2009) estimates the rate of non-agricultural workers at 40%, we use this to inflate our agricultural output. One may argue that this will overestimate people working in manufacturing since many of those may be having by-employment in the agricultural sector. Indeed, as argued by Adam Smith, the more an economy progresses towards manufacturing, the lower the share of by-employment becomes (Smith reprinted 1976, 15-16). Since Mesopotamia is an ancient economy with a large agricultural sector, one would hence expect by employment to be a problem. However, as shown by Saito and Settsu (2010, figure 2), the importance of by-employment shows an inverted u-curve. If the share of agriculture is very high, this also reduces by-employment. Hence, we may safely assume that in Mesopotamia by-employment is not a serious problem.

Using above assumptions, we arrive at 11200 talents total GDP, or 0.00241 talents per capita. This is equivalent with 8.676 shekel a year, which, if we assume a price of 8.056 shekel per 1000 litre for barley (the median of the sixth century BCE), was enough to buy approximately 1077 litres annually. The caloric equivalent of this is 5665 kcal per day per person, which is far more than the minimum required intake and leaves ground for trade and necessities above food. Bedford (2007) also relied on the production approach when estimated Mesopotamian GDP following Hopkins. Unlike us, he assumed a larger population (5.5 million) and much lower grain prices (1 kur (180 l) = 1 shekel, which equals 5.56 shekel/1000 litres). So he arrives at an agricultural production estimate of 4965 talents, which he increases to 12400 talents as total GDP. This, if we take population differences into account, is about 6% lower in per capita terms than our estimate.

In order to make these estimates comparable to other regions and//or time periods, we have to convert them into a common unit, usually Geary-Khamis (G-K) international dollar at 1990 prices. This is done by using a comparable good, either grain equivalents or gold. The final result, though, depends strongly on if the comparison is made in precious metal or in grain. Lo Cascio and Malanima (2009) demonstrate convincingly that, with the massive inflow of precious metals since the early modern period, gold has got much cheaper relative to other goods. So comparison in gold is bound to yield underestimated G-K dollar equivalents. Using grains seems safer but again a lot depends on whether one uses a single grain (the importance of which may vary by region) or an average price of a bundle (where the weights are often arbitrary). Also the method is sensitive to the choice of base year. Lo Cascio and Malanima claim that this is a source of the underestimation of Roman GDP by Maddison (2007) who relied on the grain prices by Gregory King for 1688, when grain prices were exceptionally low. Using a 20 years average instead, they arrive at their revised estimates at least twice as high as the original.

We follow Lo Cascio and Malanima by converting to 1990 G-K dollar using England as reference. One should avoid using barley equivalents though since tastes were very different in the two societies. While barley was a preferred good in Babylon, it was deemed as inferior to wheat in England. Therefore, we follow Scheidel (2010) who uses a conversion factor of 0.8 to convert barley to wheat in terms of caloric value. Using this, we arrive at 861.6 litre wheat per person annually in Babylon around 500 BCE. The median wheat price in England between 1676 and 1700 was 4.25 shilling per bushel or 0.2125 pound per bushel. One bushel is equivalent with 35.239 litres, so we arrive at a price of 6.03 pound per 1000 litre. If we accept Gregory King's estimates of per capita income of 9.958 pounds, the average

English person could buy 1651 litre of wheat. According to Maddison's estimates this is equivalent with 1411 G-K dollars at 1990 prices implying an exchange rate of 1.17 litre wheat per one G-K 1990 dollar. Hence calculated in wheat equivalents the income per capita in Mesopotamia around 500 BCE was 736 G-K dollar.

We can use the income approach as cross-check. Jursa's (2010) estimates the average wage at 2.5 shekel per month for a male worker, and two-third and one-third of this sum for a woman and a child respectively. We can assume that each household had 5 members, but it is very unlikely that all of them could earn a wage. It is safer to assume a wage per household between 2-4 shekels per month. This yields 4.8 – 9.6 shekels per year per person, which is enough for 596-1192 litres of barley per individual (still potentially supplying them with 3134-6268 kcal per day). This is reasonably close that what we have already found with the production method. Using the method of wheat equivalents, we arrive at an estimate of 477-953 litres of wheat per person per year[5], which can be converted into 407-815 G-K dollar at the exchange rate 1.17 l/$. This is however only the wage bill estimate. A part of the per capita income comes from other factor incomes, like land rents, or even capital returns (however small this could have been, it cannot be ruled out). For an agricultural society it is safe to assume that no more than 10% of the total income resulted from other production factors as land and labour, and it is very likely that labour had a larger share than land rents. Without any certain knowledge of the real proportions we assume here 70% for the labour, 20% for land, and 10% for the rest. Using these estimates we arrive at a per capita annual income 582-1164 1990 G-K dollars. Since we know little about the income generated per households, the income based measure cannot be more accurate. It is noteworthy, however, that if we assume that each household earned 2.5 shekels a month (a full wage for the whole household), we arrive at 728 G-K dollars, which nicely coincides with the production side estimates.

Finally, we can turn to the expenditure approach. For this we need some assumptions about consumption, investment and public spending. Trade could not have been significant, and probably trade was balanced in the long-run anyway due to the usage of silver as currency. As such net exports can be safely taken as null in the long run. Jursa (2010) calculated that on average 76% of the household expenditure was spent on food while the rest on housing and

[5] Scheidel (2010) reports wages in wheat equivalents similar to our lower bound from 321 BCE (1.3 liter a day).

other goods and services. If we assume that a 5 member household had a composition of 1 father, 1 mother, and 3 children, we can estimate an absolute minimum and a convenient calorie intake. An Indian medical report (ICMR, 1958) suggests that a hard working male requires about 3500-4000 kcalories per day, while a woman has a requirement of about 2500-3000 kcal. A child, depending on age and sex requires about 1500-2500 kcal per day, so we can take an average of 2000. In this case the calorie requirement per person per day was 2500 kcal on average. This can be taken as a convenient estimate that is, when everyone is well fed. It is possible to survive on less, say, 2000 kcal per person as well at the price of lower productivity, lower fertility, and higher chance of lethality due to diseases. This is our minimum estimate since much lower intake would not be feasible in the long-run.

