CGEH Working Paper Series

Markets in pre-industrial societies:
storage in Hellenistic Babylonia in the English mirror

Bas van Leeuwen, Utrecht University

Peter Földvari, University of Debrecen

Reinhard Pirngruber, Free University, Amsterdam

January 2011

Working paper no. 3

http://www.cgeh.nl/working-paper-series/

Markets in pre-industrial societies:
storage in Hellenistic Babylonia in the English mirror

Bas van Leeuwen, Utrecht University

Peter Földvari, University of Debrecen

Reinhard Pirngruber, Free University, Amsterdam

Abstract
Recent research has shown early economies to exhibit market behavior by using institutions that reduce price volatility. In this paper we focus on storage as a price stabilizing strategy in Babylon using a recent dataset with agricultural prices for the Late Achaemenid and Hellenistic periods (ca. 400 – 65 BC). This dataset allows us to assess the importance of inter-annual storage (carry-over) in this economy. Comparing this economy with that of medieval England using a cost-benefit analysis, we find, after correcting for the differential crop structure in both regions, a low level of inter-annual storage. Yet, contrary to the expectations of the cost-benefit analysis, the evidence does not indicate a lower interest rate (i.e. costs) in Babylon. This implies that both social structure as well as access to capital markets played a more important role than traditionally assumed in the question of carry-over.

Keywords: storage, England, Babylon, seasonality, ancient history, medieval history

JEL Codes: N10, N55, O13, O53

Corresponding author: Bas van Leeuwen; bas.vanleeuwen1@googlemail.com

Introduction

Market efficiency, defined as the capability of markets to reduce the risk of shortages either via trade, technology or storage, is a broadly discussed topic in recent decades.[1] It also has been argued that market efficiency and economic development are closely related.[2] Recently, a new dataset on Babylonian prices has come available that allows an analysis for the second half of the First Millennium BCE, the so-called Hellenistic era when the region fell under the sway Alexander the Great and his successors, the Seleucid dynasty. This period, for which there is no comparable dataset, has the additional benefit of slow technological development[3] and a marginal trade in bulk goods[4], which means we can concentrate on the third risk reducing strategy of inter-annual storage, or carry-over.

In this paper we compare storage in Hellenistic Babylon and medieval England, periods about which we have little information on the working of markets. Given the link between market efficiency and economic development, this comparison can therefore shed light on the question whether economic efficiency already started to increase before the Middle Ages. In addition, even though the choice for these two countries is certainly also a matter of available data, as it is always when past societies are at issue, we hope to show such a comparative approach also can shed light on particularities in each of the societies dealt with. Fundamentally, in both cases we are dealing with largely agrarian, rural societies not

---

[1] E.g. Karl-Gunnar Persson, *Grain markets in Europe, 1500-1900: Integration and Deregulation*, Cambridge: Cambridge University Press, 1999; Peter Temin*, '*Price behavior in ancient Babylon', *Explorations in Economic History*, 39, 1, 2002, pp. 46-60*; Roman Studer*, 'India and the Great Divergence: Assessing the efficiency of Grain markets in Eighteenth- and Nineteenth-Century India', *Journal of Economic History*, 68, 2, 2008, pp. 393-437.

[2] Studer, 'India and the Great Divergence', pp. 393-437; Victoria, N. Bateman, 'The evolution of markets in early modern Europe, 1350–1800: a study of wheat prices,' *Economic History Review*, 2010, Article first published online: 23 SEP 2010, DOI: 10.1111/j.1468-0289.2010.00540.x

[3] Moses Finley, 'Technical innovation and economic progress in the Ancient world', *Economic History Review*, 18, 1, 1965, pp. 29-45 argued for stagnation in the Greco-Roman world. And Finlay thought this idea applicable to the entire Ancient world, cf. K. Greene, 'Technological innovation and economic progress in the ancient world: M.I. Finley re-considered', *Economic History Review,* 53, 1, 2000, pp. 29-59.

[4] See now Laetitia Graslin-Thomé, *Les échanges à longue distance en Mésopotamie au Ier millénaire. Une approche économique* Paris : De Boccard 2009, in particular pp. 271-76. The *locus classicus* is Leo Oppenheim, 'Essay on Overland Trade in the First Millennium B.C.', *Journal of Cuneiform Studies* 21, 1969, pp. 236-54, 242-244.

subject to significant imports of basic food commodities on a meaningful scale. It is true that the agricultural structure in both regions differs. However, it is precisely the difference in crop structure (discussed in the next Section) that enables our approach to shed light on the shortcomings of the McCloskey-Nash model that equates potential costs and benefits from storage: as regards Babylonia, we will see that the interest rates, being the largest costs factor, are higher than predicted on the basis of their model, to be best explained by a very restricted access to capital.

The importance of storage for the pre-industrial economies follows from the fact that it was an important method to reduce price volatility and, hence, increasing market efficiency. However, although storage in medieval England is a hotly debated topic,[5] a quantification of the magnitude of storage has hardly ever been attempted for other regions and time periods[6] in spite of the often rich evidence for storage found for many societies – from Nigeria 600 BCE to the Inca Empire to Classical Rome.[7] This can be partially explained by a lack of quantifiable data, i.e. prices. For most pre-industrial societies, price data are at best fragmented and at worst non-existent.[8] However, the situation has changed dramatically for Ancient Babylonia. From the city of Babylon itself, we now have access to hundreds of observational cuneiform tablets, the so-called 'Astronomical Diaries', recording celestial as

---

[5] Cf. Stefano Fenoaltea, 'Risk, Transaction Cost, and the Organization of Medieval Agriculture', *Explorations in Economic History*, 13, 2, 1976, pp.129-151; Stefano Fenoaltea, 'Transaction costs, Whig history, and the common fields', *Politics & Society,* 16, 2-3, 1988, pp. 171-240; Donald McCloskey and John Nash, *Corn at Interest: The Extent and Cost of Grain Storage in Medieval England*, The American Economic Review, 74, 1, pp. 174-187 ; John Komlos and Richard Landes, 'Anachronistic Economics: Grain Storage in medieval England,' The Economic History Review, 44, 1, 1991, pp. 36-45; Nicholas Poynder, *Grain Storage in Theory and History*, Paper presented at Third Conference of European Historical Economics Society, Lisbon, 1999.

[6] Exceptions are, for example, Kenneth Pomeranz, *The making of a hinterland: state, society, and economy in inland North China, 1853-1937*, Berkeley: University of California Press, 1993, pp. 32-33.

[7] See for example Giovanna Vitelli, 'Grain Storage and Urban Growth in Imperial Ostia: A Quantitative Study', *World Archeology*, 12, 1, 1980, pp. 54-68; Terry Y. Levine, *Inka Storage Systems*, Norman: University of Oklahoma Press 1992; Detlef Groneborn, 'An Ancient Storage Pit in the SW Chad Basin, Nigeria', *Journal of Field Archeology*, 24, 1997, pp. 431-439.

[8] Important studies of price data of antiquity include Dominic Rathbone, 'Prices and Price Formation in Roman Egypt', in J. Andreau et. al., eds., *Économie antique. Prix et formation des prix les économies antiques*, Saint-Bertrand-de-Comminges: Musée archéologique departmental, 1997, pp.183-244; Gary Reger, *Regionalism and Change in the Economy of Independent Delos,* Berkeley: University of California Press, 1994; Sitta von Reden, *Price Fluctuations in Babylonia, Egypt, and the Mediterranean World, third to first centuries BC*, paper presented at the conference 'Too many data? Generalizations and model-building in Ancient Economic History on the basis of large corpora of documentary evidence, Vienna, 17-19 July 2008.

well as terrestrial phenomena for the period between ca. 385 and 60 BCE.[9] Besides astronomical as well as socio-political information and measurements of the river level of the Euphrates, also the prices of six basic commodities were recorded. These commodities include barley and dates, the two main crops.[10] Reliable data are available theoretically for every month, with sometimes multiple observations per months. However, due to the numerous gaps in the documentation there is data on barley prices in 535 out of 3887 possible months, i.e. 13.76%. For dates, the percentage is similar, 12.58% of all available months. As shown by Földvári and Van Leeuwen (2009), however, the missing data are "missing at random" and are thus uncorrelated with our variables of interest: seasonality.[11]

Besides the link with economic development, market efficiency, and crop structure, storage also directly touches upon the primitivist-modernist debate. In the field of Ancient History, the "Finleyan orthodoxy" of Ancient Man being driven by social factors rather than by genuine economic interest has increasingly been parted with.[12] A particular case in point is first millennium BCE Babylonia, the economic actors of which have been conceptualized (at least implicitly) as a kind of utility maximizing agents already since the 1980s.[13] Since the

---

[9] H. Hunger/A. Sachs, *Astronomical Diaries and Related Texts from Babylonia.* 3 volumes: I: 652- 262 BC, Vienna 1988; II: 261- 165 BC, Vienna 1989; III: 164- 61 BC, Vienna 1996.

