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On the role of families and kinship networks in pre-industrial agricultural societies: An analysis of the 1698 Slavonian census

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Abstract. This paper uses the 1698 Slavonian census to illuminate features of social organization and productive activity of an eastern European population under the New Feudalism of the 17th century. In particular we investigate the ability of community or kinship networks to provide substitutes for missing markets in securities and production factors. It is found that kinship networks increase the efficiency of agricultural production by facilitating the exchange of oxen. This confirms contemporary reports that draft animals were the critical constraint to the expansion of agricultural output. We also find that kinship networks fail to reduce the variability of output through mutual harvest insurance.

JEL classification: D1, D8, N3

Key words: Kinship networks, pre-industrial societies, missing markets

1. Introduction

The institutions of medieval agricultural economies are shaped by the interaction of social structure, environmental constraints and economic incentives (de Janvry et al. 1991, Fafchamps 1992, Townsend 1993). This paper illuminates features of the social organization and productive activity of an eastern European population under the New Feudalism of the 17th century, implementing tools from historiography, historical ethnology, demography, and economics. We concentrate on grain cultivation, the marshalling of human

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and animal labor, and the diversification of agricultural production in the setting of frontier Slavonia. Besides the inference of agricultural conditions and primary economic constraints, we examine particularly the ability of kinship and community networks to increase the efficiency of agricultural production and to provide insurance against output variability.

We begin our analysis with a description of the economic and social situation in 17th century Slavonia in Sect. 2, followed by an explanation of the 1698 census and its augmentation to establish kinship networks in Sect. 3. In Sect. 4, we shift to the economic analysis and focuses on the allocation of production inputs among related households, both theoretically and empirically. Section 5 investigates the diversification of agricultural production and addresses the role of kinship networks for mutual insurance.

2. Historical background

Slavonia lies between the Sava, Drava, and Ilova rivers, thus between Zagreb and a line about 140 kms. west of Belgrade (the boundary of Srem), and within the borders of modern Croatia (Fig. 1). Before the 17th century it included Moslavina, which lies west of the Ilova, and extended along the upper Sava as far as Zagreb. The region had been the western part of Roman Pannonia, with its capital at Siscia (modern Sisak). Overrun by Goths and others in the fifth century AD, it was settled by Slavs around the 6th and 7th centuries and controlled in various degrees by Croatian and Bosnian nobles until the 12th century. In 1122 AD the Croats came under the control of the Hungarian crown. In the late 13th century the Ottoman Turks began their drive into Europe, taking Belgrade in 1521 and annihilating the Hungarian forces at Mohacs on the Danube in 1526. At this point the Croats came under Habsburg

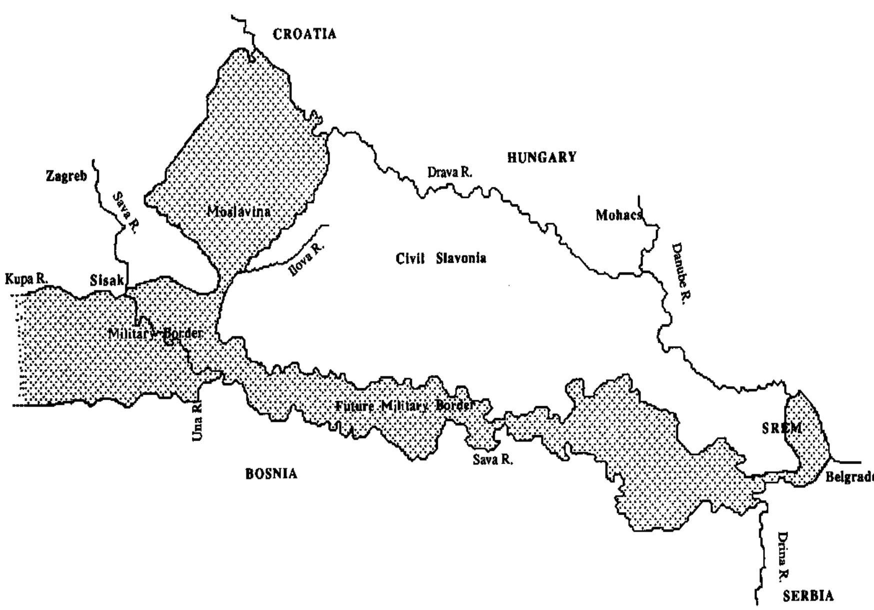

Fig. 1. Map of Slavonia, 1698

control, and defensive zones were established along the Alpine and Dinaric foothills. Nevertheless by 1683 the Turks controlled Slavonia to the Ilova and were at the gates of Vienna. Routed there in that year, they were driven back to the Sava by 1691, and the prosperous population of about a quarter million persons in that region was reduced to about 80,000. Refugees from other Habsburg and Hungarian regions, and both Orthodox and Catholics from Bosnia and Serbia migrated in large numbers to Slavonia and other parts of Pannonia. In 1698 the Austrian Crown commissioned a census of Slavonia to establish the basis for taxation and conscription, in defense against the continuing Ottoman threat. Ultimately the population was divided into two parts, one of civil serfs in a resurrection of mediaeval serfdom, the other of military serfs free of the usual feudal dues but obliged to provide perpetual military service, in a revival of a system that had manned Roman forts as far back as the third century.[1] In the late 17th century Slavonia was largely wilderness. Its once settled portions were devastated by war, and the region was covered by enormous swamps and stands of giant hardwoods like oak and beech surviving from the primeval European forest.

The region is notable for an entity serving as the basic economic and social unit: the *zadruga* (Hammel 1972, Rothenberg 1960). The zadruga consisted of a large patrilineally extended or fraternal joint household, possibly including several nuclear families, with collective ownership of land and strong internal discipline. In the environment of a self-subsistent agricultural society, exposed to the additional risk of severe military related manpower drain, the extended family unit zadruga prevailed until the 19th century.

The theories about the dissolution of the zadruga are manifold (Mosely 1940, Tomasevich 1995). They range from the institution of individual property rights that allowed nuclear farm families to hold land, to the termination of the organized military border, and the abolition of certain tax laws that were thought to explain the existence of the extended family. Yet, these views place too much emphasis on legal forms and paid insufficient attention to the social and economic conditions surrounding the zadruga. Tomasevich concludes that the major setback to the zadruga came from penetration of money and market economies. These changes forced the zadruga to be integrated in the economy via specialized production and market exchange, and allowed peasants to turn to the market for the services that could previously only be performed by extended family units and kinship networks: risk insurance and provision of production factors, such as labor or oxen, during peak season.

The theory that the dissolution of extended family units is linked to market penetration requires, however, that the zadruga could indeed provide these services previously. The analysis of labor and kinship networks in the agricultural production is therefore a first step in rationalizing the transformation of the zadruga, and more generally, in understanding the interaction of family structure and economic incentives in pre-industrial contexts.

3. The data

3.1. The 1698 Slavonian census

The census of 1698 (Mažuran 1988) provides most of the data for our analysis. Written in the bureaucratic Latin of the time, it gives detailed information on about 4,500 households (and less detailed information on more). Where the information is detailed, it gives the composition of the household by name of household head, kinship relationship to the head and a listing of the amount of land in various crops and the livestock owned, by kind of animal. (See Hammel and Wachter 1996a and Hammel and Wachter 1996b for analysis of the household structure and other population information in the census) After a village level summary, the census provides a prose account of current conditions and recent history, in a set of standardly numbered paragraphs. This prose summary provides important insights into the conditions faced by the inhabitants.

The census information is supplemented by data on the latitude, longitude, and altitude of the villages, most of these being identifiable on modern maps.[2] Because the religion of the inhabitants of the villages is often noted in the prose summary, it is also possible to assemble a list of first and last names that occur only in homogeneously Orthodox or homogeneously Catholic villages, in both of these kinds of villages, and in villages of mixed or unspecified religious composition.[3] From this evidence we are often able to impute religion at the household level, according to the name of the head. Similarly, the prose summary often gives an indication of whether the inhabitants of villages were military or civil serfs, or whether they were inclined to accept one or the other status; we used this information as a village-level variable. Some villages, and some inhabitants within some villages, are identified as having come from Bosnia, but this information is not consistently provided, and we use it only tentatively.