If the calorie intake was supplied from barley and dates exclusively (with equal proportions) (price of barley is 8.056 sh/1000 l, dates 7.5 sh/1000 l (Jursa 2010)), one person had to acquire between 190.1-237.6 liters of barley and dates each annually at least, which would have cost 2.96-3.69 shekels per year. This is however only 76% of the total consumption, so finally we arrive at 3.89-4.86 shekels per person. We do not have any data on investments, but since we know that Babylonians managed to erect buildings, resowed their lands, kept animals, and had some farming equipment, they had to save at least a small proportion of their income. This could not have been a significant amount so we set it at 15% of total income at most. We can expect that government had a similar share in total income, so our estimate should be increased by 30%, so that we arrive at 6.4-8.32 shekels per annum. We already found that 8.676 shekel income was equal to 736 G-K dollar at 1990 prices when calculate in wheat equivalent, so now we can use this ratio to arrive at an estimate from the expenditure side: 471-589 G-K dollars. But let us not forget, that this is calculated under the assumption of a minimum calorie intake, so it can be seen as a long-run minimum with a predominantly plant based diet. Once we assume that Mesopotamians consumed 3000 kcalories per day per person (meaning of course that they consumed less kcalories but could afford meat and processed grain (beer) from time to time), we arrive at 707 G-K dollars, which is already reasonably close to the previous estimates.

Again we find a value similar to the other two ways of calculations. We can hence draw the conclusion that the ancient Mesopotamian GDP, in the 5th century BCE, must have been between 700-750 G-K dollars. A word of caution: in this particular exercise we used price data for the 6th century BCE, but there are periods, especially in the 4th century BCE, when much higher grain prices are recorded. This means that the contemporary equivalent of nominal income, expressed in silver, must have exhibited enormous fluctuations.

Our estimate for Mesopotamia is more than the subsistence level of 400 G-K dollars, but less than the estimate for Rome (Lo Cascio and Malanima, 2009) and Byzantium (Milanovic, 2006). Obviously, if one interprets the Malthusian theory of population so that all societies should have the same level of per capita income expressed in some currency unit, these findings are in obvious contradiction with theory. This contradiction is less serious than it seems, though. It rather appears that the average wage was similar in these countries in terms of caloric equivalent, but of course the price of calories might have differed a lot. That is why the production structure of an economy plays a prominent role. Countries with predominantly arable agriculture like Mesopotamia or China could produce a unit calorie considerably cheaper than countries with a considerable pasture, like Spain or England. As such, one expects that even prior to the period of stable economic growth, the level of income when expressed in monetary units had to be higher in countries with more meat consumed (and possibly the agricultural population density was lower there).

3. AN ESTIMATION OF CHANGE SIN PER CAPITA INCOME IN AN AGRICULTURAL SOCIETY: MESOPOTAMIA CA. 400-50 BCE

Now we have a benchmark level of GDP per capita, it is useful to see if this level remained stable over time and or it responded to changing economic circumstances during this 300 year period. This also allows us to compare directly to existing estimates from Athens and Rome that are available for later periods only. Unfortunately, we largely have only price data[6], so we must develop a method to predict developments of per capita income using price data exclusively.

The basic idea behind this method is that people will have different preferences depending on their income level. If they are close to the subsistence level of income their first concern is to ensure they have enough calorie intake to survive and tastes are of no importance. When they are above the subsistence level, however, the pure caloric value of a meal becomes marginal and tastes takes lead in consumer decisions.

It can be shown with a simple model that, with above mentioned assumptions, as a society's income level approaches an absolute minimum level, and the first type of

[6] The data are for Babylon and are derived from Slotsky, 1997; Vargyas, 2001; Slotsky and Wallenfels, 2010. These data are made consistent, extended and made electronically available by Van der Spek (2010). Personal communication.

preferences dominate, the price ratios of the two main foodstuffs will tend to equal the ratio of their calorie content.

In order to make the model manageable we need some further assumptions.

1. We assume that the whole society can be divided into two groups. One with subsistence level of income per capita (ymin), dubbed 'the poor (p)', and a second with a higher income level per person (ymax) referred to as 'the rich (r)'. The share of the two groups in the society is λ and 1-λ respectively. The total income of the two groups are $Y^r = (1-\lambda) y^{\max} N$ and $Y^p = \lambda y^{\min} N$, where N denotes the population.
2. We assume that the group poor has linear preferences, since it maximizes its calorie intake under given budget restrictions, that is: $U^p = c_1 Q_1^p + c_2 Q_2^p$ where U^p is the utility of the poor, c_1 and c_2 denotes the calorie content of the two crops, Q_1^p and Q_2^p are the quantities of the two crops consumed by the poor (barley and dates).
3. The group rich has different preferences, for example Cobb-Douglas type, such as $U^r = \left(Q_1^r\right)^{\gamma} \left(Q_2^r\right)^{1-\gamma}$ the notation is similar to that of the poor in point 2. The parameter gamma is above 0.5 if product 1 is preferred to product 2.
4. We assume that the supply (S_1 and S_2) is fixed. This is necessary to keep the model simple, but it is also a feasible assumption, since we can safely argue that when the actual consumption decisions are made, the supply cannot be adjusted anymore, and also, because changing the production structure in agriculture is a difficult and time-consuming process. Changing the production is of course just one decision that can affect supply, storage is the other. Theoretically, when prices are low, producers could postpone selling their crop, and this would make supply depend on prices even without changes in the production structure. Research on this field is quite conclusive however that storage was not significant in pre-industrial societies and can be safely ignored. Having a perfectly inelastic supply means that demand will determine prices ultimately.
5. Our model needs budget constraints: $Y^r \geq p_1 Q_1^r + p_2 Q_2^r$, $Y^p \geq p_1 Q_1^p + p_2 Q_2^p$, and two equations of equilibrium conditions: $S_1 = Q_1^r + Q_1^p$, $S_2 = Q_2^r + Q_2^p$.
6. We assume that both consumer groups attempt to maximize their utility independently of each other, that is, there is no representative agent or social planner for the whole economy. The choices of the two groups are however interlinked through the prices and supply constraints.