[10] For prior analyses of the data see Alice L. Slotksy, *The Bourse of Babylon. Market Quotations in the Astroniomical Diaries of Babylonia*, Bethesda MD: CDL Press, 1997 (with the important review of Van der Spek, R. J./ Mandemakers, C., *Sense and nonsense in the statistical approach of Babylonian prices, Bi.Or* 60 (2003), pp. 521-537; Peter Vargyas, *Les prix des denrées alimentaires de première nécessité en Babylonie à l'époque achémenide et hellénistique*, in Jean Andreau et al., eds., *Économie antique. Prix e formation des prix dans les économies antiques*, Saint-Bertrand-de-Comminges: Musée archéologique departmental, 1997, pp.335-354. See Alice L. Slotksy and Ronald Wallenfels, *Tallies and trends. The Late Babylonian commodity price lists*, Bethesda MD: CDL Press, 2010, for some additional price data.

[11] Peter Földvári and Bas van Leeuwen, *The structural analysis of Babylonian price data: a partial equilibrium approach*, Paper presented at the World Economic History Congress, Utrecht, 2009.

[12] Jean Andreau, 'Twenty Years after Moses I. Finley's The Ancient Economy', in Walter Scheidel and Sitta von Reden, eds., *The Ancient Economy*, Edinburgh: Edinburgh University Press, 2002. See also the contributions in W. Scheidel *et al.,* eds., *The Cambridge Economic History of the Greco-Roman World* Cambridge: Cambridge University Press 2007 for the ever increasing broadness of approaches and perspectives.

[13] Ever since the publication of M. Stolper, *Entrepreneurs and empire. The Murašû archive, the Murašû firm, and Persian Rule in Babylonia,* Leiden, 1985, the term 'entrepreneur' as economic actor typically engaged in agricultural management or large scale trade and other monetary transactions has occupied a prominent position in research. See for example C, Wunsch, *Die Urkunden des babylonischen Geschäftsmann Iddin-Marduk. Zum Handel mit Naturalien im 6. Jh,. V. Chr. (Cuneiform monographs 3a+b),* Groningen: Styx 1993; M. Jursa, *Agricultural management, tax farming and banking: Aspects of entrepreneurial activity in Babylonia in the Late Achaemenid and Hellenistic periods*, P. Briant and F. Joannès (eds.) La transition entre l'émpire achéménide et

storage model from McCloskey and Nash (1984) is based on the existence of rational economic actors, we consider it rewarding to apply their quantitative model also to the Babylonian price data. Their main argument runs quite simply: the increase in price after the harvest must be equal to the cost of storing grain, in other words the difference of the current and expected grain price must be equal to the marginal cost of its storage.[14] After all, if there is the possibility to make a profit by storing grain and selling it at a later date, it is unlikely that people would not have done so. Yet, storing grain and selling it at a later date will reduce the price after harvest, at the margin up to the point that no profit is made by storing more grain. Hence, post harvest prices must reflect the cost of storing grain. These costs of storing grain are generally described as the costs of renting a barn, depreciation (loss) of grain, and foregone investment.[15]

Even if storing grain sounds seems a straightforward way of action, many studies in this field claim that storage in historical societies was marginal only. McCloskey and Nash as well as Clark claim that in England the high interest rates significantly reduced potential profits from storage:[16] because of the high foregone earnings, storage is expensive and hence rare.[17] As will be shown below, this scenario equally holds true for Babylonia even though there exists a fundamental difference between England and Babylon is the agricultural supply situation. In England, agriculture was dominated by barley and wheat. The output of both crops was positively (though weakly) correlated, with the harvests lying close together. This implies that it is a justifiable simplification to model English agriculture as if it had been

---

les royaumes héllenistiques (*Persika* 9), Paris : De Boccard, pp. 137-222 ; Laetitia Graslin-Thomé, *Les échanges à longue distance*.

[14] McCloskey and Nash, '*Corn at Interest.*'Similarly, Gregory Clark, 'The cost of capital and medieval agricultural technique', *Explorations in Economic History*, 25, 3, 1988, pp. 265-294; Poynder, 'Grain Storage in Theory and History'.

[15] McCloskey and Nash, *Corn at Interest*; Poynder, *Grain Storage in Theory and History*.

[16] McCloskey and Nash, 'Corn at Interest'; Clark, 'The cost of capital'.

[17] On the other hand, some authors argue for much bigger role for storage. For example, Stefano Fenoaltea, '*Risk, Transaction Cost, and the Organization of Medieval Agriculture*', p. 139 argued that storage in England could easily be in the order of magnitude of 1.5 times the annual consumption. However, with such a high storage rate one either needs implausibly higher variances in grain yields or the almost complete absence of famines, neither of which exists.

dominated by a single food crop. Babylon, on the other hand, had a dual crop structure with an autumn harvest of dates and a spring harvest of barley, two crops the production of which was at best negatively correlated. This implies that that intra-annual price changes and, hence, potential profits from storage, were probably reduced.[18] Consequently, according to above model the costs of storage must be lower as well. Yet, contrary to the expectations by McCloskey and Nash that interest rate was the main cost factor in storage, and seasonal variation must reflect the total costs of storage,[19] the dual crop structure with lower seasonal volatility did not result in substantial lower interest rates in Babylon. This either implies that barn rents and storage losses in Babylon were considerably lower, or that the socio-economic structure somehow inhibited farmers from storing food crops.[20] In order to see which option is the more likely one, we will discuss the evidence for storage in the next section. Section 3 then explores the benefits and costs of storage and, after a discussion of the discrepancy of costs and benefits in section 4, in section 5 a conclusion will be provided.

Evidence for storage

The direct evidence for storage is limited. A simple model would suggest that in a society with a single crop harvested once a year (or two related crops harvested at approximately the same time) the entire crop was stored for six months on average to assure a smooth

---

[18] Dates played a fundamental part in the dietary habits of the Middle East until well into the 20th century: according to a study quoted in Michael Jursa *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* (with contributions by J. Hackl, B. Janković, K. Kleber, E.E. Payne, C. Waerzeggers and M. Weszeli), AOAT 377, 2010, p. 50, an Iraqi small farmer consumed 65.1 kilograms of dates a year as compared to 75.3 kilos of wheat, barley, rice; both commodities together accounted for about two thirds of total caloric intake. A similar proportion in antiquity is indicated by the 'ration' system of the Ebabbar-temple of Sippar in northern Babylonia which ideally provided workers with equal amounts of barley and dates; cf. M. Jursa, '*The remuneration of institutional labourers in an urban context in Babylonia in the First millennium BC*', in: P. Briant et al., eds., *L´archive des Fortifications de Persépolis. État des questions et perspectives de recherches.* (Persika 12), Paris: De Boccard, 2008.
[19] McCloskey and Nash, 'Corn at Interest'.
[20] Komlos and Landes, 'Anachronistic Economics'.

consumption path. In England prior to the Black Death we can distinguish barley and wheat as the two main crops. Broadberry *et al.* estimated the share of barley and wheat in the total output of the arable sector around 1300 to be close to 60%.[21] Winter wheat was harvested in May/June while spring barley was harvested around September. In the period prior to the Black Death, barley still played an important role in human diet as bread ingredient, although Overton and Campbell estimate that by 1600 this had changed, and that only 35% of total barley output were consumed in that way. They furthermore state that by "the late sixteenth century, most English ale was being brewed from barley, in contrast to the situation 300 years earlier when significant quantities had been brewed from dredge and oats."[22] Hence, we may assume that both barley and wheat were the main foodstuffs before the Black Death and that in the period between September and May people had to rely on storage.

In Babylon the situation was different. Although, just as in England prior to the Black Death, there were two main crops (dates and barley), they were harvested further apart. Babylon had a barley harvest in March/April while the date harvest came in around October. Hence, if we follow the literature[23] in assuming 1) roughly equal shares of both crops in the diet, and that 2) the two crops are perfect substitutes[24], this implies that in order to prevent starvation, each crop in principle had to be stored for only 3 months on average until the harvest of the other main crop. Additionally, we must take into consideration that whereas the quality of barley and wheat deteriorates with storage, dates may actually increase in value.

---

[21] Steve Broadberry, 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, 2-7 Aug, 2009.

[22] Mark Overton and Bruce Campbell, 'Production et productivité dans l'agriculture anglais, 1086-1871', *Histoire et Mesure,* 11, 3-4, 1996, 255-297, Table XII.