3.2. Imputing kinship

Last names were used to impute kinship relatedness. The leap of faith in this method is justified by family reconstitution records from c. 1720–1900, in which last names are fairly regularly inherited in the paternal line.[4] Our assumptions could be upset if the ancestral Slavic system of assigning patronymics as last names, based on the baptismal name of the father, were in full force, but it appears not to have been.[5]

There were 1679 Catholic households with 1064 unique names, and 1467 Orthodox households with 836 unique names, thus 0.63 names per household among Catholics and 0.57 names per household among Orthodox. By ‘unique name’ we mean a unique tokenized name that ignores minor spelling differences. In imputing kinship we eliminated all names that were indicative simply of Bosnian origin, e.g. tokenized as Bosnjak, since sharing such a name would be no grounds for assuming kinship relation. This removes one token from the Catholic and Orthodox namelists, 26 households from the Catholic and 126 households from the Orthodox household lists. The ratios of households to names are then 1063 : 1657 and 835 : 1341, thus 0.64 and 0.62 for Catholic and Orthodox, respectively. These ratios are virtually identical, but simulation experiments show that the distribution of names is such that a randomly drawn Orthodox household is more likely to find another household with a matching name than a Catholic household is. We allowed putative kinship to decay with distance. That is, for a household with last name X, another household with name X in the same village was assumed to be in the same kinship network. This inclusion in the network fell off rapidly as households with the same name were found further and further away.

For each household we aggregated the resources of labor, oxen, and cultivated land that were found in all other households with the same last name into network (NW) variables for labor, oxen and cultivated land. The resources of these households were weighted by distance. Specifically, we used a *bell-shaped* weight $w_b(d) = \exp(-(0.1 \cdot d)^2)$ and the *exponential* weight $w_e(d) = \exp(-0.1 \cdot d)$, where d is the distance between households in kilometers. The former captures the fact that the 'value' of network resources decreases only slowly with distance as long this distance is small, whereas the value diminishes more rapidly for large distances. In the latter case, the exponential weight assumes a constant rate of decay in the 'value' of network resources with distance. In both cases, we considered the network resources separately from the resources of the household and did not combine the two in one single measure.

For instance, consider household 'Tomasevich' for whom exist two other households with identical last names, with 4 and 5 male members respectively, at a distance of 3 and 10 kilometers. Then the network resources of labor (NW labor) for Tomasevich is calculated by $4 \cdot e^{-0.1 \cdot 3} + 5 \cdot e^{-0.1 \cdot 10} = 4.8$ network males for the exponential weight or $4 \cdot e^{-(0.1 \cdot 3)^2} + 5 \cdot e^{-(0.1 \cdot 10)^2} = 5.5$ for the bell-shaped weight. Experiments showed that the rate of decay made little difference to the outcome. Similar calculations were performed for network resources of oxen (NW oxen) and land (NW land). For each household we also obtained non-network (NNW) labor, oxen and land by aggregating the respective resources in households with different last names. The former NW variables hence reflect the amount of resources in a household's kinship network, and the latter NNW variables indicate the availability of production factors in the unrelated households in the same community. The results obtained in Sects. 4 and 5 did not turn out to very sensitive to the choice of the decay parameter of -0.1; in particular, qualitatively similar results were obtained when the measures of network resources, NW oxen and NW land, where replaced by a dummies that indicated whether or not the household had access to the respective network resources at all.

3.3. The economic setting of 1698 Slavonia[6]

Initial statistical examination of the census data showed that households consisted of about 3 male household members. The households held on average about 3 yokes of grainland[7], variously distributed across different kinds of grain, about half a row of grape vines, about 2 yokes in hayfield, around 1 ox, 1 cow, 1 calf, 3 sheep and goats, 2 pigs, and a beehive, plus 1 horse for every two households (Table 1).[8] The distributions are all sharply skewed; most medians are zero.

We do not know anything about redistribution or even original distribution of land. It is unlikely that at this date it could be sold or exchanged by the peasants but only by officials and feudal lords. There was no land market for peasants until the middle of the 19th century.

There is little or no evidence for specialization or substitution in the cultivation of land. For example, the correlation coefficients between all forms of livestock are positive (Table 2). This circumstance argues for a general differ-

Table 1. Descriptive statistics (4453 Households)

	mean	std. dev.		mean	std. dev.
Ethnicity/religion			Agriculture		
Proportion of households who are			Amount of land cultivated with[d]		
Catholic[a]	0.383	0.486	Vine Rows	0.689	1.271
Orthodox	0.329	0.47	Grain[e]	1.396	1.878
Protestant/Orthodox	0.009	0.097	Barley	0.210	0.504
Catholic/Orthodox	0.124	0.329	Oats	0.293	0.605
Military Serfs[b]	0.454	0.498	Maize	0.187	0.433
Bosnian Origin	0.026	0.159	Millet	0.391	0.943
Household size			Wheat	0.669	1.505
Number of males in			Other land		
household[c]	2.291	1.105	Uncultivated Land	1.031	2.636
Lifestock, etc.			Haycarts[f]	1.830	2.018
Number of			Scythes[g]	0.051	0.441
Horses	0.425	0.702	Network resources[h]		
Oxen	0.936	1.076	Number of		
Cows	1.012	0.895	NW labor	1.672	3.052
Calves	1.258	1.304	NW oxen	0.712	1.509
Sheep and Goats	2.662	6.313	NNW labor	578.7	244.9
Pigs	1.829	3.329	NNW oxen	246.4	131.9
Beehives	0.786	1.749			

Notes: [a] Religion Variables in the tables refer to the religion listed for the village unless imputed by last name. In 1121 households the religion is not identified in the census, and we interpreted this as 'unknown religion'. The religion dummies in the above Table therefore do not add up to one.
[b] This variable equals one for households in villages which seemingly have military status according to the census records.
[c] Males presumed to be over age 15 and possibly less than 60, in this and other tables.
[d] Land is measured in 'yokes', probably the amount of land that could be plowed in a day, thus about an acre.
[e] Frumentum, i.e., "grain", in this and later tables, but possibly "rye" or "rye-wheat mixture".
[f] Currus foeni, perhaps with the meaning of the land needed to grow a cartload of hay, in this and later tables.
[g] Falcator, perhaps with the meaning of the meadow land that could be scythed in a day, in this and later tables.
[h] The network resources were computed only for 4114 households due to missing information on the location of the villages for the other households. The calculations assumed the exponential weight.

Table 2. Correlation matrix for animals (4453 households)

	Horses	Oxen	Cows	Calves	Sheep and Goats	Pigs
Horses	1.00					
Oxen	0.49	1.00				
Cows	0.42	0.63	1.00			
Calves	0.49	0.57	0.76	1.00		
Sheep and goats	0.32	0.43	0.24	0.18	1.00	
Pigs	0.39	0.47	0.42	0.41	0.36	1.00
Beehives	0.21	0.21	0.23	0.21	0.14	0.31

Table 3. Correlation matrix for crops (4453 households)

	Vine rows	Grain	Barley	Oats	Haycarts	Maize	Scythes	Millet	Wheat
Vine rows	1.00								
Grain	0.29	1.00							
Barley	0.11	0.12	1.00						
Oats	0.22	0.21	0.201	1.00					
Haycarts	0.24	0.25	0.250	0.29	1.00				
Maize	0.02	0.22	0.005	0.01	−0.04	1.00			
Scythes	−0.04	0.14	0.056	0.03	−0.10	0.22	1.00		
Millet	0.08	−0.26	0.159	0.27	0.20	−0.16	−0.05	1.00	
Wheat	0.07	−0.33	0.248	0.36	0.31	−0.19	−0.05	0.60	1.00
Uncult. land	0.09	−0.27	0.220	0.27	0.30	−0.17	−0.04	0.49	0.64
	Vine rows	Grain	Barley	Oats	Haycarts	Maize	Scythes	Millet	Wheat
HH males	0.13	0.19	0.17	0.15	0.22	−0.01	0.07	0.15	0.15
HH oxen	0.21	0.35	0.32	0.47	0.40	0.00	0.11	0.33	0.46

entiation of the population by wealth, with the richer having more of all kinds of stock, and the poorer less. Similarly, there is no strong evidence of substitution in crops (Table 3). The only apparently strong exception is the negative correlation between frumentum on the one hand and milli and tritici on the other. Milli and tritici are millet and wheat, while frumentum means grain in general (like the German Korn); it may have been a synonym for either millet or wheat, although it appears not to have been for oats (avenae) or barley (hordei). Thus, this substitution appears to have been performed verbally by the census takers, not actually by the peasants. There is some weak support for the idea that maize (kukuruz) was a substitute for other kinds of grain, from statements in the prose descriptions (see below). Maize was introduced to the Balkans by the Ottomans, probably in the 16th or 17th C. The Slavic term, kukuruz, is derived from Turkish kokoroz, possibly from -oroz (rice) and koko- (stench), thus the 'rice of the lower classes.' Note the alternative Serbian term, mumuruz, possibly from -oroz and mumu- (with meaning parallel to koko-); see also the alternative term from Rumanian, mamaliga (Skok 1972, p. 228–229).