We start with deriving the first order conditions for the utility maximization of the two groups and express the price ratios at the optimal choice:

$\frac{p_1}{p_2}=\frac{c_1}{c_2}$ for the poor and $\frac{p_1}{p_2}=\frac{\gamma Q_2^r}{(1-\gamma)Q_1^r}$ for the rich

We can use these, together with the budget constraints to derive the demand functions:

$$\left(Q_1^p\right)^d=\frac{Y^p}{p_1}+\frac{p_2}{p_1}Q_2^p=\frac{Y^p}{p_1}+\frac{c_2}{c_1}Q_2^p \text{ and}$$

$$\left(Q_2^p\right)^d=\frac{Y^p}{p_2}+\frac{p_1}{p_2}Q_1^p=\frac{Y^p}{p_2}+\frac{c_1}{c_2}Q_1^p \text{ for the poor.}$$

For the rich we get the following demand functions:

$$\left(Q_1^r\right)^d=\frac{Y^r}{p_1}+\frac{p_2}{p_1}Q_2^r=\frac{Y^r}{p_1}+\frac{(1-\gamma)}{\gamma}Q_1^r=\frac{Y^r\gamma}{p_1} \text{ and}$$

$$\left(Q_2^r\right)^d=\frac{Y^r}{p_2}+\frac{p_1}{p_2}Q_1^r=\frac{Y^r}{p_2}+\frac{\gamma}{(1-\gamma)}Q_2^r=\frac{Y^r(1-\gamma)}{p_2}$$

The demand of the two groups can be added, and we can use the equilibrium conditions:

$$S_1=\left(Q_1\right)^d=\left(Q_1^p\right)^d+\left(Q_1^r\right)^d=\frac{Y^p}{p_1}+\frac{c_2}{c_1}Q_2^p+\frac{Y^r\gamma}{p_1}$$

$$S_2=\left(Q_2\right)^d=\left(Q_2^p\right)^d+\left(Q_2^r\right)^d=\frac{Y^p}{p_2}+\frac{c_1}{c_2}Q_1^p+\frac{Y^r(1-\gamma)}{p_2}$$

We can eliminate the Q_1^p and Q_2^p form the above expression by using the equilibrium conditions:

$$S_1=\frac{Y^p}{p_1}+\frac{c_2}{c_1}(S_2-Q_2^r)+\frac{Y^r\gamma}{p_1}=\frac{Y^p}{p_1}+\frac{c_2}{c_1}(S_2-\frac{Y^r(1-\gamma)}{p_2})+\frac{Y^r\gamma}{p_1}$$

$$S_2=\frac{Y^p}{p_2}+\frac{c_1}{c_2}(S_1-Q_1^r)+\frac{Y^r(1-\gamma)}{p_2}=\frac{Y^p}{p_2}+\frac{c_1}{c_2}(S_1-\frac{Y^r\gamma}{p_1})+\frac{Y^r(1-\gamma)}{p_2}$$

Using these we can express the equilibrium prices:

$$p_1=\frac{Y^r\gamma+Y^p}{S_1+\frac{c_2}{c_1}\left(S_2-\frac{Y^r(1-\gamma)}{p_2}\right)}=\frac{(1-\lambda)y^{\max}N\gamma+\lambda y^{\min}N}{S_1+\frac{c_2}{c_1}\left(S_2-\frac{(1-\lambda)y^{\max}N(1-\gamma)}{p_2}\right)}$$

and $p_2=\frac{Y^r(1-\gamma)+Y^p}{S_2+\frac{c_1}{c_2}\left(S_1-\frac{Y^r\gamma}{p_1}\right)}=\frac{(1-\lambda)y^{\max}N(1-\gamma)+\lambda y^{\min}N}{S_2+\frac{c_1}{c_2}\left(S_1-\frac{(1-\lambda)y^{\max}N\gamma}{p_1}\right)}$

It is useful to examine two limiting cases: first when the society is extremely poor and probably at the verge of famine.

$$\lim_{\lambda\to 1} p_1 = \frac{y^{\min} N}{S_1 + \frac{c_2}{c_1} S_2} \text{ and } \lim_{\lambda\to 1} p_2 = \frac{y^{\min} N}{\frac{c_1}{c_2} S_1 + S_2} \text{ that is: } \lim_{\lambda\to 1} \frac{p_1}{p_2} = \frac{c_1}{c_2}.$$

In words, the closer a society gets to the famine level (an absolute minimum level of income) the equilibrium price of products (under the assumptions we mentioned above) should reflect the ratio of their calorie contents.