[23] Makis Aperghis, *The Seleucid Royal Economy: The Finances and Financial Administration of the Seleukid Empire*, Cambridge: Cambridge University Press, 2004 and the literature quoted therein; Michael Jursa, *Aspects of the Economic History of Babylonia*. See already the information provided above, footnote 15. An important corroboration us also the finding of P. Vargyas, who could show that the date harvest constituted a relief in the supply situation of the foodmarket, resulting in higher barley equivalents, or, phrased differently, lower barley prices; cf. P. Vargyas, *Les prix des denrées alimentaires*.

[24] As argued further on in the text, this assumption can be defended in times of famines when people just need calories. Barley and dates are thus considered simply as sources of kcalories and, hence, substitutes.

Dates sold just after harvests are fresh, i.e. their water content is considerably higher. These fresh dates cannot be stored, and consequently about two months after harvest dried dates start to dominate.[25] Dried dates not only have higher sugar content, but also less volume. Since in Babylon dates were sold by volume (per *qa*, which can conveniently be set at 1 liter), soon after the harvest prices therefore start to rise again which strongly influences the seasonal pattern of prices. It is therefore important by calculating the costs and benefits of storage, to take account of this different agricultural structure.

It is obvious that all economies need to have some basic kind of short-run storage. After all, if people do want to eat also all months after harvest up to the following harvest, food for these months has to be stored. Since each month circa 1/12 of the crop is consumed, average storage time with one main harvest should be 6 months. Yet, carryover from grain from one year to the next (inter-annual storage) can still be zero if no reserves were present on the eve of the new harvest. McCloskey and Nash argue that for England direct evidence shows that average carryovers were at best 5% of the harvest and took largely place at the manors and royal storage facilities.[26] Although they show that in plentiful years some carryover might have existed,[27] the normal situation was one of insignificant carryovers. The same conclusion was reached by Beveridge who concluded that only little grain was stored beyond the following harvest.[28]

Similarly, M. Jursa allows for a minimal role only for storage in first millennium BCE Babylonia, this mainly being due to the socio-economic situation. He argues that, in order to meet tax requirements, the big producers (i.e. the temples) were forced to sell the lion's share of their cash-crop production immediately after harvest. Having revealed a seasonal pattern in

---

[25] E.g. V. Dowson, *Dates and date cultivation in the 'Iraq*, [S.I.]: Agricultural Directorate of Mesopotamia, Part 1, 1921, p. 41.
[26] McCloskey and Nash, 'Corn at Interest.'
[27] *Idem*, p.174.
[28] William H. Beveridge, 'The Yield and Price of Corn in the Middle Ages, Economic History Review,' 1, 1927, pp. 155-167.

the sales of dates of the Ebabbar-temple in Sippar (with dates usually being described as the temple's main cash crop) he concludes that "by and large the temple did not hoard dates with the intention of making them available to outsiders after the intensive phase of selling following the harvest."[29] In other words, due to the tax demand of the central government, the temples were not able to store commodities on a larger scale for selling in the following year.

Additionally some indirect information on the small size of carryovers in Babylon can be found in the price material of the so-called Astronomical Diaries (ADs). There are several observations of "old" and "new" barley and dates among the price quotations of the ADs. Yet, these refer largely to the new harvest and therefore cannot be interpreted as the existence of carry-overs. Indeed, new barley generally appears in the texts during the harvest period (Babylonian months I and II). This "new" (*eššu*) barley is always cheaper, and either replaces barley without additional attribute (as in AD -308)[30] or runs parallel to it (S/W, texts 9 and 12);[31] in either case the price decreases. A clear example is given in Table 1 where we report the rates (in liters per shekel of silver) for barley during the harvest month. We can see that prices (i.e. the inverse of the rates) are higher until day 15 when the new barley enters the market. Afterwards, prices are considerably lower. This effect can be best explained as an effect of the alleviation of supply with the arrival of the new harvest rather than as a difference in quality. Hence, no evidence of inter-annual storage is available for barley.

Table 1 about here

As regards "new dates", the same pattern applies. It is not surprising that during harvest prices for both barley and dates fell as a consequence of an improved supply situation. It is important to note that the price of dates fell stronger than that for barley: on average,

---

[29] Jursa, *Aspects of the Economic History of Babylonia,* pp. 591-592.
[30] I.e. not specified by either description "old" or " new".
[31] S/W x: Text number in Slotsky and Wallenfels, *Tallies and trends.*

regular (=old) dates are ca. 20% more expensive than new dates while for barley this figure is 10%. Yet, as mentioned before, dried (=old) dates are expected to be more expensive because they have a higher weight per liter and higher sugar content. Hence, the stronger decrease in date prices during the harvest can be explained by the fact that we compare dried old dates with fresh new dates. That this is a common pattern can also be seen in Egypt where Drexhage[32] found fresh dates to be cheaper than dried dates.

As pointed out earlier, there are also a few texts which explicitly refer to "old" dates. The most interesting cuneiform text for our purpose is S/W text 6, which is the only instance referring to either old or new dates not during the harvest season. The most plausible interpretation of this passage is that it refers to inter-annual storage: if the regular dates stem from the preceding harvest of autumn 138 BCE, then the dates designated as old must be from an earlier harvest, autumn 139 BCE or even before.

Evidence referring to "old" produce, with "old" defined here as stored for longer than one harvest period, is thus very meager in the rich corpus of Late Babylonian price records (and we are talking about more than 3.500 price observations). This finding is consistent with the notion of carry-over having played a very minor role only in Late Babylonian economies.

Indirect evidence of small levels of storage is also plentiful for both Babylon and England. Many stories exist of famines, with the great European famine of 1315-1317 being just the best known example. Making this kind of comparison between the two regions, it is of course always difficult to establish what exactly was considered a famine by the respective chroniclers or historiographers. However, it is not an aim of this paper to consider the extent, the consequences, and the comparability of each famine reported in the English and Babylonian evidence. We shall thus apply a broad definition of the term "famine" which also includes food crises as characterized "by rising prices, popular discontent and hunger, in the

---

[32] Hans-Joachim Drexhage, *Preise, Mieten/Pachten, Kosten und Löhne in römischen Ägypten* St Katharinen: Scripta Mercaturae Verlag, 1992 p. 36.

worst cases leading to death by disease or starvation" rather than only the most catastrophic occurrences of mass starvation.[33] By relating this to extremely high prices, as is common in both the literature on England (e.g. Hoskins 1964, 1968)[34] and Babylon (e.g. Vargyas 1997; Van der Spek 2006)[35], basic comparability of famines in both datasets is warranted.

On average, England experienced famine every 10-15 years,[36] which frequency by itself is powerful evidence for the lack of inter-annual storage on a larger scale. For Babylon less information is available on famines. One possible source are the so-called "siege documents" edited by Oppenheim. These are contemporary economic documents drawn up during periods of warfare when the respective city lay under siege, and give us thus a rare insight in what Babylonians themselves considered famine prices.[37] However, the prices in these documents are mere formulations rather than actual sale prices (in the style of 'barley costs a million nowadays") and give thus conspicuously low equivalents (=extremely high prices): in all cases these equivalents ranged between 2 and 12 litres of barley per shekel. As has been shown by I. Eph'al, one has to remember that these prices are best considered literary *topoi* of little historical value.[38] The famine prices recorded in the Astronomical Diaries are considerably lower and more reliable. We actually know from a couple of instances in the historical sections of the same tablets that recorded the prices famines could

---

[33] Peter Garnsey, 'Famine in history', in: P. Garnsey, ed., *Cities, peasants and food in Classical Antiquity*, Cambridge: Cambridge University Press 1998, p. 272- 292, quotation from p. 275. Note however that the Babylonian famine threshold employed seems to meet one important criterion of famine as defined more narrowly, namely a "collapse of the social, political, and moral order" (Garnsey, 'Famine in history', p.275) – at least, this is how we would interpret the fact the people were reported to sell their children in order to prevent starvation. Cormac Ó'Gráda, *Famine: a short history*, Princeton: Princeton University Press, 2009, pp. 3-7 holds a similar pragmatic view on the definition of famines.

[34] W.G. Hoskins, 'Harvest fluctuations and English economic history 1480-1619', *Agricultural History Review*, 12, 1964, pp. 28-46; 'Harvest fluctuations and English economic history 1620-1759', *Agricultural History Review*, 16, 1968, pp. 15-31. He uses as definition of famine those years when the price is higher than 10% above a 31 year moving average.