The census gives no evidence of the cultivation of the potato, but it is likely it had recently been introduced. The Slavic term, krumpir, is from German Gruntbir, Grundbirne (ground pear, cf. pomme de terre; see Skok 1972, p. 215). The potato was cultivated in Spain by the third quarter of the 16th century (Salaman 1949, p. 143) and possibly introduced to Austria by the Habsburgs. Most of the scanty evidence suggests it reached the Balkans after maize (Čapo 1995). Even the Austrian censuses of 1830–47 do not mention the potato, but neither do they mention any other tubers or vegetables such as turnips, cabbage, etc., which were surely being grown. There is thus every reason to believe that some households were growing potatoes and other garden crops in addition to grain, and to conjecture that some may have been engaged in essentially swidden horticulture without growing grain at all.

It appears, therefore, that the census concentrated on economic assets that were felt taxable or capable of commercial exploitation; this area did engage later in commercial grain production on the large estates. It is also of interest to note a weak but significant negative correlation ($r^2 = 0.10$, $p < 0.0001$) between the percentile rank of households in a village list and the total amount of land devoted to grain cultivation; that is, there is some weak ordering of households by wealth, the poorer being listed last.

Travellers through the region in the 19th century generally deplored the state of agricultural practice, especially in the Military Border where there was no commercial development but only subsistence agriculture (Marczali 1910). The accounts suggest that agriculture was extensive rather than intensive. Certainly in 1698 there appear to have been too few farm animals to provide enough manure for regular fertilization. Fragmentary evidence from the chronicle of the monastery of Cernik from an even later date (Jančula 1980) suggests that cattle were usually pastured in the commons or waste; without stall-feeding it is difficult to recover enough manure for fertilization. Similarly, sheep must be carefully penned on the grainfields to utilize their manure; there is no evidence at all of this practice in Slavonia at any time. The large swine herds, later a characteristic of the region, seem not have appeared by 1698, and even in the 19th century swine were pastured mostly in forest, not on stubble. To be sure, the relationships that emerge from our analysis cannot take into account that realm of economic activity unrelated to major field crops, but we believe that they provide a reasonable description of grain agriculture.

The last two lines of Table 3 show that the labor and oxen resources of the household are positively correlated with the amount of cultivated land in different crops. In particularly, the number of oxen is strongly correlated with the cultivation of grain, barely, oats, millet and wheat, and to a somewhat lesser extent is the number of males correlated with these crops (all correlations with these crops are significant at 1%). Households with abundant male labor and oxen hence tend to have more land under cultivation. Nevertheless, there are intriguing clues in the prose summaries that led us to look further. Here are some examples:

Incolae hi haidonicales pro exercenda sua rurali oeconomia et terreno incolendo per defectum pecorum insufficentes sunt, ex eo vicinos fundos non usuant. (These military serf inhabitants have insufficient cattle for the exercise of their rural economy and inhabited terrain and on account of that do not use neighboring lands.) Sentences of this meaning, with numerous variations, are extremely common and almost universally found in some districts. Sometimes the statement only says that the inhabitants are incapable of cultivating their land, without mentioning the lack of cattle, but such statements are much rarer. It is extremely rare to find the statement that the inhabitants of a village have sufficient capacity to use the land of a neighboring village. The collective noun pecus (gen. pl. pecorum) means ‘stock’ and could refer to any of the animals listed in the census. However, sheep, goats, pigs, and bees are not employed in working the land. Similarly, although horses and cows can be used to pull a plow, their use is rare except on light soils (or where plow horses, like Belgians, have been bred for this purpose). The best horses in Pannonia in historical times have usually been Hungarian, and they are riding horses, not plow horses.[9] Thus, it seems most likely that the lack of cattle refers particularly to oxen, who were the main source of power for plowing in mediaeval Europe and in 19th century Croatia. Oxen would have also been important in Slavonia for pulling stumps in the extensive forest clearing that was necessary prior to cultivation of field crops (but not garden crops). We concentrate on the oxen as a limiting factor of production.

A second clue is an occasional sentence that refers to annual floods of the Sava, e.g. *Locus hic inter palludes et sylvas alninas collocatus* ... (This place is located between swamps and alder forests[10]).... *Quamvis fundus hic tam palludinosus sit per inundationes Savi* ... (This land is very swampy because of the floods of the Sava ...). In the chronicle of the monastery of Cernik during the 18th century, there is evidence that these swamps were malarial (Jančula 1980), and later travellers in the region also noted such conditions in Pannonia (e.g. 'Banat fever' after the neighboring region of Banat in Pannonia). We use information on the altitude of villages to approximate these circumstances, which would have made tillage more difficult, not only because of disease but because of drainage and other soil problems.

A third clue is the rare sentence that suggests that inhabitants in forested regions and lacking oxen might plant maize in the clearings as a substitute for other grains; e.g. ... *ob defectum iumentorum sunt incapaces, suntque meri fossores kukurczarii* ... (... because of a lack of plow oxen they are incapable [of field agriculture] and only [plant] maize in clearings ...). This suggests the modest substitution noted in the correlations earlier.

We have already suggested the general absence of specialization and substitution between kinds of crops or kinds of animals listed in the census. This is an interesting finding, since the inhabitants of the area came from diverse ecological and cultural backgrounds. For example, about 33% of the households have names that are found only in homogeneously Orthodox villages. The Orthodox population of the region is generally thought to have been more inclined to pastoralism and is usually referred to as Vlachs in the general historical literature on the region. There were also Catholic Vlachs, known as Bunjevci, but they are indistinguishable in these data from other Catholics. While a complete analysis of the economics of households is beyond the scope of this paper, we can briefly observe that there appear to be no substantial differences between Orthodox and Catholics other than that the Orthodox seem to be slightly richer. Thus, the Orthodox have more animals per household than do the Catholics, but they also have more grain land. The ratio of grainland to livestock and of oxen to male labor is also higher for the Orthodox, suggesting a more settled and secure existence, rather than the poverty of upland pastoralism with which they are associated in the mountains of Bosnia, Serbia, and the Dalmatian hinterland. It is of course possible that most of the Catholics were Bunjevci, but that seems unlikely in regions so close to the Danube, since some Catholics had been resident under the Ottomans and others had migrated in from more northerly regions of Croatia or from Hungary. Most Croatian historians assume that the remnant population of Slavonia in 1691–1698 was Catholic. We might imagine that the remnant population might have more assets than any immigrants, yet the data for 1698 suggest that the Orthodox had more assets than the Catholics. The census does show that individuals labeled as immigrants from Bosnia had less than average assets. Were such immigrants more often Catholic than Orthodox? Were Catholics the core of the remnant population, or did Orthodox form a large part? These are important historical puzzles (fraught with current political implication), and we do not attempt to treat them here in more than a cursory way.

Since the census listings on female household members appear erroneous (see Hammel and Wachter 1996b) we use the term 'labor' in this analysis for male household members only. Furthermore, data problems restricted the subsequent analyses to a subset of the 4453 census households. First, for 339 households we were unable to obtain adequate information, especially on location and thus on altitude. Second, we concentrated on those households that had at least one ox and that were not named simply 'Bosnian' – a name indicating purely the origin of a recent immigrant but no family relation.[11] These numbered 2427. The excluded households consist of 458 cases that reported no cultivated land, and of 1228 cases that apparently engaged in grain agriculture but had no oxen. We could not explain the cultivated land of these households by any inter-household factor exchange. Since oxen are indispensable for ploughing, we do not yet understand the conduct of grain agriculture by these households. Several explanations are possible. First, maybe households with cultivated land and no oxen were poor in oxen, but not otherwise, and were allowing others to cultivate their land in some share-cropping arrangement? Second, maybe such households were recent arrivals who had received a land allocation (which they declared to the census takers) but did not yet have the resources in oxen to actually cultivate it? Third, maybe such households were cultivating crops that did not require oxen, such as maize? None of these alternatives can at the moment be confirmed by our data and the investigation of this pattern is left for future analyses. In the context of the present analyses, however, there seems to be no evidence that the land cultivation of these households is facilitated via network oxen that are borrowed or exchanged from related households: the amount of cultivated land for households without own oxen is not systematically different depending whether or not the household has access to network oxen. Hence, for these household having network oxen does not improve the ability to cultivate land.