When a society is better off, the price ratios should rather reflect tastes. This is again easy to show once we take the case when lambda converges to zero:

$$\lim_{\lambda\to 0} p_1 = \frac{c_1 p_2 y^{\max} N\gamma}{p_2 c_1 S_1 + p_2 c_2 S_2 - c_2 y^{\max} N(1-\gamma)} \text{ and } \lim_{\lambda\to 0} p_2 = \frac{p_1 c_2 y^{\max} N(1-\gamma)}{p_1 c_2 S_2 + p_1 c_1 S_1 - c_1 y^{\max} N\gamma}$$

$$\lim_{\lambda\to 0} \frac{p_1}{p_2} = \frac{c_1}{c_2} \frac{p_2 y^{\max} N\gamma \left[p_1 c_2 S_2 + p_1 c_1 S_1 - c_1 y^{\max} N\gamma \right]}{p_1 y^{\max} N(1-\gamma) \left[p_2 c_1 S_1 + p_2 c_2 S_2 - c_2 y^{\max} N(1-\gamma) \right]}$$

, which is, under reasonable parameters, different from the calorie ratios. It can also be seen that now the price ratio depends on the supply of the two goods and the tastes (gamma) as well. We can assume however that tastes are not likely to change quickly in a preindustrial society.

The above model is indicative that, as we get closer to the subsistence level of income, prices should more and more reflect the calorie ratios and less and less the ratio of the quantities supplied. Although this relationship is not linear, we still can approximate it by functional forms linear in parameters.

There are very few historical series which can be used to test the idea and on which we could estimate this relationship. We can use Medieval Holland and England to test if this relationship exists since we need both GDP and prices. For Holland we use the price ratio of wheat and, the less preferred, rye together with the GDP per capita estimates by Van Leeuwen

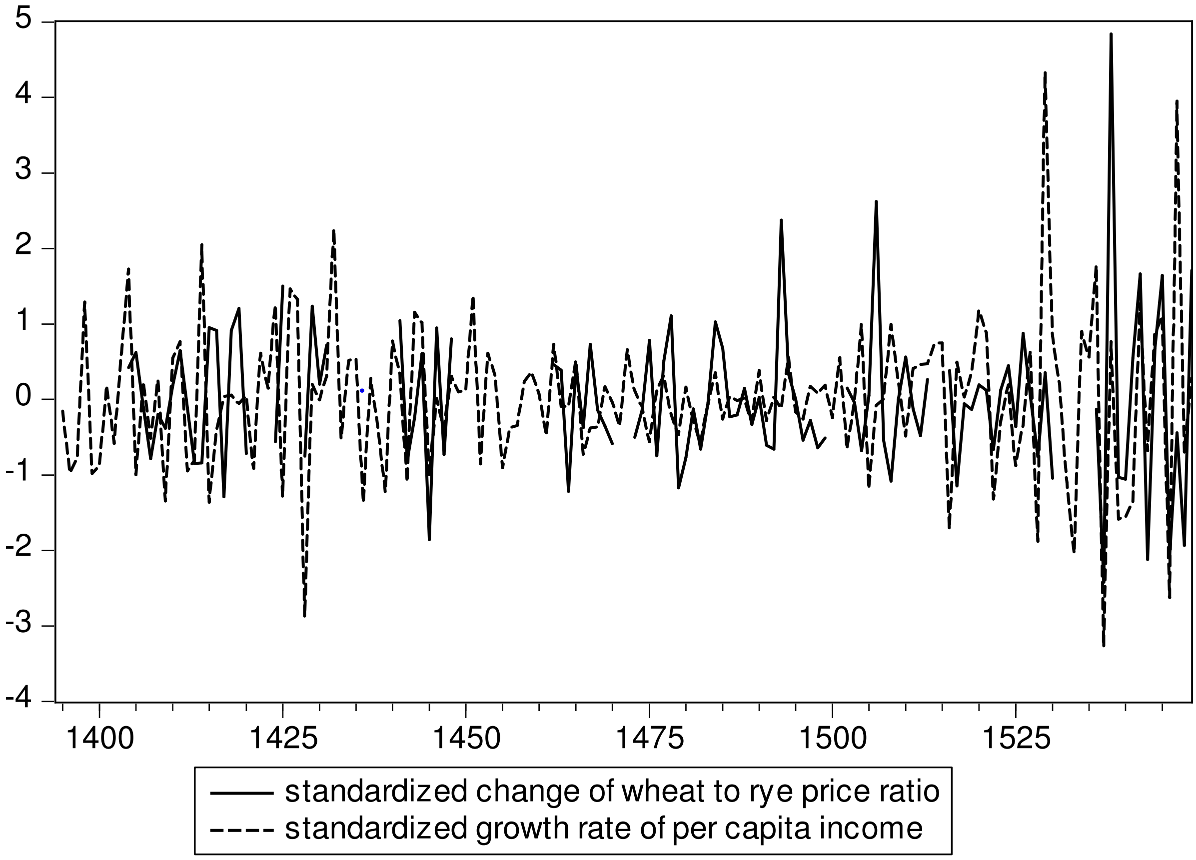

Figure 1. Comparison of the growth rate of the standardized wheat to rye ratio and the standardized per capita GDP in Holland, 1370-1540

Source: Van Leeuwen and Van Zanden (2009); Posthumus (1964).

and Van Zanden (2009). The results are given in Figure 1. As one can see, the cycles show the comparable patterns, hence suggesting that the method works on Holland.

We can do the same for England. Since we have for England not only prices of barley, wheat and GDP/cap, but also the quantities of wheat and barley, we will go somewhat deeper into these estimates and use the resulting parameters for the estimates of per capita income in Mesopotamia.