[35] Vargyas, *Les prix des denrées alimentaires de première nécessité*. Robartus Van der Spek, 'How to measure prosperity? The case of Hellenistic Babylonia', in R. Descat *et al.* (ed.), *Approches de l'économie hellénistique* , Paris: Entretiens d'Archéologie et d'Histoire St-Bertrand-de-Comminges 7, 2006, pp. 287-310.

[36] Donald N. McCloskey, 'English Open Fields as behavior Towards Risk', in P. Uselding, ed., Research in Economic History, Vol. 1, Greenwich: JAI Press, 1976, pp. 124-70, p. 144.

[37] A. Leo Oppenheim, 'Siege documents from Nippur', Iraq, 17, 1955, pp. 69-89.

[38] Israel Eph'al, *The city besieged: Siege and its manifestations in the ancient Near East*, Leiden: Brill, 2009.

afflict the country (or rather the city itself and thus also the higher strata of society, namely the literate elite) so severely that "people sold their children" – which is incidentally the same transaction as recorded in the abovementioned siege documents. Using these data, based on contemporary notions of the Babylonian scribes, Van der Spek has shown that a price at (or below) ca. 39 liters per shekel can be considered evidence of famine.[39] We take 40 liters/shekel as a limit and additionally assume that there was a famine only when this condition applied for both the barley and dates prices. This assumption is based on the fact that the amount of kcalories per liter for barley and dates is roughly equal, and it is logical to assume that the cheaper product will be bought in order to prevent starvation. Using this method, we can identify 9 famines in the 133 years for which we have data. This means a famine about every 14th year.

As pointed out, this relatively high famine frequency in both England and Babylon is a strong argument against large carryovers. We can also formalize this by estimating the expected time that a famine will take place given a certain level of inter-annual storage. For this, we need to calculate the standard deviation of agricultural output. This is straightforward if we only have one crop, but in England we have wheat and barley and in Babylon barley and dates. Yet, since wheat and barley are more similar (i.e. in terms of the harvest date and type of food product) than barley and dates, we expect that output of wheat and barley in England is stronger correlated than that of barley and dates in Babylon. This has effects on the standard deviation and hence on the likelihood of famines. Since the standard deviation is nothing more than the square root of the variance, we will, for simplicities sake, combine the variance of two series. This implies that we treat dates and barley as perfect substitutes. This assumption can be defended in cases of famines since, when there is famine, people maximize

---

[39] Van der Spek, 'How to measure prosperity?'. His estimate confirms the earlier assumption of Peter Vargyas, who took 50 litres per shekel as famine threshold; cf. Vargyas, *Les prix des denrées alimentaires de première nécessité*.

their calorie intake[40] and one litre of dates and one litre of barley have approximately the same caloric content[41]. Hence, in this exercise, when we add their quantity, we simply add calories. Thus, we start with:

$$X \sim (\mu_X, \sigma_X^2)$$

$$Y \sim (\mu_Y, \sigma_Y^2)$$

, where μ and σ² denote the mean and the variance of the series *X* and *Y* respectively and *s* and *z* are their variances. Now, if add the total of the two variables together, we get

$$Z = X + Y$$

where the new series *Z* has a mean $\mu_X + \mu_Y$, and if they are uncorrelated, the variance is simply the sum of their individual variances. In case the series are correlated, like in England, *Z* still has the same mean as before but the variance becomes:

$$\sigma_Z^2 = \sigma_X^2 + \sigma_Y^2 + 2 \cdot \sigma_{XY}$$

where σ_{XY} is the covariance of X and Y. In other words, if the series are positively correlated, the variance of the sum of the series will go up even further and so will the standard deviation.

McCloskey and Nash assumed the standard deviation of crop production to be at a value of 35 (with mean 100) and set the famine level at 50.[42] This latter figure seems to be somewhat low since even during the Great Famine the decline in output only amounted to ca. 38% for wheat and 26% for barley: hence, even a 35-40% drop in production only happened in exceptional situations like the Great Famine. Estimated directly, the combined variance of barley and wheat output for England between 1252 and 1345 is 28.1 mln.[43] If we look at the sub-series, the variance for wheat in England is 18.5 mln and for barley 8.5 mln with a

---

[40] And see additionally what has been said above, p.5-6, footnotes 15 and 20 on the important role of dates in Mesopotamian diet and more particularly on the price-alleviating effect of the date harvest on barley prices.
[41] Jursa, *Aspects of the Economic History of Babylonia*, p.51.
[42] McCloskey and Nash, 'Corn at Interest', p. 176. Their estimates of the parameters and the average waiting time between two famines are based on McCloskey, 'English Open Fields'.
[43] This estimate is based on the data underlying Broadberry *et al.* 'British economic growth, 1300-1850'.

correlation between both series of 0.04. Applying above equation, we arrive at $18.5+8.5+2\cdot0.04\cdot18.5^{0.5}8.5^{0.5}=28.1$ mln, which is slightly higher than the sum of the variances of the two series; taking the square root and dividing by the mean results in a coefficient of variation of roughly 13. This result is substantially lower than the 35 used by McCloskey and Nash. Yet, as outlined, their figures were extremes that only happened during periods of great crises. Even if we look at individual manors, we find only infrequently coefficients of variation exceeding 35.[44] However, correlations of yields between the regions in England are around 0.4-0.5, suggesting that the coefficient of variance for over-all output is lower than for individual series. Indeed, as argued by Ó Grádá, famines like the Great European famine were not that frequent since "given that life expectancy was low even in non-crisis years, frequent famines would have made it impossible to sustain population."[45]

Obtaining similar information for Babylon is complicated by the fact that we basically only have prices rather than output data. Jursa gives the output per hectare for barley as 1,728 liters, while one hectare of dates yielded around 5,328 litres.[46] Clearly, these reflect mean yields and thus do not give much information about the variance. However, they do convey information over the relationship between barley and dates. Assuming that the annual variance of barley and dates production is equal, the mean output of dates is much higher, indicating a correspondingly lower coefficient of variation. Indeed, if we take present day Middle Eastern countries with a substantial amount of dates and barley production, the annual coefficient of variation of dates is about half of that of barley.[47] Since we do not have an estimate of the standard deviation of the barley output for Babylon, we proxy it using barley

---

[44] Bruce M. S. Campbell (2007), *Three centuries of English crops yields, 1211-1491* [WWW document]. URL http://www.cropyields.ac.uk [accessed in 2009]

[45] Cormac Ó Grádá, 'Making famine history', *Journal of Economic Literature*, 45,1, pp. 5-38, p. 8. See also the distinction between food shortage and famine made by P. Garnsey, *Famine in history*.

[46] Jursa, *Aspects of the Economic History of Babylonia,* pp. 48-53. Both values come from the northern Babylonian town of Sippar.

[47] Calculated from the Food and Agricultural Organisation (FAO), *ResourceStat: Land*, 2010 (downloaded from: http://faostat.fao.org/site/377/default.aspx#ancor), taking into consideration only those countries where both crops have an almost identical share in total output.

output in medieval England. This can be seen as an upper bound since grain volatility in the medieval period was larger than in modern times due to modification of the today's grain crops and because in Babylon profited from a relatively developed system of irrigation.

We thus follow the literature that barley and dates are produced at equal amounts and that the variance of dates being half that of barley. Furthermore, given the recent data from the Food and Agricultural Organisation (FAO), the second assumption is that barley and dates are negatively correlated with a correlation coefficient of -0.55.[48] In other words, a failed barley harvest is often followed by a better date harvest, possibly because climatic factors have a different effect on barley and dates. This means that the relative variance in Babylon becomes $8.5+8.5 \cdot 0.5+2 \cdot (-0.55) \cdot 8.5^{0.5} \cdot 8.5^{0.5}=3.4$ mln, hence, given the total hypothetical output of barley and dates of 16 mln bushel, we end up with a CV of 6%. Hence, the presence of dates almost halves the relative standard deviation of agricultural output for Babylon.

Using these standard deviations and the resulting famine lines (the percentage below which a harvest must drop before a famine occurs), we use Monte Carlo simulations (500 experiments a time) in order to estimate how many years, at a given famine line and level of carryover, each famine will be apart (see appendix 1). The results are presented in Table 2. As one can see, assuming no storage and a famine line of 90 (a 10% failed harvest) yields an approximately correct period between two famines for Babylon (roughly 19 years). For England, an assumed famine line of 90 and 0 carryover results in an inter-famine period of 3.5 years which is too low. Famines would be too frequent even with 10% carryover. Hence, a famine line close to 80 seems more reasonable (that is English medieval agriculture must have produced more output per person than Babylon on average). Given the higher volatility of output in England, this must be the case since otherwise frequent famines would have made it impossible to sustain the population levels.