Figure 2 depicts histograms for household labor and oxen, and network labor and oxen respectively, for the 2427 households which are included in the subsequent econometric analyses (i.e., households which cultivate land and have at least one ox), and Table 4 reports the respective summary statistics. The households with no network resources constitute the peasants with unique last names. For the remaining households the histograms show that network resources may augment the household's own production factors, sometimes even to a substantial extent.

4. Kinship networks and agricultural production

This environment of 1698 Slavonia allows us to investigate the effect of kinship network on agricultural production. Binswanger and McIntire (1987) establish features of preindustrial agricultural societies that, given the nature of economic environment in 1698 Slavonia, should be detectable in the census information. They show under relatively weak assumptions, such as low population density and abundance of cultivable land, that (*a*) there is no locally resident non-cultivating labor class, (*b*) there is practically no hiring and exchanging of labor among resident farmers, (*c*) cultivated area per working household member is largely invariant to household size and wealth, and (*d*) that livestock is a major form of wealth and insurance substitute. These arguments assume, however, that there are no bottlenecks in production. This may not be true in many situations. If bottlenecks exist, Binswanger and McIntire's conclusion does not hold and cooperation among peasants becomes advantageous.

The scarcity of oxen indicated in the prose of the census is confirmed by a simple OLS regression of household grainland on household oxen, household

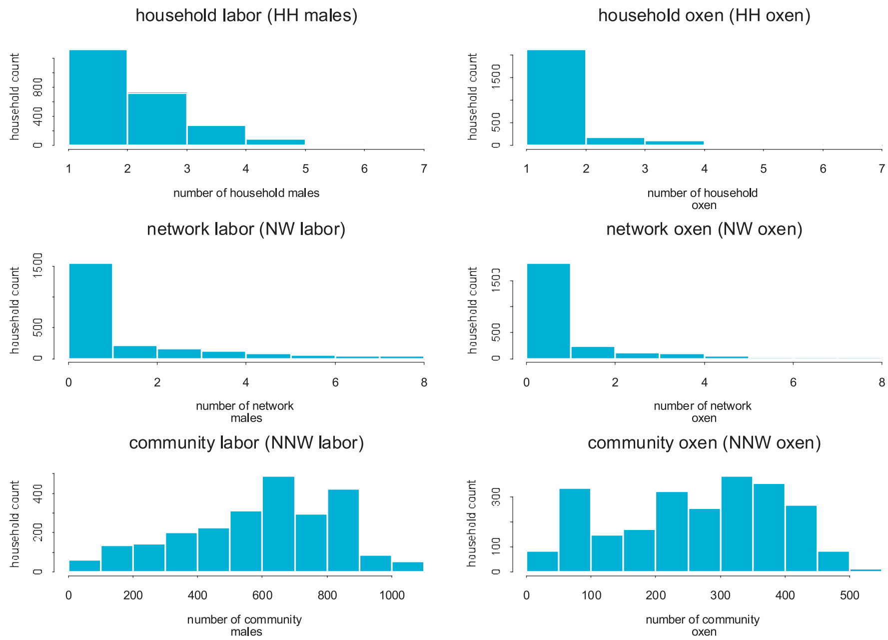

Fig. 2. Histograms of the labor and oxen resources available to households (only for households which are included in econometric analysis, i.e., households which cultivate land and have at least one ox)

Table 4. Summary statistics for the households which are included in the econometric analysis (2427 households)

	mean	std. dev.
Proportion of households who are		
Catholic	0.283	0.341
Orthodox	0.240	0.330
Total amount of cultivated land	4.497	3.090
Household resources		
Number of HH males	2.513	1.109
Number of HH oxen	1.619	0.975
Number of NW males	1.756	3.084
Number of NW oxen	0.838	1.639
Number of NNW males	596.2	235.8
Number of NNW oxen	263.4	126.4

labor, network oxen and network labor (see Table 5). As expected, oxen and labor are both associated with more cultivated land, although the latter has only a minor effect. Interestingly, network oxen contribute significantly to the variation in households' arable land. This simple initial result led us to speculate that the oft-mentioned insufficiency of oxen (defectum pecorum) might have been ameliorated by the lending of oxen between kin- related households. The question of whether these factor exchanges are restricted to kinship networks or extend to a more general help among neighbors follows naturally.

Table 5. Linear regression of household grainland on household and network labor and oxen

Variable	Value	Std. Error	*t* value	*p* value
(Intercept)	0.3834	0.1287	2.9802	0.0029
Household oxen	2.0242	0.0485	41.7350	0.0000
Household labor	0.2926	0.0421	6.9410	0.0000
Network oxen	0.2882	0.0552	5.2211	0.0000
Network male	−0.0795	0.0293	−2.7176	0.0066

Notes: Network resources were calculated on the basis of exponential weights. Residual standard error: 2.248 on 2422 degrees of freedom; Multiple R-Squared: 0.4715; F-statistic: 540.3 on 4 and 2422 degrees of freedom.

The next two subsections treat the problem of factor exchange among peasant households theoretically, starting with a household optimization problem and leading to the estimation of this relation from the limited 17th century data. The results are reported in Sect. 4.3, and readers less interested in the technical details may skip the formal analysis.

4.1. On the estimation of production functions without observed outputs and allocation data

The 1698 Croatian census provides information about the inputs into agricultural production, but does not indicate the output of the household's agricultural activity. This subsection shows conditions for which information on cultivated land, labor and oxen allow inferences on the household production of grain without observing output and the allocation of household resources. This inference is possible by considering agricultural production as a two stage process determining separately the *extent of cultivated land* and the *intensity of cultivation*. The first stage reflects the agricultural tasks such as clearing, ploughing, harrowing, sowing, weeding and ditching that are proportional to the area of cultivation. The resources devoted to this stage determine the extent of arable land, and later processes that take this amount as given. The second stage of production captures the fact that agricultural practices differ in the intensity of land use. The peasant can influence the fertility of land and the efficiency of harvest by varying his inputs into tasks such as weeding, threshing, reaping etc. These tasks have in common that the resource inputs per acre are highly correlated with the grain yield per acre, but are relatively independent of the total amount of cultivated land.[12] However, for the time and place under consideration, the ability to influence the fertility of the soil is relatively limited: fertilizer is still unknown and even manure is not systematically used. (See Sect. 3.3)

An optimizing peasant will allocate his resources between these two stages, the extension of land and the intensity of cultivation, such that the marginal productivities in these activities are equal (Singh et al. 1986). For the case in which production follows a Cobb Douglas function we show that the proportion of resources allocated to the first and second stage of the production process is fixed (i.e., independent of the household's resource endowment) and only determined by the coefficients of the production function.[13] This relation allows the regression of cultivated land on household labor and oxen without knowledge about the resource allocation. Combined with a conjecture on the importance of labor inputs for grain yields per acre this analysis enables inferences on a household's grain production as a function of the observed inputs.

Assume a household with N members that maximizes the household utility function $U(c)$. The household members supply $L = N$ units of labor inelastically (i.e., each member supplies one unit). The household chooses the number of oxen B and the allocation of resources between *extending the cultivated land* and *intensity of cultivation* optimally to maximize the household utility function. The household's problem is therefore[14]

$$\max_{B,\lambda,\omega} U(c) \quad \text{subject to}$$

$$c = Y - c_B B \tag{1}$$

$$Y = A_Y T^{\alpha}((1-\lambda)L)^{\beta}((1-\omega)B)^{\gamma} \tag{2}$$

$$T = A_T(\lambda L)^{\theta}(\omega B)^{\phi}. \tag{3}$$

Equation (3) determines the amount of cultivated land T, which is cleared, ploughed and sowed using the shares λ and ω of the household's labor and oxen. In Eq. (2) the amount of land T is taken as given, and labor and oxen are used for tasks such as reaping, threshing, etc., that determine yield per acre and together with T the final output of grain. In Eq. (1) c_B denotes the cost of feeding one ox; all output Y that is not fed to the oxen is consumed by the household members. Standard maximization implies the optimal resource allocation $\lambda^* = \left(1 + \frac{\beta}{\theta\alpha}\right)^{-1}$, $\omega^* = \left(1 + \frac{\gamma}{\alpha\phi}\right)^{-1}$ and $B^* = \left(\frac{A^*}{c_B} L^{\alpha\theta+\beta}\right)^{1/(1-\alpha\phi-\gamma)}$, where $A^* = A_Y A_T^{\alpha}(\lambda^*)^{\alpha\theta}(1-\lambda^*)^{\beta}(\omega^*)^{\alpha\phi}(1-\omega^*)^{\gamma}$. Hence, the optimal allocation of resources λ^* and ω^* does not depend on the household's endowment with labor, whereas the optimal use of oxen B^* increases with the household's labor resources L and the quality of land A^*.