We have the price and output of two major crops wheat and barley. We used data only until 1429 since the consumption structure changed a lot during the early modern period and the use of barley changed over time. If the relationship we derived above holds in the long run, we should find that the price ratios, the quantity ratios and the per capita income are cointegrated (provided they are non-stationary). This we test with two unit-root tests:

TABLE 1
The unit root test results

series	log of the price ratio of wheat and barley	log of income	log of wages	log of the quantity ratio of wheat and barley
KPSS (H0: stationarity)	1.180 (p<0.01)	1.833 (p<0.01)	1.475 (p<0.01)	1.462 (p<0.01)
ADF (H0: non-stationary)	-8.42 (p<0.01)	-1.640 (p>0.1)	-1.336 (p>0.1)	-4.433 (p<0.01)

The KPSS test seems to indicate that all the three series are non stationary, while the ADF test rejects the null hypothesis of non-stationarity for the ratio of prices and quantities. Since there is no obvious way to decide which results we should believe (even though the KPSS test is usually thought to be superior to the ADF test), we have to turn to a Johansen test of cointegration (where in case the series are stationary, we should find the coefficient matrix be of full rank (3 in this particular case).

The information criteria preferred a VAR model with 3 lags when we used income, and 4 lags when we used the wage index by Allen. The results of the Johansen test are reported in the next table:

TABLE 2
Cointegration test results

	with log of income per capita		with wages	
No. of cointegration vectors (r)	Trace-test	Maximum eigenvalue test	Trace-test	Maximum eigenvalue test
0	95.51 (p<0.01)	56.80 (p<0.01)	78.69(p<0.01)	56.14 (p<0.01)
1	38.71 (p<0.01)	33.45 (p<0.01)	22.56 (p<0.01)	20.03 (p<0.01)
2	9.16 (p>0.1)	5.26 (p>0.1)	2.52 (p>0.1)	2.52 (p>0.1)

Note: The null-hypothesis of the trace-test is that the number of cointegrating relations is r, the alternative hypothesis is that it is 3 (all series are stationary). The hull-hypothesis of the max eigenvalue test is that the number of cointegrating relations is r, the alternative is that it is r+1.

The test indicates the presence of two cointegrating relations, which is a logical finding, since the ratio of output and prices should be interlinked, and so should the ratio of prices be linked with the per capita income.

Using this type of restrictions, we have the following two cointegrating relations (normalized at per capita income or wage):

$$\ln y_t = 1.457 + 6 \cdot \ln\left(\frac{p_t^{wheat}}{p_t^{barley}}\right)$$

t-stat: (8.56) (37.0)

$$\ln\left(\frac{p_t^{wheat}}{p_t^{barley}}\right) = 0.506 - 0.184 \cdot \ln\left(\frac{Q_t^{wheat}}{Q_t^{barley}}\right)$$

t-stat: (17.8) (-10.7)

with wages:

$$\ln w_t = 2.484 + 3.945 \cdot \ln\left(\frac{p_t^{wheat}}{p_t^{barley}}\right)$$

t-stat: (16.3) (17.0)

$$\ln\left(\frac{p_t^{wheat}}{p_t^{barley}}\right) = 0.551 - 0.447 \cdot \ln\left(\frac{Q_t^{wheat}}{Q_t^{barley}}\right)$$

t-stat: (12.6) (-8.21)

For our purposes it is more useful to estimate a single cointegrating vector:

$$\ln y_t = 4.092 + 0.795 \cdot \ln\left(\frac{p_t^{wheat}}{p_t^{barley}}\right) - 0.958 \cdot \ln\left(\frac{Q_t^{wheat}}{Q_t^{barley}}\right)$$

t-stat: (48.7) (4.82) (-10.0)

$$\ln w_t = 3.729 + 1.687 \cdot \ln\left(\frac{p_t^{wheat}}{p_t^{barley}}\right) - 1.009 \cdot \ln\left(\frac{Q_t^{wheat}}{Q_t^{barley}}\right)$$

t-stat: (31.1) (7.11) (-7.03)

That is, in both cases we find the elements of the cointegrating vector of the expected sign. In case of per capita income, the long-run elasticity of income per capita with respect to the price ratio of the two main crops is roughly 0.8.

To apply this approach to ancient Mesopotamia, we use the price ratio of barley and dates both expressed in shekel of silver per 1000l. Existing estimates on the caloric value of barley and dates per liter show that the two crops are very similar in this respect with 1920 and 1928 kcal/l respectively. Based on this, one would expect that if lambda equals one (everyone maximizes calorie intake) the price ratio should be one. Let us not forget however that a part of barley seeds is not directly edible so there is a loss of weight before consumption, and also ancient people were not aware the real caloric value of crops, they only had experience about survival and their perception on which plant alleviates hunger more. Based on this it is more likely that the net caloric value and the perceived caloric value of barley were lower than that of dates, finally leading to a price ration below one. It is reasonable to assume that 20% of the barley's volume was inedible, so the price ratio should be rather around .8. Indeed, this is what we find: between 384 and 60 BCE the average price ration of barley and dates was 1.74 with a maximum 5.2 and a minimum 0.45. The price ratio was below one in 28.8% of the cases. Sometimes the relatively low price of barley can be a result of a supply shock as well, so not all the low price ratios should signify exceptional poverty.

Since we do not know the elasticities for Ancient Mesopotamia, we have to assume that the elasticities obtained for medieval England to close to what we would find in Mesopotamia and so we arrive at some estimates of the change of per capita income.