---

[48] Calculated from the Food and Agricultural Organisation (FAO), *ProdStat: crops*, 2010 (downloaded from: http://faostat.fao.org/site/567/default.aspx#ancor , taking into consideration only those Middle-Eastern countries where both crops have an almost identical share in total output.

Yet, for both England and Babylon any storage above 1% of total output is highly unlikely since the waiting time until the next famine becomes between ca. 88 and 501 years for Babylon and between 51 and 212 years for England. Summing up, had there been extensive storage, the frequency of famines or even food shortages recorded would have been much lower than can be actually observed.

Table 2 about here

A cost-benefit analysis of storage

Benefits

In the previous section we have argued that storage existed in both Babylon and England, but that it must have been insignificantly small in both instances. This finding seems to be independent from the agricultural structure. Clearly, the dual crop structure in Babylon reduced intra- (and inter-) annual price changes, but this had mainly the effect of further lowering the standard deviation of the harvest and, hence, the frequency of famines. Now, the question arises why carryovers were so small.

McCloskey and Nash (1984) argued that storage was simply very expensive and thus hardly feasible.[49] However, there has been criticism that this model neglected the impact of the social structure, making it more than difficult for small farmers to borrow money for storage.[50] In order to analyze this question also for Babylon, it is important first to assess the possible benefits of storage in both regions while the costs are discussed in the next subsection. Any discrepancy between the costs and the benefits arising from this model is discussed in the next section.

---

[49] McCloskey and Nash, 'Corn at Interest'.
[50] Komlos and Landes, 'Anachronistic Economics'.

15

We start by taking McCloskey and Nash's (1984) model as a point of departure and assume that the intra-annual price changes must be equal to the costs of storage. This, in turn, is also applicable to inter-annual carryovers, the basis being that the increase in prices between harvests reflects storage costs: after all, one will store grain as long as the costs are smaller than the benefits. It is generally accepted that if the price increase between harvests is higher than the costs of storage, people will store more, thus pushing the price up to the point that the marginal costs and benefits are equal. McCloskey and Nash as well as Clark claim that the costs of storage consist of a) rent of a barn, b) losses (spoiled grain and theft), and most importantly c) foregone earnings, best approximated by the interest rate on capital.[51]

As a first step let us determine the monthly increase in prices after harvest in the same way as McCloskey and Nash. In England, harvest time for winter wheat is around June and for spring barley in early September. Since we use wheat, being the dominant crop, we will use September as the benchmark to make it easier to take account of the barley harvest. We can rewrite this as annual growth per month.

Table 3a and 3b about here

Table 3b is based on Table 3a by taking the average in the Northeast corner above the month pair. For wheat in England the annual price increase is 24.4%. It is, however, important to keep in mind that this estimation technique is based on the assumption of a single harvest per year. If two crops of similar importance are harvested half a year apart, like in Babylon, taking the average of the growth rates of the complete Northeast corner will overestimate the growth (or underestimate the price decline after the second harvest).

A clear example of this can be seen below. Table 4b for barley in Babylon arrives at annual net revenue of no less than 37.8% for barley. This is about 13 percentage points higher

---

[51] McCloskey and Nash, *Corn at Interest*; Clark, *The cost of capital*.

than in England. However, real potential annual benefits must be much smaller than this. After all, we can clearly see that during the months after the dates harvest in September-December the monthly growth rates become negative on the diagonal in table 4a partly caused by the new dates harvest and partly by the prospects of the coming new barley harvest around April. Taking the whole North-East corner would also include the positive growth rates from before the harvest until way after the harvest. Hence, the average figure will be too high. Therefore, we calculated the growth rate from December onwards separately. This results in an annual potential profit from storage of 15.3%.

Table 4a and 4b about here

Below we do a similar exercise for dates as we did for barley. Table 5a shows that, using the McCloskey and Nash method, average annual benefits accrue to 31.0% while, taking account of the barley harvest, which depresses the prices of dates, we increase the potential benefits of storage to 50.4%. This high figure, however, is an overestimate. We can clearly see that in January/February the price changes are strongly positive with growth rates up to 15%. As pointed out in the previous section, this is caused by a strong increase in prices for dried dates. Since it is obviously dried dates that are stored, we cannot include this jump in prices. Accounting for this anomaly, we get an increase of only 16.0%, which is about the same as barley in Babylon, but much lower than wheat in England.

Table 5a and 5b about here

In sum, it is clear that, after taking care of the differences in agricultural structure of the two regions, the intra-annual price change in Babylon was substantially below the English

level. Whereas in England annual volatility amounted to 24.4%, barley and dates in Babylon were both around 16% per annum. This can be the reason why Slotksy refuted the existence of seasonality in the Babylonian price data,[52] a stance which has already been departed with.[53] If we had not corrected for the dual crop structure, using the McCloskey and Nash (1984) method results for barley and dates in figures of 37.8% and 31.0%. Hence, potential profits from inter-annual storage in Babylon are strongly reduced by its dual crop structure. This alone, however, is just one side of the coin: the costs of storage need to be compared as well.

Costs

We have seen that whereas in England annual benefits may accrue to 25%, in Babylon, mainly due to its dual crop structure, the average it is at best also around 16%. This suggests especially for Babylon that costs must also be small if any storage is to exist. Now, how can we calculate the costs? As pointed out in the introduction, the major cost factors are barn rent, storage losses, and foregone earnings from investment. We can ignore imports and exports, since in both cases they are marginal, which leaves us with the other three factors.

As pointed out by McCloskey and Nash, barn rent can only make up a small portion of actual costs.[54] In addition, there is quite some evidence that much less attention was paid to the building and renovation of barns than houses. Yet, if we look at the more abundant data on house rents as best available proxy, we find that around 1300 house rent in England was equal to about 15 bushel of barley, which about halved after the Black Death.[55] This is equivalent to about 525 litres of barley. For Babylon, Jursa estimates house rent to be around 3-4 shekel as minimum per annum, a quite substantial amount of money equaling one or also two months of

---

[52] Slotsky, *The Bourse of Babylon.*
[53] Temin, 'Price behavior in ancient Babylon,'; Foldvari and Van Leeuwen, 'The structural analysis of Babylonian price data'.
[54] McCloskey and Nash, *Corn at Interest*, pp. 182-183.
[55] Gregory Clark, 'The Condition of the Working-Class in England. 1209-2004', Journal of Political Economy, 113, 6, 2005, pp. 1307-1340.

wage for full-time employment in the 6th century BC.[56] This boils down to around 400 litres of barley. These figures are clearly maximum figures, since barns were of less value than houses. Even so, as is shown for England, it is unlikely that barn rents to have exceeded 6% of annual value of the grain stored.[57] Assuming that house rentals expressed in grain are proportionate to barn rents, this suggests a slightly lower figure for Babylon.

A similar result is obtained as regards storage losses. For England, Overton and Campbell have estimated storage losses at around 10% per annum.[58] For Babylon we do not have comparable data. However, a survey by Adamson showed that grain storage losses in Ancient Egypt were also at about the same level (10%), whereas in his opinion it must have been slightly higher in Mesopotamia due to less favorable climatic circumstances.[59] That fungal (and, similarly, lichen) attacks indeed posed a considerable threat to stored produce is shown by the numerous references in Babylonian scientific literature. One line of the omen collection *šumma ālu* dealing with various terrestrial phenomena reads: "If there is green fungus in a storage bin, there will be no grain in the man's house".[60] The mere fact that an entire tablet (comprising about 120 different presages) was dedicated to both fungus and lichen bespeaks volumes about the unpleasant experiences Babylonians had with crop parasites. In general, storage losses for dates were likely to be lower than for grain, and we may assume for barley and dates together an average storage loss of around 10%. Yet, even though this number is clearly subject to wide margins of error, the share of storage losses in total storage costs is sufficiently small to take this number as given.

This brings us to the most important and most discussed variable, interest rates. Interest rates are difficult since they may vary widely from 10% on standard loans to more than 50% on consumption credit for farmers. Also the way in which credits are calculated can

---

[56] Jursa, *Aspects of the Economic History of Babylonia,* p. 686.

[57] G.E. Fussel, ed., *Robert Loder's farm accounts: 1610-20*, Camden Soc. 1936, pp. 158-159.

[58] Overton and Campbell, *Production et productivité dans l'agriculture anglais.*

[59] P.B. Adamson, *Problems over storing food in the Ancient Near East*, Welt des Orients, 16, 1985, pp. 5-15.

[60] Sally M. Freedman, *If a city is set on a height*, Vol. 1 (OPSNKF), Philadelphia, 1998.

vary. Consumption credit for farmers may be given close to the new harvest, when grain prices are still high. Expressed in part of their harvest, they have to repay for example 2 bushel of barley. Yet, if, just after the harvest, they have to repay and prices are halved, they have to repay 4 bushel of barley. The choice of interest rate is therefore of crucial importance.