If household production is described by the above optimization problem, then the production function determining the amount of cultivated land can be expressed as

$$T = A_T^* L^{\theta} B^{\phi},$$

where $A_T^* = (\lambda^*)^{\theta}(\omega^*)^{\phi} A_T$. This constant term absorbs the optimal allocation λ^* and ω^* of resources between the extension of land and intensity of cultivation. Hence, an estimation of the production function (3) for cultivated land on the basis of the household's labor endowment and use of oxen provides unbiased estimates for the coefficients θ and ϕ despite the unobservability of the household's allocation of labor and oxen.

Similarly, the household's production function (2) for grain can be written as

$$Y = A_Y^* T^{\alpha} L^{\beta} B^{\gamma}, \tag{4}$$

where $A_Y^* = (1-\lambda^*)^{\beta}(1-\omega^*)^{\gamma}A_Y$. Although the census does not provide information about the production of grain Y, we can infer from this equation that an increase in the amount of cultivated land is necessarily associated with an increased production of grain. In particular, if production is characterized by constant returns to scale (CRS) with $\alpha+\beta+\gamma=1$ and $\theta+\phi=1$ then doubling the household's labor endowment doubles the household's demand for oxen and increases the households grain production also by a factor of two.

From the Croatian census we cannot make any inferences on the size of α, β and γ. Intuitively, however, we expect constant returns to scale because the arable land has not yet been extended to marginal areas. Furthermore, because peasants in 17^{th} century Croatia had very limited possibilities to improve the productivity of land we can interpret cultivated land as a proxy for household output.[15]

Together with the CRS assumption in agricultural production this allows inferences about the relative rental price for labor and oxen that would have prevailed in 1698 Croatia if the households had been integrated in a competitive market for labor and oxen. Imagine a household which is currently using labor L and oxen $\bar{B}$, and consider the fictitious situation that this household is offered the possibility to rent additional oxen and workers at rental costs r_B and w. We may now ask for the relative price ratio $\frac{r_B}{w}$ that would make the observed labor to oxen ratio $\frac{L}{\bar{B}}$ 'optimal' in the sense that the peasant would not change this ratio given the rental opportunity. In other words, the peasant would rent labor and oxen in the same proportion $\frac{L}{\bar{B}}$ as he is currently employing. For this analysis we write the additional consumption c_{rental} that the household gains by using additional production inputs as $c_{rental} = \tilde{Y}(B_{rental}, L_{rental}) - r_B B_{rental} - wL_{rental}$, where B_{rental}, L_{rental} are the rented inputs and $\tilde{Y}(B,L)$ is the overall production function obtained by substituting equation (3) into (2). If we observe a labor to oxen ratio $\frac{L}{\bar{B}}$, then in presence of rental markets this allocation would only be 'optimal' if[16]

$$\frac{r_B}{w} = \frac{\alpha\phi+\gamma}{1-\alpha\phi-\gamma}\frac{L^*}{B^*}. \tag{5}$$

Observe that for small γ, $\frac{\alpha\phi+\gamma}{1-\alpha\phi-\gamma} > \frac{(\alpha+\gamma)\phi}{1-(\alpha+\gamma)\phi} = \frac{(1-\beta)\phi}{1-(1-\beta)\phi}$ and hence a lower bound for the relative price of oxen to labor can be obtained from an estimate of ϕ in Eq. (3) together with a guesstimate for β. In the interpretation of our regression results, this ratio will allude to the overall scarcity of oxen that must have prevailed in 1698 Slavonia.

4.2. Constraints on oxen and integration in kinship networks

The above analysis focused on the case where households inelastically supply labor L, but optimally choose the input of oxen B^*. However, the peasant economy of 17^{th} century Croatia had not yet developed formal markets for oxen trade or rental. Presumably, the absence of oxen trade is historically influenced by the sparse and new settlement in the area and unfavorable terms of trade. The non-existence of rental markets in agricultural societies is generally explained by two arguments.[17] (*a*) *compensation problem*: In a land-abundant society, easy access to land and simple technology imply that an ox's output is at least as large on the lessee's plot as on the lessor's plot. Since leasing implies cost of supervision, a lessee cannot compensate the lessor for his forgone output, and hence there is no incentive to engage in draft animal rental. (*b*) *incentive problem*: Every lease is associated with an incentive problem, requiring from the lessor an incentive and supervision scheme that prevents the lessee from 'mistreating' the oxen during the employment on his plot. This problem can be solved with contracts that include respective penalties for improper usage; however, agricultural societies may generally lack the institutions that make 'feasible' lease contracts enforceable. Similar arguments hold with respect to labor markets.

For the individual household this absence of formal markets implies that the household cannot choose B^* optimally based on Eqs. (1–3), but is restricted in the short and medium term to his fixed amount of oxen $\bar{B}$ which is inherited or raised in the past.[18] Similar to labor L these oxen $\bar{B}$ are supplied inelastically to the household's productive activities. The formalization of the production functions (1–3) implies that $\bar{B}$ is allocated in the same proportions λ^*, ω^* to the extension of arable land and the intensification of cultivation as the optimally chosen oxen input B^*. All aforementioned relations regarding the estimation of Eq. (3) and the magnitude of the coefficients continue to hold.

Within a family structure, however, altruism and solidarity may overcome the compensation problem, and the ability to exert social pressure often suffices to eliminate the incentive problem for rentals among family members. Hence, the integration of a household in an extended kinship network provides potential access to an informal rental market for production factors among related families. The integration into kinship networks then relaxes the household's resource constraints and increases household output and consumption; in the framework of Eqs. (1–3) this advantage will be indicated by an increase in the amount of cultivated land.

Let $\bar{T}_i$, $\bar{Y}_i$ and $\bar{c}_i$ denote cultivated land, grain production and consumption that is implied by household *i*'s endowment with oxen $\bar{B}_i$ and labor L_i. Let T_i^*, Y_i^* and c_i^* be the respective values that are obtained with the optimal choice of oxen B_i^*. Furthermore, denote with B_i^{NW}, L_i^{NW} the number of oxen and workers in household *i*'s kinship network, and let B_i^{NNW}, L_i^{NNW} refer to the oxen and labor in the unrelated households in the vicinity.[19] In agricultural production household oxen and network oxen are prefect substitutes; however, the latter are available only a fraction of the time since they are also employed on the lesser's plots. Similarly, household labor and network labor are perfect substitutes, with the later being only available after they have worked on their own fields. A priori we do not want to rule out the possibility that factor exchange extends beyond extended family networks. These arguments then suggest a modification of the household's production function in the form of

$$T_i = A_T^*(L_i + \theta_1 L_i^{NW} + \theta_2 L_i^{NNW})^{\theta_0}(\bar{B}_i + \phi_1 B_i^{NW} + \phi_2 B_i^{NNW})^{\phi_0}. \tag{6}$$

The coefficients θ_1, θ_2, ϕ_1, ϕ_2 reflect the availability of network and non-network resources for household i's agricultural production; the additivity within the parentheses captures the high substitutability between own and network resources once the latter are employed on i's land. In informal rental markets among relatives or neighbors the acceptance of help from others may not require any form of payment, but usually implies counterobligations in the form of reciprocal help. Network and non-network resources are therefore more expensive than the household's own resources and will only be employed if household i faces a resource constraint that prevents it from achieving its optimal production plan. The role of network and non-network resources therefore differs depending on the resource constraint that the household faces:

(1) If $\bar{B}_i > B_i^*$, i.e., the household has an excess of oxen, then $\bar{T}_i > T_i^*$, $\bar{Y}_i > Y_i^*$ but $\bar{c}_i < c_i^*$. In particular, due to its own excessive supply this household has no incentive to lease oxen from related households. Consequently the output of this household is not affected by potential access to oxen rental through family links or close neighbors, and therefore $\frac{\partial Y_i}{\partial B_i^{NW}} = \frac{\partial Y_i}{\partial B_i^{NNW}} = 0$. However, the household has an incentive to employ additional labor to use with its excessive oxen, and we expect $\frac{\partial Y_i}{\partial L_i^{NW}} > 0$, and possibly $\frac{\partial Y_i}{\partial L_i^{NNW}} > 0$ if labor exchange is not limited to related households.