Another crucial variable is the ratio of quantities. There are indications that the share of barley in total consumption reduced in favor of dates during the second half of the first millennium BCE, partly due to the salinization of the soil, or perhaps also due to government policy favoring dates. Still barley was kept at a higher esteem and was probably the preferred food of the higher income groups. Without any sure knowledge about the evolution of quantities, however, it is safer to assume that no change took place. If we follow this assumption we arrive at an index where 100 means our estimate of income when the two goods have the same price, e.g. subsistence level. We can therefore arrive at an estimate of GDP per capita by assuming that when prices are equal the per capita income equals 450 G-K dollar at 1990 prices, which seems a safe assumption for a subsistence level of income. Even though the price ratio can give us a more detailed view about the fluctuations in income, one should not interpret this as being a prefect indicator of per capita income, since price ratios are

TABLE 3
Per capita income in Mesopotamia, ca. 384-60 BCE

Period (BCE)	average income per capita index	average income per capita (1990 G-K USD)
Persian Empire (384-331)	160.5	722
Hellenistic Empire (330-141)	137.1	617
New Persian Empire (240-60)	174.3	784

Source: Authors own calculations.

affected by numerous shocks. It is safer to filter out the effect of these shocks by taking averages of the estimated index and use that instead as an indication of per capita income movements as given in Table 3.

The decline in per capita income in the hellenistic period as described in Table 3 was caused by internal struggle. Whereas the Achemenid empire was characterised by stability, the Hellenistic period was characterised by internal conflicts which eventually culminated by a take over by the Parthen in 141 BCE. The Hellenistic period was most likely also charcterised by population growth. This can by no means be interpreted as indicative of economic growth, however. It is important that these results need to be interpreted within the framework of a Malthusian society and by no means from a modern perspective. Namely, while today growth of income per capita usually means a more prosperous period, in a Malthusian regime it signifies usually large scale loss of population, mostly due to some catastrophic event. Hence, in a Malthusian society a larger population is usually paired with lower per capita income. As such, the per capita income decline in the 3rd century BCE may very well be caused by population pressure. This period ended when Babylon was conquered by the Parthian kings in 141 BCE. Initially, this led to a betterment in the economic situation during the reign of Mithridates II (the Great) between 124 and 88 BCE, before a decline was to emerge.

4. COMPARING NATIONAL INCOME IN THE HELLENISTIC WORLD

Above we sketched the development of the Mesopotamian GDP/cap between ca. 400 and 50 BCE. Our estimate was between 600-700 G-K dollars, which seems to be more than the generally accepted subsistence minimum of 400 dollars, but seems to be less than the estimate for Rome or Athens.

Our estimates show that Mesopotamia is an overwhelmingly agricultural society with a relatively low GDP per capita. We can use Athens for comparison. Amemiya (2007) estimates a total GDP of 4430 talents for the 4th century BCE Athens, of which 2477 was created in manufacturing signifying the outmost importance of the secondary sector in Athens. With the estimated population of 220000 we arrive at 0.020136 talents per capita, or 523.5 grams of silver (using Attic talent equalling 26kg). Von Reden (2008) reports a barley price of 37 gram silver per 100 litres, which means that this per capita income would have been enough to buy 1415 litres of barley (equivalent with 1132 litres of wheat in caloric value). Using the 1.17 litres wheat/G-K dollar ratio we arrive at 967 1990 G-K dollars as estimate for Athenian GDP per capita in the 4th century BCE, significantly (30-40%) higher than our estimate for Mesopotamia in about the same period. Even if Athenians were better fed and ate more meat than the Mesopotamians, such a large difference has to come from a different economic structure with manufactures and pasture. Indeed, we can calculate that around 56% of the economy consisted of manufacturing (Amemiya 2007). The main explanation is large scale food imports. This thus suggests a far more productive manufacturing sector.

The Roman Empire is the next available economy for comparison, but here we have a number of competing estimates. Maddison (2007) and Goldsmith (1984) estimated the GDP per capita in Rome at around 570 GK dollars. However, recent revisions of Milanovic and Malanima set it rather at 900 GK dollars around 1 CE. It is indeed clear that Rome was increasing in this period while Mesopotamia was politically on the decrease. However, still Table 3 shows that per capita GDP in Mesopotamia around 100 BCE was still 784 G-K dollars. Yet, the difference becomes larger when we look at the Italian part of the Roman Empire which Lo Cascio and Malanima (2009) set at as high as 1400 GK dollars. This is about twice as much as the 600-700 GK dollars we find for Mesopotamia. Indeed, if we compare wheat wages this relationship seems to hold: Scheidel reports 7 litres per person in Rome while wages did not buy more than 2.5 litres in Babylon. Higher wages in Rome imply more value added per person, so either Rome was much more productive in agriculture (which is possible but Roman agriculture was certainly not 3 times as productive as in Mesopotamia) or similarly the Roman manufacturing caused this bonus in labor productivity. Indeed, if we look at urbanization, an often used indicator for manufacturing (i.e. Malanima 2009, Álvarez-Nogal and Prados de la Escosura 2009) we see that urbanization around 1 CE in the Italian part of the Roman Empire was around 27% (Geraghty (2007, p. 1044, fn. 39, and p. 1048).[7] This is much higher than the 10% estimated for Mesopotamia. Hence, if we assume that labor productivity in manufacturing was about twice as higher as in agriculture, the difference in structure alone would explain 20% income gap between Rome and Mesopotamia.[8]

Other factors may play a role as well in explaining the income gap. A recently suggested factor may be pasture (Broadberry and Campbell 2009). Since a unit of calorie from meat is about ten times as expensive as from grain products (i.e. Broadberry *et al* 2009) and the Malthusian logic dictates that in Ancient economies most people must have been at subsistence level (in terms of calories at least), higher share of pasture must be paired with a higher GDP per capita both in monetary units and in grain equivalents. That Mesopotamians ate less animal products is supported by anthropometric evidence: the height of Mesopotamian skeletons seems not to deviate much from the Greek skeletons (Jursa: 797 using the data of Wittwer-Backofen 1983). Possibly, this is caused by a large intake of dates,

[7] For the whole of the Roman Empire, Goldsmith (1984, 272-73) estimated urbanization between 9 and 13%.