For Babylon direct evidence on interest rates is scarce. Some evidence is summarized in Table 6. Admittedly, most of these data – the promissory notes concerning the redemption of a silver (or, seldom commodity) deposit – are rather to be interpreted as penalty clauses, i.e. people pay only after an initial interest free period.[61] Yet, since the penalties are formulated as interest rates (and likewise they accrue monthly) we would not hesitate to identify these as *de facto* interest rates, especially in the light of the fact that Late Achaemenid "real" interest rates were hardly smaller, ranging between 25 and even 40% per month for silver loans. The most interesting point, however, is that interest on commodity loans was always higher than silver loans. [62] The average interest rate on silver was about 34% per annum, yet for commodity loans we find interest rates as high as 80% and 100%. These numbers suggest that the risk on loans in grain was much higher although on average the amounts borrowed were much smaller. While the value of silver loans reached 30 shekels on average, grain loans remained around a few shekels per transaction usually. Also, the repayments were also in grain, which suggests a lack of direct money income.

Table 6 about here

---

[61] See Michael Jursa, *Agricultural managing, tax farming and banking: aspects of entrepreneurial activity in Babylonia in the Late Achaemenid and Hellenistic periods*, in P. Briant and F. Joannès, eds., La transition entre l´empire achémenide et les royaumes hellenistiques (Persika 9), Paris: De Boccaard 2006, pp. 137-222.

[62] Sidney Homer and Richard Sylla, *A History of Interest Rates,* Fourth edition, New Jersey: John Wiley, 2005, p. 27 point out already the Code Hammurabi had set a higher maximum interest rate on loans in grain than loans in silver. This changed only around 600 BCE when the maximum for both commodities became equal. However, as pointed out in the text, *de facto* the interest on loans in produce remained higher.

These interest rates are slightly higher than in medieval England where, as argued by Homer and Sylla interest rates between 10% for institutional loans[63] and more than 50% for individual loans[64] are attested.[65] It is remarkable, though, that the height of the interest rates in both periods is so similar, especially after the much lower interest rates in the intervening centuries. The structure of both sets of interest also bears a marked resemblance. Whereas the usury laws in England were well known, the term "interesse", which became standard from 1220 onwards, became used to circumvent these laws. It referred to a compensation or penalty for delayed repayment of a loan.[66]This compares well to the penalty clauses in the Babylonian contracts where, after an initial interest free period, a monthly interest was asked.

It is, however, useful to have direct comparison of interest rates in both countries using a common unit. A possible proxy for interest rates, as suggested by McCloskey and Nash, is the net revenue to the value of capital invested in animals. In order words, the net annual output of an animal (i.e. minus costs) divided by the total value of the animal yields an estimate for the interest rate.[67] For this exercise we use sheep, first, because they were both abundant in Babylon and England, second, because they generally are not fed on additional food like beans or oats (thus little extra costs are incurred), and third because sheep flocks reproduce and hence we are not confronted with depreciation. We can look at it more formally as:

$$i \cdot P = R - C$$

, where i is the interest rate, P is the price of a sheep, and R and C are the revenue and costs of a sheep. Rewriting gives:

$$i = \left(R/P\right) - \left(C/P\right)$$

---

[63] See also Clark, 'The cost of capital'.
[64] See also McCloskey and Nash, 'Corn at Interest', p. 183.
[65] Homer and Sylla, *A History of Interest Rates*, p. 89.
[66] *Idem*, p. 17/
[67] *Idem*, pp. 183-184.

, where the costs (C/P), as just argued, are close to zero. This implies that the annual interest rate is almost equal to the annual revenue divided by the price.

McCloskey and Nash estimate for Crawley, Hampshire estate of the Bishop of Winchester around 1250 that the yearly stock of sheep was worth £56 and the earnings were £25.2, i.e. an interest of 45%.[68] For Babylon, the estimates are even more straightforward. Aperghis estimated the total value of sheep flocks as 1204 talents of silver for 3.648 mln sheep. Furthermore, he estimated the value of the total meat of those sheep as 241 talents and the wool as 620 talents for wool, which altogether yields an interest rate of 71.5%.[69] This suggests a lower interest rate in medieval England, although it is likely that, because of its abundance, the relative price of pastoral produce in England was lower than in Babylon, hence probably the gap in interest rate based on sheep is slightly overestimated. Nevertheless, both our sheep-based and our direct estimates confirm that interest rates in Babylon, contrary to the expectations of the McCloskey-Nash model, were slightly higher than in medieval England.

If we assume, following our discussion in the section on benefits of storage, that average annual benefits from storing in England would roughly be 25%, then only institutions and wealthy merchants were able to store grain against ca. 10% interest with 5-10% storage loss and ca. 5% barn rents. However, this assertion rests on a very low estimate of the actual storage costs and the assumption that wealthy merchants did not have alternative investment opportunities. As we have argued, storage loss in Babylon was the same, while the interest rate (opportunity costs) was higher. Combined with a lower potential profit from inter-annual storage, this makes private storage in Babylon even less likely than in England. It is therefore

---

[68] *Idem.*

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

likely that McCloskey and Nash model needs to be augmented and that some socio-economic factors also prevented storage.

The role of small farmers

The situation that at best only large institutions and wealthy merchants could possibly store grain profitably is not surprising when we view the relatively high interest rate in Babylon. Given that the possible profit in Babylon, as argued in Section 3, is lower than in England, this implies that, if McCloskey and Nash are correct, the interest rate in Babylon should be lower than in England. However, we do not find any evidence for this. This suggests, following the argument of Komlos and Landes (1991), that there were social barriers to obtain or supply loans in Babylon for small farmers. Since they were unable to invest in the capital market, their opportunity costs were of course lower; hence they could decide to store their produce, even when unprofitable, in order to prevent famine. However, this also does not match with the evidence for low storage from Section 2.

Indeed, there is plenty of evidence for both countries that small farmers were unable to easily acquire (or provide) loans. In England small farmers could not have borrowed much since they often had to repay commodity loans in money at unfavorable terms. The most frequently recurring scenario saw peasants borrowing just before the harvest when they either ran out of seed or out of food more generally. Repayment took place after the harvest. If now, as can be seen in our data, the prices after the harvest were ca. 20% lower, the consequence is that a monetary amount of 2 bushel before the harvest at 20% interest amounts rather to 3 bushel after the harvest, i.e. an actual interest rate adding up to 50% instead of the written 20%.

As regards Babylonia, we do find in Table 6 that interest on loans in barley or dates have much higher interest. In addition, these are very small loans compared to those in silver. One

possible explanation of this phenomenon was given by Flynn and Gíraldez:[70] due to the small extent of monetization silver was a more sought after commodity, hence repayments in kind were charged a comparatively high interest to make repayment in cash more attractive. Such a line of argument is also congruent with our notion of high interest rates due to a low level of monetization and low availability of silver. It is also clear that the silver loans considered so far stem from an urban context, the people involved in these transactions were high temple officials or urban entrepreneurs (or both) with a certain access to cash money. As regards small farmers in a rural setting, however, the evidence points quite unambiguously to lack of access to capital markets. The promissory notes from the Murašû-archive (Late Achaemenid period, late 5th century) from Nippur in Southern Babylonia (as well as those from several other smaller archives) shows that in a rural context credit was in most cases extended by specialized entrepreneurs to tenants of "fiefs" (no specific analogy to the feudal system of medieval Europe is implied; the term is used here simply to denote land on which service was incumbent in a general way) so that the latter could pay their tax obligations – and not for productive purposes.[71] This claim is in so far justified as repayment in this substantial text corpus is invariably stipulated a) in kind and b) in the harvest month. The importance of loans to fulfil tax obligations is shown by other archival evidence which shows an increasing tax burden for the later part of the Achaemenid reign over Babylonia, starting with Darius I (523-486).[72] Credit for productive purposes on the other hand, e.g. in form of so-called *harrānu*

---

[70] Dennis Flynn and Arturo Gíraldez, 'Cycles of Silver: Global Economic Unity through the Mid-Eighteenth Century', *Journal of World History,* 13, 2, 2002, pp. 391-427.

[71] The system was first described by Matthew Stolper, *Entrepreneurs and empire. The Murašû archive, the Murašû firm, and Persian rule in Babylonia*, Istanbul, 1985. On credit see particularly p. 104-107. The most recent description of the system is in Jursa, *Aspects of the Economic History of Babylonia*, pp.198-203.