(2) If $\bar{B}_i < B_i^*$, then $\bar{T}_i < T_i^*$, $\bar{Y}_i < Y_i^*$ and $\bar{c}_i < c_i^*$. Since for $\bar{B}_i < B_i^*$ the derivatives of consumption, output and cultivated land with respect to oxen in Eqs. (1)–(3) are all positive, a household with a shortage of oxen benefits from the integration into an extended kinship network if the family lineage overcomes the compensation and incentive problem in the oxen rental market. Then $\frac{\partial Y_i}{\partial B_i^{NW}} > 0$. If rental extends across family lineages, then also $\frac{\partial Y_i}{\partial B_i^{NNW}} > 0$. The household has no incentive to employ additional labor who work with its oxen $\bar{B}_i$. Hence we expect $\frac{\partial Y}{\partial L_i^{NW}} = \frac{\partial Y}{\partial L_i^{NNW}} = 0$.

In the 1698 census output is not observed, but the monotonic relation between household i's output and its cultivated land T_i allows the inference of these derivatives from the observation of cultivated land. Since the data-set contains presumable households with $\bar{B} < B^*$ and with $\bar{B} > B^*$ the estimation of the effect of kinship and community networks on household production has to be based on the relation

$$T_i = \begin{cases} A_T^*(L_i + \theta_1 L_i^{NW} + \theta_2 L_i^{NNW})^{\theta_0} \bar{B}_i^{\phi_0} & \text{if } \bar{B}_i > B_i^* \\ A_T^* L_i^{\theta_0} (\bar{B}_i + \phi_1 B_i^{NW} + \phi_2 B_i^{NNW})^{\phi_0} & \text{if } \bar{B}_i \leq B_i^* \end{cases}, \tag{7}$$

where T_i serves as a proxy for the unobserved agricultural production Y_i. In an environment that exhibits constant returns to scale, the unobserved B_i^* is proportional to the household's labor endowment and therefore the selection criteria in equation (7) can be replaced with $\frac{L_i}{\bar{B}_i} < \delta_i^*$ and $\frac{L_i}{\bar{B}_i} \geq \delta_i^*$ respectively, where δ_i^* is the optimal labor to oxen ratio

$$\delta_i^* = \frac{L_i}{B_i^*} = (A_T^*)^{-\alpha/(1-\alpha\phi-\gamma)} \left(\frac{c_B}{(\lambda^*)^{\alpha\theta}(\omega^*)^{\alpha\phi} A_Y^*} \right)^{1/(1-\alpha\phi-\gamma)}$$

implied by the optimization problem in Eqs. (1–3).

The constant term A_T^* in the estimation of Eq. (7) is amended by information on the altitude of the village and religion of the household in the form $A_T^* = \exp(\alpha_0 + \alpha_1 \cdot altitude + \alpha_2 \cdot altitude^2 + \alpha_3 \cdot 1_{\{\text{Household is orthodox}\}})$, where $1_{\{.\}}$ is the indicator function. The optimal labor to oxen ratio then follows as $\delta^* = \delta_0 \cdot (A_T^*)^{\delta_1}$. This optimal ratio is identified, despite the absence of any information on factor prices, by observing the labor to oxen ratio when households change from utilizing 'outside' oxen to 'outside' labor. The parameters $(\alpha_0, \alpha_1, \alpha_2, \alpha_3, \delta_0, \delta_1, \theta_0, \theta_1, \theta_2, \phi_0, \phi_1, \phi_2)$ are estimated in a maximum likelihood procedure by taking logarithms of equation (7), adding a normally distributed error term with variance σ^2 on the right hand side, and accounting for the selection on the basis of δ^*.

4.3. *Discussion of results*

The estimation of Eq. (7) on the information of 2427 households that had oxen and cultivated land is given in Table 6. The table reports the results based on the exponential and bell-shaped weight in the calculation of the network resources of each household. Choice of this weighting function has no implications for the overall conclusions of the regression. The principal results are as follows (calculations are based on the estimates with exponential weight):

(*a*) The amount of grainland increases with altitude but decreases in altitude squared, showing that more extensive cultivation with higher productivity was possible above the swampy bottomlands but below the higher, mountainous regions.

(*b*) The Orthodox households have a higher agricultural productivity than the other groups; this advantage amounts to about 7%, all else equal. This observation is surprising given the settlement history and the presumably more recent arrival of Orthodox households.

(*c*) The mean optimal ratio of labor to oxen calculated from δ_0 and δ_1 together with altitude information is 1.18 workers to oxen, or conversely 0.85 oxen per man. If the average household could optimize its possession of oxen, it would employ $B_i^* = \frac{1}{1.18} L_i$ oxen on the basis of its endowment with labor L_i. In other words, if a household's labor to oxen ratio (at average altitude) equals $\delta = 1.18$ the peasant has no incentive to change $\frac{L}{B}$ by augmenting *one* factor with network or community resources. This implies that about two thirds – or equivalently 1625 out of 2427 – of the households suffer a shortage of oxen with respect to their male labor force, while only one third has a sufficient endowment with draft animals. The optimal workers to oxen ratio δ^* decreases in A_T^*. In other words, households with the most suitable soils for farming have the highest number of oxen per worker. These households ben-

Table 6. Estimation of the household production function for cultivated land on the basis of Eq. (7). Model 1 used an exponential weight, and Model 2 a bell-shaped weight for the calculation of network resources.

Aggregation of network resources based on		Model 1 exponential weight	Model 2 bell-shaped weight
Parameter	Variable		
α_0	(constant)	0.21017	0.22216
		(0.05632)***	(0.05486)***
α_1	(altitude)	0.00313	0.00376
		(0.00048)***	(0.00046)***
α_2	(altitude^2)	−0.443E-5	−0.535E-5
		(0.816E-6)***	(0.786E-6)***
α_3	(dummy for Orthodox)	0.10081	0.09580
		(0.03464)***	(0.03564)***
δ_0	(parameters to calculate	2.25118	2.46801
		(2.49560)	(2.35648)[a]
δ_1	optimal labor to oxen ratio)	−1.02622	−1.07590
		(1.50101)	(1.15241)[a]
θ_0	(exponent of labor in prod. function)	0.27360	0.27335
		(0.03975)***	(0.03694)***
θ_1	(NW labor)	0.01857	−0.00027
		(0.07618)	(0.07249)
θ_2	(NNW labor)	0.00285	0.00282
		(0.00077)***	(0.00083)***
ϕ_0	(exponent of oxen in prod. function)	0.76315	0.71758
		(0.03304)***	(0.03210)***
ϕ_1	(NW oxen)	0.04989	0.05218
		(0.02003)**	(0.02095)**
ϕ_2	(NNW oxen)	0.00083	0.00044
		(0.00024)***	(0.00024)*
σ^2		0.26636	0.26724
		(0.00686)***	(0.00688)***

p-values: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.
Notes: [a] If the optimal labor to oxen ratio were equal to one and independent of the land quality A_T, then the parameter δ_0 and δ_1 would equal one and zero respectively. For model 2 (bell-shaped weight) a Wald test rejects the linear restriction that $\delta_0 = 1$ and $\delta_1 = 0$ at the 5% level.
[b] An approximate goodness of fit measure for the analysis, which is similar to the R^2 in regression analysis, is obtained by relating the variance of the predicted variable, $\log(T_i)$, in the above models to the respective variance of the observed variable. In both model this ratio is 0.39.

efit twice: first they have good soils to cultivate, secondly they achieve a higher oxen to worker ratio – as implied by the maximization problem in Eqs. (1) to (3) – that allows them to increase their output more than proportionally to the gain in soil fertility.