[8] 1/3 of the roman population is urban and 2/3 is rural. If we assume labor productivity to be twice as high in the urban areas than in the countryside we arrive at a total labor productivity of (1/3)*2+(2/3)*1=1.3. For Babylon, the same numbers are: (1/10)*2+(9/10)*1=1.1. Hence, labor productivity is about 20% higher in Rome purely because of the more extensive manufacturing sector.

which causes an increased production of proteins, increasing human stature. Indeed, Jursa also notes that the larger incidence of caries in Babylonian corpses from 3th Millennium BCE indicating a higher intake of carbohydrate and sugar. This may be caused by increased dates consumption which, in dried form, has a high percentage sugar. This suggests that the intake of pastoral products was probably low. Indeed, Sołtysiak (2010) shows that the Hellenistic Near East was characterized by an increase in deficiency diseases and infections.

Around 1000 CE, GDP per capita in Byzantium was considerably higher even though little evidence for extensive manufacturing sector exists. However, there is plenty of evidence that pasture increased between ca. 200 BCE and 1000 CE. For example Wick, Lemcke and Sturm (2003, 671) show a decrease Quercus (oak) pollen percentages and expansion of *Artemisia* in Lake Van in Southeastern Turkey. Since *Artemisia* has a strong aroma and bitter taste that discourages herbivory, the increase of its pollen is indicative of increasing pasture. The same evidence exists for Roman provinces around the Danube that show a considerably increase in Roman cattle and pig breeding (i.e. Bokonyi, 1988). Indeed, if we look at Byzantium ca. 1000 CE, we again find that a considerable amount of meat in the consumption. Meat rations in the army were around 60 kg per annum (Milanovic, 2006, table 1) and an average close to 30 kg. Indeed, as pointed out by Milanovic, current meat consumption in Turkey is around 40 kg per year, so this estimate is not unfeasible. With 30 kg a year meat consumption, meat must have made up 17.5% of the food budget, twice the share of pasture in Mesopotamian agriculture. If we add other animal products like wool, cheese and milk, and assume that 80% of the total consumption was food (14% is then the share of meat in total consumption), we can safely increase the share of pasturage in GDP to 28%. For simplicity's sake, let us assume that meat consumption in Italy was the same as in Byzantium. In that case, under the scenario that all agricultural output had been grain, agricultural value added would have been 0.28*0.1+(1-0.28)=74.8%, hence, 25.2% lower in Rome. Altogether, differences in manufactures and pasturage can explain 45% difference in per capita incomes. Taking 1400 dollars for Italy and 736 dollar for Babylon, the observed income differential, 47%, is very close to this.

5. CONCLUSION

Estimating income levels in ancient societies become more and more important with the recent upward revisions of medieval incomes. At first sight this would imply that modern economic growth started between earlier than we though. However, recent revisions show that ancient income levels have also been underestimated. The observed cross- country differences in income can be caused not only by divergent development paths on the analogue of modern first world/third-world division but also by different economic structure. So far what we knew about income in ancient economies was derived from estimates for Rome and Athens, and both regions had large manufacturing sector and pasturage. Babylon on the other hand was much more dependent on arable agriculture.

We find that Babylonian GDP per capita is around 700 G-K dollars in 400 BCE. Using an approach based on a dependence of preferences on income level we estimated the movement of GDP per capita forward, we find that, after a peak around 110 BCE, a strong decline followed during the troubled period during the Parthian rule. This means that even at its peak around 200-100 BCE, Mesopotamian GDP/cap was still lower than in Athens around 250 BCE. This can largely be explained by the higher share of manufacturing. Similarly, Rome had a higher GDP per capita and a higher share of pasture and manufacturing. Yet, it is important to note that anthropometrical evidence suggests that heights in Babylon were not lower than elsewhere, if not taller. This implies that in terms of kcalories the difference was not big.

REFERENCES

Adams, Robert McC., and Hans J. Nissen, *The Uruk countryside – the Natural setting of urban societies*, University of Chicago Press, Chicago, 1972.

Adams, Robert McC., *Heartlands of Cities. Surveys of Ancient Settlement and Land Use on the Central Floodplain of the Euphrates*, University of Chicago Press, Chicago-London, 1981.

Álvarez-Nogal, Carlos, and Leandro Prados de la Escosura, "The Rise and Decline of Spain (800-1850)," Paper Presented at the World Economic History Congress Utrecht 2009.

Amemiya, Takeshi, *Economy and Economics of Ancient Greece*, Routledge, London and New York, 2007.

Angel, Lawrence J., "Health as a crucial factor in the changes from hunting to developed farming in the eastern Mediterranean," in Mark N. Cohen and George J. Armelagos (eds.), *Paleopathology at the Origins of Agriculture,* (proceedings of a conference held in 1982), Academic Press, Orlando, 1984, 51-73.

Aperghis, Makis, "ABACUS Historical Modeling System," *Paper presented at the Francqui Conference Long-Term quantification in Ancient Mediterranean History,* Brussels November 2009.

Aperghis, Makis, *The Seleukid Royal Economy: The Finances and Financial Administration of the Seleukid Empire,* Cambridge University Press, Cambridge, 2004.

Bairoch, Paul, *Cities and economic development: from the dawn of history to the present*, Mansell Publishing, London, 1988.

Bedford, Peter, "The Persian Near East," in Walter Scheidel, Ian Morris and Richard P. Saller (eds.), *The Cambridge Economic History of the Greco-Roman World*, Cambridge University Press, Cambridge, 2007.

Bokonyi, Sandor, "Animal Breeding on the Danube," in C.R. Whittaker (ed.), *Pastoral Economies in Classical Antiquity*, Cambridge University Press, Cambridge, 1988, 171-176.

Broadberry, Steve, and Bruce Campbell, "GDP per capita in Europe, 1300-1850," Paper Presented at the World Economic History Congress Utrecht 2009.