[72] Michael Jursa and Caroline Waerzeggers, 'On aspects of taxation in Achaemenid Babylonia: new evidence from Borsippa', in P. Briant and M. Chauveau, eds., *Organisation des pouvoirs et contacts culturels dans les pays de l' empire achéménide* (Persika 14), Paris, pp. 237-269. Also Jursa, *Aspects of the Economic History of Babylonia,* p. 252 emphasizes the dependence of these small-scale farmers "on outside funds in order to be able to fulfil their tax obligations" considered "potentially disruptive to the economy" (Jursa 2010, p.60)

*(*trading)-partnerships is again confined to the higher strata of (urban) society.[73] Hence, it is not implausible that those loans were in certain ways comparable to the consumption loans made to small farmers in England around 1300.

Small farmers thus clearly had only limited access to the capital market. This suggests that, notwithstanding the low opportunity costs, small farmers were still largely unable to store grain. Indeed, if, following Jursa (2010), even a large producer as the temple in Ebabbar was unable to store grain, this was even more unlikely for the small farmers.[74] At the same time, we saw that many small farmers borrowed solely for immediate consumption and taxation needs, which will have left them little opportunity to store their products for speculative behavior the next year. In addition, in Section 2, we showed that there must have been a famine line of close to 90 in Babylon. This suggests that only a 10% failed harvest could already result in famine. Such high famine line, especially in combination with high taxes, makes it unlikely that farmers were able to store anything, even with low opportunity costs.[75] Hence, inter-annual carryover must have been limited and restricted largely to some leftovers of seasonal -and government storage.

Conclusion

Storage is one of the main ways of reducing risk, and hence increasing market efficiency, in food markets. Using a large corpus of price data on Babylon which has recently come available, we find that storage was small, which is in agreement with findings for medieval England. Following the literature, this seems to suggest that market efficiency and, hence,

---

[73] Jursa, *Aspects of the Economic History of Babylonia*, pp. 206-208. On the distinction between rural consumption loans and urban credit for business activities see also the succinct summary remarks (p.249-50) in: C. Wunsch, 'Debt, interest, pledge, and forfeiture in the Neo-Babylonian and Early Achaemenid period: the evidence from the private *archives'*, in: M. Hudson and M. van der Mieroop (eds.), *Debt and economic renewal in the Ancient Near East*, Bethesda MD, 2002, pp. 221-255.

[74] Jursa, *Aspects of the Economic History of Babylonia.*

[75] For a similar argument on subsistence and famine frequency see Ó Grádá, *Making famine history*, p.8,

economic development between the last centuries BCE and the late medieval period was limited.

In order to compare storage in Babylon and England we use the model of McCloskey and Nash (1984) as a point of departure. We have to make some modifications though to capture the divergent agricultural structure in both countries. In England wheat and barley were comparable crops with a correlation of annual production close to zero. Hence, their variances can be added together, which results in relatively high annual price fluctuations and, hence, relatively high potential profits. In Babylon, however, the production of dates and barley were negatively correlated. This implies that the effect of a harvest failure in barley was likely to be mitigated by a better harvest of dates. This reduced the standard deviation of total crop output and, hence, reduced price volatility and therefore lowered potential profits of storage compared to England.

Since in the McCloskey and Nash model costs and benefits must be equal in the long-run in this model, one would expect that the lower average intra-annual price volatility in Babylon would go hand in hand with lower interest rates; however our finding is that interest rates are higher in Babylonia, and more importantly, access to the capital market was limited to the urban elites. The case of Late Achaemenid/Hellenistic Babylonia thus underscores the importance of the objections of Komlos and Landes (1991) and points to the crucial role of socio-economic structure in determining the level of the interest rate and the plausibility of storage taking place: in Babylonia, tax requirements prevented both the larger institutions and the small peasantry from storage on any significant scale. Additionally, the unexpected behavior of Babylonian interest rate challenges the explanatory power of McCloskey and Nash's model: the limited access to capital markets seems emerges as more powerful explanatory factor, the mere focus on a cost-benefit dichotomy disregards the economic reality of pre-industrial societies.

Appendix A.1. A Monte Carlo simulation of the Impact of storage on famine

In order to explore the possible impact of storage on hunger, we have applied a Monte Carlo Simulation. The model is based on the following assumptions:

1. The production (P) is a normally distributed random variable with an expected value of 100 and a standard deviation differing by region (13 in England, 6 in Babylon).

2. The famine limit (F) is 70, 80, or 90. When the production (P) drops below this level, people do not store any grain, and when the consumption (C) drops below it they will use up as much from their storage (providing there is enough grain stored) that their consumption reaches the limit. If there is not enough grain stored in the storage they empty the storage completely.

3. The storage mechanism works as follows: when the production is less than or equal to the famine limit, people consume all the produced grain, none is stored, and as described at point 2, the stockpile (S) may even be reduced. When the production is above the limit, a fixed percentage (denoted by a) (0, 1, 5 or 10%) of the production above the hunger limit is brought to the storage.

4. We assume that the stored grain does not perish. Even though this is of course not true, still we wanted to keep the model as simple as possible.

The model is the following algebraically:

if $P_t > F_t$: $S_t = S_{t-1} + a(P_t - F_t)$ and $C_t = P_t - a(P_t - F_t)$

if $P_t \leq F_t$ & $S_{t-1} \geq F_t - P_t$: $S_t = S_{t-1} - (P_t - F_t)$ and $C_t = F_t$

if $P_t \leq F_t$ & $S_{t-1} < F_t - P_t$: $S_t = 0$ and $C_t = P_t + S_{t-1}$

In the Monte Carlo Simulation we generate a series with 3500 observation (simulating 3500 years), and we run the experiment with an initial storage of zero assumed 500 times under different assumptions regarding the key parameters of the model. For each of the 500

experiments we save the number of years where the consumption falls below the famine limit. The average of these, divided by 3500 gives the estimate of the probability of famine (p).

In order to estimate the average waiting time between two famines, we used a geometric distribution with parameter p, which has the probability mass function: $(1-p)^k p$. The average waiting time is simply the expected value, that is $\frac{1-p}{p}$.

Table 1. Barley rates (litres per shekel) in Babylonian month II 186 SE (27 Apr.-25 May 126 BC in the Julian calendar)

Commodity	Designation	Day	Price equivalent
Barley	---	1	18 (-35)
		until 7	20
		8-10	18
		11-end of month	21
	new	15	36
		16-17	45
		18	36
		19-22	33
		26-end of month	40

Source: Slotsky and Wallenfels, *Tallies and trends*, text 9.

Table 2. Expected number of years between famines for various famine lines and carryovers

(average production =100)

Country	Famine line relative to 100	Carryover (percent)			
		0	1	5	10
England	70	93.9	167.3	2,499.0	72,915.7
	80	15.1	18.8	50.7	212.4
	90	3.5	3.7	4.7	6.3
Babylon	70	Inf.	Inf.	Inf.	Inf.
	80	2,332.3	8,292.8	Inf.	Inf.
	90	19.9	25.9	87.6	501.2

Note: 500 simulations, std dev England =13, Babylon 6.

Table 3a. Average growth per month for wheat prices in England, 1270-1345

					To:						
From:	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**
September	5.86%	3.51%	3.35%	5.21%	1.59%	1.83%	3.54%	3.45%	2.99%	3.29%	1.67%
October		7.27%	2.86%	4.91%	1.96%	1.09%	2.42%	2.61%	1.79%	3.41%	1.28%
November			7.54%	1.78%	1.98%	1.44%	2.36%	0.75%	0.30%	1.07%	0.62%
December				6.29%	3.77%	2.77%	2.18%	1.75%	2.11%	0.84%	0.25%
January					11.10%	4.86%	6.45%	6.60%	4.24%	0.33%	-0.71%
February						4.93%	2.81%	4.89%	2.58%	2.45%	0.80%
March							1.14%	3.39%	1.73%	0.72%	-0.80%
April								1.36%	-0.37%	1.07%	-1.90%
May									2.82%	2.81%	-0.42%
June										1.77%	0.67%
July											-1.25%

Table 3b. Monthly averages of growth of wheat prices in England, 1270-1345

September-October	3.30%	January-February	2.51%	May-June	1.30%
October-November	3.00%	February-March	2.39%	June-July	0.96%
November-December	2.49%	March-April	2.15%	July-August	0.02%
December-January	2.29%	April-May	1.71%		

Source: Table 3a and 3b calculated based on the monthly price data from Nick Poynder, 'Grain storage in theory and history', downloaded from http://www.iisg.nl/hpw/data.php#united).