(*d*) The coefficients θ_0 and ϕ_0 add up to one. This implies constant returns to scale as we expect under conditions of an extensive, undeveloped agriculture in which additional land coming under cultivation is as yet of no poorer quality than the core holding. Consequently, the optimal demand for oxen B_i^* and the optimal amount of cultivated land T^* vary proportionally with the number of males in the household. If a household does not succeed in increasing the amount of cultivated land proportional to the number of workers, then this due to a shortage of oxen.

(e) Households with $\bar{B}_i < B_i^*$, i.e., households with a deficit of oxen compared to their labor force seem to benefit from having oxen in their kinship network, but get little or no benefit from having oxen just in their neighborhood. An ox owned by a related household is 'worth' about 0.05 of an ox owned by the household; households with at least one 'related ox' within 10 km of their dwelling gain on average an additional 1/8 of an oxen for their agricultural tasks. There also is some exchange across unrelated households, but a 'related ox' is worth about 60 times the productive value of an 'unrelated ox'. The exchange of oxen along kinship lines, and not among general community members, confirms the expectations grounded in the idea of trust prevailing between kin more than between neighbors. This trust overcomes the incentive problem in the rental market for production factors and allows intra-lineage exchange of oxen where formal markets fail.

(f) Households with $\bar{B}_i > B_i^*$, i.e. households with a relative excess of oxen or a relative shortage of labor seem to engage in an exchange of labor with the nearby community; however, having males in the network seems to confer no particular advantage. Thus it seems that the traditional patterns of cooperative labor exchange (Croatian sprega) crossed kinship lines. The average household with an excess of oxen gains about 1.49 workers in help from other households.

(g) Oxen are a much more important determinant of cultivated land – and with our conjectures on α and β also of output – than human workers: the overall coefficient for labor $\theta_0 = 0.27$ whereas the overall coefficient for oxen $\phi_0 = 0.76$. Hence, the marginal productivity of oxen per worker declines quite slowly, while productivity of workers increases quite rapidly and with little flattening as the number of oxen per male increases. Conversely, the marginal productivity of labor (per ox) declines very rapidly, and cultivated land increases only modestly by adding more workers.

(h) With the discussion after Eq. (5) we can make an educated guess on the fictitious relative rental costs for oxen and labor that would have prevailed in 1698 Slavonia. Based on our guesstimate for $\beta \approx 0.14$ (see footnote 15) and our estimate of the average labor to oxen ratio $\delta = 1.18$ we can infer that the fictitious relative rental price of oxen to labor must exceed 2.2. However, this price ratio does not seem be justified by the pure costs of feeding oxen. This high price for oxen must indicate a general scarcity of draft animals, a finding that recurs throughout this analysis and manifests itself in the relative prices.

In summary, this estimation reveals several interesting features about the agricultural environment: there is an advantage to living at altitudes above swamps but below high elevations, and there is a modest wealth advantage for those of Orthodox religion. Moreover, there are clear advantages to the ownership of oxen, and low returns to human labor in agricultural production. The quantitative evidence in the census supports the idea that grain agriculture was not highly developed technically. It lacked intensification (e.g., through manuring) and the marginal land seems to have been of about the same quality as core holdings. Land, then, was not in short supply as it came to be within a few generations. The population probably also engaged in garden horticulture, perhaps cultivating potatoes and other root crops as well as vegetables, so that grain production was not the sole source of subsistence. Nevertheless, if peasants optimized their resources, allocating them in some Chayanovian pattern (Chayanov 1986), the picture of their grain agriculture is a reasonable one, even though their horticulture remains unknown to us.

In addition, this analysis indicates patterns of reciprocal assistance among members of the community and kinship network. The most valuable production factor, oxen, is primarily exchanged along kinship lines, and only to a substantially lesser extent between unrelated households. This observation is consistent with the theoretical argument that predicts the absence of formal markets unless 'mutual trust,' as it exists among kin and relatives, overcomes incentive problems. In 1698 Slavonia there are clear advantages to having a kinship network containing additional oxen. These oxen help to expand a household's cultivated area, whereas oxen in the general community do not. Shortages in human labor, however, are lessened by a form of general neighborhood help, independent of kinship relations. Impediments to factor exchange seem therefore smaller for human labor than for animal labor, and the former does not require common lineage to facilitate informal factor exchanges.

5. Kinship networks and insurance

The previous section was concerned with bottlenecks in agricultural production and the role of kinship and community networks to alleviate resource shortages faced by individual households. This part of the analysis takes the household's resources labor L, oxen B and cultivated land T (and their potential augmentation by network and community assistance) as given and addresses the optimal choice of crops to minimize the household's risk with respect to harvest failures.

As in the previous section, monitoring and incentive problems can be used to explain the absence of a formalized market in securities in preindustrial societies (de Janvry et al. 1991, Fafchamps 1992, Rosenzweig 1988, Townsend 1993). The kinship network is one possibility that is thought to overcome both of these problems. Monitoring is resolved because information on income and wealth within an extended family is readily available due to geographic proximity and frequent personal contact. The incentive problem is attenuated because families have credible options to threaten punishment, such as refusal of assistance or expulsion from the family unit, that are not available to the society as a whole. In particular, in an environment with high emphasis on family and lineage, as in Croatia, these mechanisms may allow family insurance to operate when formal insurance markets fail.

The risk in agricultural societies is primarily related to yield variability. Townsend (1993, p. 22) argues that the coefficient of variation is typically around 0.35. This implies that if a yield of less than 50% of the mean output is disastrous, the probability of a disaster in a given year is approximately 0.075, or a frequency of 13.4 years. In the absence of insurance markets, this variability of yields has fatal consequences for an autarchic peasant family when the harvest falls below a certain subsistence level. The need to maintain a yield above this subsistence income induces a highly risk-averse behavior in the preindustrial farmer. Instead of choosing agricultural techniques that yield a high average harvest, the farmer is forced to lower variability of yields at the cost of reduced average harvest. Many risk-reducing structures of medieval economies, such as scattered land-holdings or diversification of crops, can be explained by this trade-off between risk and average yield. (See for instance Townsend 1993) When formal or familial insurance become available these practices disappear and more efficient agricultural techniques are adopted.

Table 7. Number of different crops grown by household and total amount of cultivated land (940 households for which information on the number of crops is available in the census)

	Number of crops grown				
	1	2	3	4	Total
Amount of land					
0–5	140	277	111	10	538
5–10	3	57	170	89	319
10–15	1	3	32	29	65
15–20	1	0	2	10	13
20+	0	0	0	5	5
Total	145	337	315	143	940

Notes: Land is measured in 'yokes', probably the amount of land that could be plowed in a day, thus about an acre.

For 940 households the choice of cultivated crops is reported in the 1698 census, and Table 7 shows the number of crops chosen from the five alternatives barley, oats, maize, millet and wheat as a function of the total cultivated land. The tendency of these households to increase the number of crops with the amount of cultivated land indicates a strong incentive to diversify, and also suggests the existence of fixed costs in the adoption of crops. Our goal is to infer the existence of mutual insurance among related households from the variation that is exhibited in pattern of Table 7. For this purpose the following subsection derives the optimal number of crops in a simplified theoretical framework based the theory of optimal choice under risk (e.g., Hirshleifer and Riley 1992). This model is then the basis for an ordered probit model which is applied to the census data.