Broadberry, Steve, Bruce Campbell, Alex Klein, Mark Overton, and Bas van Leeuwen, "British economic growth, 1300-1850: some preliminary estimates," Paper Presented at the World Economic History Congress Utrecht 2009.

Geraghty, Ryan, "The impact of globalization on the Roman Empire, 200BC – AD 100," *The Journal of Economic History*, 67 (4), 1036-1061, 2007.

Goldsmith, Raymond W., "An Estimate of the Size and Structure of the National Product of the Early Roman Empire," *Review of Income and Wealth*, 30 (3), 263-88, 1984.

Hopkins, Keith, "Taxes and trade in the Roman empire (200 B.C. – A.D. 400)," *Journal of Roman Studies,* 70, 101-125, 1980.

Horrell, Sara, Jane Humphries, and Martin Weale, "An input-output table for 1841," *Economic History Review*, 47 (3), 545-566, 1994.

Jursa, Michael, *Aspects of the Economic History of Babylonia in the First Millennium BC: economic geography,economic mentalities, agriculture, the use of money and the problem of economic growth* (M. Jursa with contributions by J. Hackl, B. Janković, K. Kleber, E.E. Payne, C. Waerzeggers and M. Weszeli). to be published in the AOAT series, will go to press in Sept. 2010.

Lo Cascio, Elio, and Paolo Malanima, "GDP in Pre-Modern Agrarian Economies (1-1820 AD). A Revision of the Estimates," *Rivista di Storia Economica*, XXV (3), 387-415, 2009.

Maddison, Angus, *Contours of the World Economy, 1-2030 AD. Essays in Macro-Economic History*, Oxford University Press, Oxford, 2007.

Maddison, Angus, *The World Economy: Historical Statistics,* OECD, Paris, 2003.

Malanima, Paolo, "Italian GDP 1300-1913," Paper Presented at the World Economic History Congress Utrecht 2009.

Milanovic, Branko, "An Estimate Of Average Income And Inequality In Byzantium Around Year 1000," *Review of Income and* Wealth, 52 (3), 449-470, 2006.

Pastor, Jack , *Land and Economy in Ancient Palestine*, Routledge, London, 1997.

Posthumus, Nicholaas W., *Nederlandsche prijsgeschiedenis*, Vol. 2., Leiden, 1964.

Report of the Nutrition Advisory Committee, Indian Council of Medical Research, New Delhi, 1958.

Saito, Osamu, and Tokihiku Settsu, "Unveiling historical occupational structures and its implications for sectoral labour productivity analysis in Japan's economic growth," Paper presented at the □Asian Historical Economics Conference, Beijing, 19-21 May, 2010

Scheidel, Walter, "Real Wages in Early Economies: Evidence for Living Standards from 1800 BCE to 1300 CE, *Journal of the Economic and Social History of the Orient*, 53 (3), 425-462, 2010.

Scheidel, Walter, Steven Friesen, "The Size of the Economy and the Distribution of Income in the Roman Empire," Princeton/Stanford working papers in Classics, January 22, 2009. Available at SSRN: http://ssrn.com/abstract=1299313

Scheidel, Walter, "A Model of Real Income Growth in Roman Italy," *Historia*, 56, 322-46, 2007.

Slotsky, Alice L, and Ronald Wallenfels, *Tallies and trends. The Late Babylonian commodity price lists,* Capital Decisions Ltd, Bethesda (MD), 2010.
Slotsky Alice, *The Bourse of Babylon. Market Quotations in the Astronomical Diaries of Babylonia*, CDL Press , Bethesda MD, 1997.
Smith, Adam, *An enquiry into the nature and causes of the wealth of nations*, R.H. Campbell and A.S. Skinner (eds.), Clarendon Press, Oxford, 1976.
Sołtysiak, Arkadiusz (2010), "Paleopathology in ancient Mesopotamia A short overview," British Association for Near Eastern Archaeology Annual Conference, Birmingham 2007.
Temin, Peter, "Estimating GDP in the early Roman Empire," in Elio Lo Cascio (ed), *Innovazione tecnica e progresso economico nel mondo romano,* Rome, Bari, 2006, 31-54.
Temin, Peter, "Price Behavior in Ancient Babylon," *Explorations in Economic History*, 39 (1), 46-60, 2002.
Van der Spek, Robertus J., "Feeding Hellenistic Seleucia on the Tigris and Babylon," Richard Alston, O.M. van Nijf (eds.), *Feeding the Ancient City*, Peeters, Leuven, 2008, 33-45.
Van Leeuwen, Bas, and Jan Luiten van Zanden, "The origins of 'modern economic growth'? Holland between 1500 and 1800," Paper Presented at the World Economic History Congress Utrecht 2009.
Vargyas Peter, *A History of Babylonian prices in the First millennium BC. 1. Prices of the basic commodities*, Heidelberger Studien zum Alten Orient 10, Heidelberger Orientverlag, Heidelberg, 2001.
Von Reden, Sitta, "Price Fluctuations in Babylonia, Egypt and the Mediterranean World, third to first centuries BC," Paper presented at: *Too much data? Generalizations and model-building in ancient economic history on the basis of large corpora of documentary evidence.* Vienna 17-19 July 2008
Wick, Lucia, Genry Lemcke, and Michael Sturm (2003), "Evidence of Lateglacial and Holocene climatic change and human impact in eastern Anatolia: high-resolution pollen, charcoal, isotopic and geochemical records from the laminated sediments of Lake Van, Turkey," *The Holocene*, 13 (5), 665-675, 2003.
Wittwer-Backofen, U., "Einige neubabylonische Skelette aus Uruk," *Baghdader Mitteilungen,* 14, 71-94, 1983.