Table 4a. Average growth per month for barley prices in Babylon, 350-60 BC

					To:						
From:	**July**	**August**	**sept**	**octy**	**Nov**	**dec**	**Jan**	**feb**	**march**	**april**	**May**
june	5.71%	2.76%	5.23%	6.41%	5.51%	7.02%	4.64%	3.55%	2.55%	2.24%	1.47%
July		-0.88%	3.92%	7.42%	3.29%	7.60%	4.75%	3.69%	2.13%	1.73%	1.29%
august			2.86%	2.79%	2.06%	4.10%	9.36%	7.71%	5.06%	3.54%	1.93%
sept				1.17%	3.53%	2.62%	7.34%	6.62%	2.16%	4.28%	0.67%
octy					4.14%	5.11%	6.60%	4.50%	1.61%	2.97%	0.06%
nov						11.51%	11.14%	6.37%	3.59%	2.81%	2.27%
dec							17.05%	9.13%	3.61%	4.33%	2.54%
Jan								-2.77%	-2.07%	-2.72%	-2.96%
Feb									-1.79%	-2.71%	-5.42%
March										-1.77%	-5.05%
April											-6.39%

Table 4b. Monthly averages of growth of barley prices in Babylon, 350-60 BC

June-July	4.28%	October-November	3.93%	February-March	1.32%
July-August	3.82%	November-December	4.35%	March-April	0.57%
August-September	4.22%	December-January	4.44%	April-May	-0.87%
September-October	4.07%	January-February	2.62%		

Source: Table 4a and 4b calculated based on the monthly price data from Slotksy, *The Bourse of Babylon*;
Vargyas, 'Les prix des denrées alimentaires de première nécessité en Babylonie'; Slotksy and Wallenfels, *Tallies and trends.*

Table 5a. Average growth per month of dates prices in Babylon, 350-60 BC

					To:						
From:	**nov**	**dec**	**Jan**	**feb**	**march**	**April**	**may**	**june**	**july**	**august**	**september**
October	1.52%	-4.11%	19.49%	13.26%	1.81%	2.72%	1.62%	1.04%	1.88%	1.36%	0.52%
November		2.52%	25.43%	15.84%	3.11%	3.77%	5.26%	6.28%	4.10%	2.11%	1.85%
Dec			12.90%	9.73%	6.38%	8.04%	4.45%	5.14%	4.63%	2.73%	2.46%
Jan				3.21%	0.85%	-2.63%	-0.67%	-0.54%	0.96%	-1.04%	-0.25%
Feb					-1.28%	-1.74%	-3.62%	-2.94%	0.06%	-0.49%	-0.48%
March						2.05%	1.38%	1.48%	2.58%	0.89%	0.39%
April							0.72%	-0.12%	1.65%	1.01%	0.95%
May								-3.09%	0.80%	-0.76%	-0.50%
June									2.50%	2.24%	3.48%
July										0.52%	0.49%
August											0.18%

Table 5b. Monthly averages of growth of dates per month in Babylon, 350-60 BC

October-November	3.74%	February-March	1.64%	June-July	1.32%
November-December	5.49%	March-April	1.54%	July-August	0.87%
December-January	6.22%	April-May	1.35%	August-September	0.83%
January-February	3.44%	May-June	1.08%		

Source: Table 5a and 5b calculated based on the monthly price data from Slotksy, *The Bourse of Babylon*;
Vargyas, 'Les prix des denrées alimentaires de première nécessité en Babylonie'; Slotksy and Wallenfels, *Tallies and trends.*

Table 6. interest rates in Babylonia

Text	Interest rate	Amount	Date	Commodity and transaction	Literature
NCBT 1052	25% p.a. (1 1/4 shekels per mina per month)	55 shekels of silver	---	Promissory note	Stolper 1990, 22
UCLM 9-2918	40% p.a. (2 shekels per mina per month)	70 shekels of *qalû*-silver	3 VIII 14 Art	Promissory note	Stolper 2000, p.676f.
HSM 913.2.212	25% p.a. (1 1/4 shekels per mina per month)	2 minas of *qalû*-silver	6 IV 34 Art (I or II)	Promissory note	Stolper 1990, 5
YBC 5331	30% p.a.[76] (1 ½ shekels per mina per month)	16 ½ shekels of silver	VIII 35 Art (I or II)	Promissory note	Stolper 1990, 14
BM 109977	80% p.a. (1 *sūtu* per *kurru* per month)	22 *kurru* of dates	12 VI 15 Dar II	Promissory note (*imittu*)	Stolper 1990, 9
HSM 913.2.220	25% p.a. (1 1/4 shekels per mina per month)	8 *kurru* of barley	19 III 16 Dar II	Promissory note	Stolper 1990, 7
CT 49 34	40% p.a. (2 shekels per mina per month)	---	IX 3 Antigonus	Promissory note (redemption of a silver deposit)	Stolper 1993, 18
BM 62684	80% p.a. (2 *sūtu* per *kurru* per month)	120 litres of dates	23 *x* 3 P.A	Promissory note (redemption of a date deposit?)	Stolper 1992, A2-4
BM 77203	40% p.a. (2 shekels per mina per month)	22 shekels of silver	1 I 4 Antigonus	Promissory note (redemption of a silver deposit?)	Stolper 1993, A2-6
BM 109974	10% p.a. (3 *sūtu* per *kurru*)	8 *kurru* of fine barley	11 XI 5? Antigonus	Promissory note	Stolper 1993, A2-8
HSM 893-5-17	40% p.a. (2 shekels per mina per month)	8 shekel of silver	23 VII 6 Alex IV	Promissory note (redemption of a silver deposit?)	Stolper 1993, A2-10
CT 49 102	100% (p.a.?)	15 kurru of white barley	24 SE?	Promissory note (redemption of a commodity deposit)	Stolper 1993, 17
CT 49 106	40% p.a. (2 shekels per mina per month)	158,5 shekels of silver	before 9? IX) 35 SE	Promissory note (redemption of a silver deposit)	Stolper 1993, 12
BM 54555	80% p.a. (2 *sūtu* per *kurru* per month)	300 litres of white, good-quality barley barley	36 SE	Promissory note (redemption of a commodity deposit)	Jursa 1998. 17
CT 49 111	40% p.a. (2 shekels per mina per month)	5 vat of prime beer, 20 loafs of good bread	13 IX 42 SE	Promissory note (redemption of a commodity deposit)	Stolper 1993, 13
BM 59748	20% p.a. (1 shekel per mina per month)	5 shekels of silver	28 XII$_2$ 42 SE	Promissory note (tithe)	Jursa 1998, 16
CT 49 112	40% p.a. (2 shekels per mina per month)	½ mina of silver	42? SE	Promissory note (redemption of a silver deposit)	Stolper 1993, 16
BM 55437	40% p.a. (2 shekels per mina per month)	6 minas of silver	4 V 46? SE	Promissory note (redemption of a silver deposit)	Stolper 1993, 15

---

[76] Jursa, Persika 9, p.161: missed deadline.

CT 49 116	40% p.a. (2 shekels per mina per month)	---	49 SE	Promissory note? (redemption of a commodity deposit)	Jursa 2006, p.185
CT 49 119	80% p.a. (2 *sūtu* per *kurru* per month)	48 litres of barley	28 x 51 SE	Promissory note (redemption of a commodity deposit)	Jursa 2006, 188f.
CT 49 120	80% p.a. (2 *sūtu* per *kurru* per month)	2 shekels of Silver (convertible to 2 *kurru* of barley after first deadline)	XII 52 SE	Promissory note (redemption of a silver/commodity deposit)	Jursa 2006, p.189f.
CT 49 121	40% p.a. (2 shekels per mina per month)	80 shekels of silver	54 SE	Promissory note (redemption of a silver deposit)	Stolper 1993, 14
CT 39 133	25% p.a.(?)	40 shekel of silver	25 [VII] 96 SE	Silver deposit	Stolper 1993, 10
CT 49 134	25% p.a.(?)	40 shekel of silver	19 [VII] 100 SE	Silver deposit	Stolper 1993, 11

Sources: Matthew Stolper, 'Late Achaemenid legal texts from Uruk and Larsa', *BaM*, 21, 1990, pp. 559-622; Matthew W. Stolper, 'Late Achaemenid, Early Macedonian, and Erly Seleucid records of deposit and related texts', *AION Suppl.*, 77, Napoli, 1993; Matthew Stolper, 'Buildings on bow lands and encumbrances on buildings', in R. Dittm,ann *et al*., eds., *Variatio delectat. Iran und der Westen (Fs. P. Calmeyer),* Münster, 2000; Michael Jursa, *Der Tempelzehnt in Babylonien vom siebenten bis zum dritten Jahrhundert v. Chr.,* Münster: AOAT 254, 1998; Jursa, 'Agricultural managing, tax farming, and banking'.