5.1. Risk aversion and the optimal choice of crops

Imagine household *i*'s cultivated land is partitioned into T_i plots $\tau = 1, \ldots, T_i$ with the same expected calorie yield $\mu_i y\left(\frac{L_i}{T_i}, \frac{B_i}{T_i}\right)$. This yield depends on the quality of peasant *i*'s soil μ_i and the respective labor and oxen inputs to each plot. The peasant knows his soil fertility μ_i and plants one of $\overline{N}$ available crops $j = 1, \ldots, \overline{N}$ on each field. The output is subject to two types of random shocks: (*a*) fluctuations in harvest that are due to a specific location, such as hailstorms, and (*b*) failures that pertain to specific crops, such as diseases or insects. Suppressing the household index *i* we can write for the household's calorie production $Y(T, L, B)$

$$
\begin{aligned}
Y(T, L, B) &= \sum_{\tau=1}^{T} (1 + \varepsilon_\tau + \nu_\tau(j_\tau)) \cdot \mu \cdot y\left(\frac{L}{T}, \frac{B}{T}\right) \\
&= \overline{Y}(T, L, B) + \mu y\left(\frac{L}{T}, \frac{B}{T}\right) \sum_{\tau=1}^{T} (\varepsilon_\tau + \nu_\tau(j_\tau)),
\end{aligned}
$$

where $\overline{Y}(T, L, B) = \mu T y\left(\frac{L}{T}, \frac{B}{T}\right)$ is the expected total harvest of the household, ε_τ is the location specific output fluctuation on plot τ, and $v_\tau(j_\tau)$ is the crop specific shock to grain type j_τ that is grown on plot τ. Assume for simplicity that ε and v are independent normal with $\mathrm{E}\varepsilon_\tau = \mathrm{E}v_\tau(j) = 0$, $\mathrm{E}\varepsilon_\tau^2 = \sigma_\varepsilon^2$, $\mathrm{E}v_\tau(j)^2 = \sigma_v^2$ for all τ, j. Let the fluctuations be correlated across plots according to $\mathrm{E}\varepsilon_\tau\varepsilon_\kappa = \rho_\varepsilon\sigma_\varepsilon^2$ for $\tau \neq \kappa$, and across crops by $\mathrm{E}v_\tau(j)v_\kappa(j) = \sigma_v^2$, $\mathrm{E}v_\tau(j)v_\kappa(l) = \rho_v\sigma_v^2$ for all plots τ, κ and crops $j \neq l$.[20]

Because diversifications are costly in terms of efficiency, tool investments, etc., we impose a fixed cost c_c for each crop. The peasant chooses the optimal number N^{**} of crops to maximize expected sum of utilities of L identical household members subject to the production constraints. Because of the separability of the problem we can focus here on the choice of N^{**} and take T, L, B as given from the previous analysis about the allocation of household resources. The decision problem is then given by

$$\max_N \mathrm{E}\sum_{k=1}^{L} u\left(\frac{c}{L}\right) = L \cdot \mathrm{E}u\left(\frac{c}{L}\right) \tag{8}$$

$$\text{subject to } c = Y(T, L, B) - N \cdot c_c$$

$$N \in \{1, 2, \ldots, \overline{N}\}.$$

For the moment we neglect the discrete nature of N and treat it as a continuous choice variable. By symmetry of the problem a peasant growing N different grains will allocate his T plots equally to all crops. Therefore $\mathrm{var}(\sum_{\tau=1}^{T} \varepsilon_\tau) = T\sigma_\varepsilon^2(1 + (T-1)\rho_\varepsilon)$ and $\mathrm{var}(\sum_{\tau=1}^{T} v_\tau(j_\tau)) = \mathrm{var}\left(\sum_{j=1}^{N} \frac{T}{N} v(j)\right) = \frac{T^2}{N}\sigma_v^2[1 + (N-1)\rho_v]$. An individuals' coefficient of risk aversion is allowed to depend on the expected share of household production in the form $r\left(\frac{\overline{Y}}{L}\right) = \frac{r}{\left(\frac{1}{L}\overline{Y}(T, L, B)\right)^\delta}$, with $\delta = 0$ and $\delta = 1$ approximating constant absolute and constant relative risk aversion respectively. With $u(c) = -e^{-r(\overline{Y}/L)\cdot c}$ the allocation problem (8) reduces to

$$\min_N \left(N \cdot c_c + \sigma_v^2 \mu^2 y\left(\frac{L}{T}, \frac{B}{T}\right)^2 \frac{T^2}{L} \frac{r(\overline{Y}, L)}{2} \frac{1 + (N-1)\rho_v}{N}\right).$$

Taking the first order condition and solving for N^*, the desired number of crops on a continuous scale, yields

$$N^*(T, L, B) = \sqrt{\frac{(1-\rho_v)\sigma_v^2 r}{2c_c}} \cdot \mu\overline{Y}(T, L, B)^{1-(\delta/2)} L^{(\delta-1)/2}. \tag{9}$$

By concavity of the objective function there exists a sequence of thresholds $\{n_j\}_{j=0}^{\overline{N}}$ with $n_0 = 0$ and $n_{\overline{N}} = \infty$ such that $N^{**}(T, L, B) = j,\ j \in \{1, \ldots, \overline{N}\}$

solves the optimization problem (8) whenever $N^*(T, L, B) \in [n_{j-1}, n_j)$. By deriving a discrete number of crops $N^{**}(T, L, B)$ from Eq. (8) this observation completes the peasant's autarchy decision problem.

In the absence of moral hazard or incentive problems, a pooling of risk across households is advantageous because it reduces the variance of each households' harvest and it reduces the fixed costs c_c. Imagine for example that $1 + k$ identical households cooperate by sharing their joint output. Then Eq. (9) implies that the desired number of crops grown by each household reduces to $\frac{1}{\sqrt{1+k}} N^*(T, L, B)$. This proportional decline of N^* holds independent of the variance or correlation of crop specific harvest fluctuations (as long as $\rho_v < 1$) and does not vary with the fixed costs c_c or the level of risk aversion. It only depends the number of (identical) households k with whom risk is pooled, or alternatively, it is determined by the size of the insurance pool relative to the own household size.

The fact that risk pooling will tend to lower the number of crops planted by the household enables us to infer about existence of intra-kinship insurance from the census reports about the number of crops planted by each household. The extent to which this reduction in N^* takes place depends on the exact form of the 'insurance contract' and the extent of risk pooling, neither of which is observed. As a first approximation we assume that the desired number of crops N^* of a household follows the relation suggested by above example, namely

$$N^*(T, L, B, k) = \frac{1}{(\sqrt{1+k})^{\zeta}} N^*, \tag{10}$$

where k is the number of households with whom risk is pooled and ζ is the 'extent' of risk sharing: $\zeta = 1$ implies optimal risk reduction among the k households, and $\zeta = 0$ implies no risk pooling and autarchy of the households. Partial insurance is reflected by $\zeta \in (0, 1)$.

The relations (9) and (10) specify an ordered probit model under the assumption that the unobserved soil fertility μ is log-normally distributed. The observed number of crops N_i^{**} grown by peasant household i with land T_i, labor L_i and oxen B_i is then probabilistic with $\Pr(N_i^{**} = 1) = \Phi[-\log(N^*(T_i, L_i, B_i, k_i)], \Pr(N_i^{**} = j) = \Phi[\log(n_j) - \log(N^*(T_i, L_i, B_i, k_i)]$ for $j = 2, \ldots, \bar{N} - 1$ and $\Pr(N_i^{**} = \bar{N}) = 1 - \Phi[\log(n_{\bar{N}-1}) - \log(N^*(T_i, L_i, B_i, k_i)]$.

A priori we want to allow for the possibility that exchange of harvest and risk pooling extends beyond to related families, and hence household i's desired number of crops N_i^* is estimated as

$$\begin{aligned}
&\log(N_i^*(T_i, L_i, B, k_i^{NW}, k_i^{NNW})) \\
&\quad = \xi_0 + \xi_1 altitude + \xi_2 altitiude^2 + \xi_3 1_{\{\text{household is orthodox}\}} \\
&\qquad + \xi_4 \log(1 + k_i^{NW}) + \xi_5 \log(1 + k_i^{NNW}) \\
&\qquad + \xi_6 \log(T_i) + \xi_7 \log(L_i) + \xi_8 \log(B_i),
\end{aligned} \tag{11}$$

where $k_i^{NW} = \frac{T_i^{NW}}{T_i}$ and $k_i^{NW} = \frac{T_i^{NNW}}{T_i}$ approximate the relative size of

Table 8. Ordered probit analysis for the number of crops planted by the peasant household based on Eq. (11)

Aggregation of network resources based on		Model 3 exponential weight	Model 4 bell-shaped weight
Parameter	Variable		
ξ_1	(altitude)	−0.0018	−0.0024
		(0.0019)	(0.0018)
ξ_2	(altitude^2)	0.400E-5	0.485E-5
		(0.298E-5)	(0.279E-5)*
ξ_3	(dummy for Orthodox)	0.3938	0.3704
		(0.1194)***	(0.1201)***
ξ_4	(kinship network)	0.1784	0.2058
		(0.1414)	(0.1486)
ξ_5	(close community)	0.1977	0.2379
		(0.1480)	(0.1105)**
ξ_6	(HH cultivated land)	2.1952	2.2111
		(0.1172)***	(0.1082)***
ξ_7	(HH labor)	−0.0292	−0.0369
		(0.0828)	(0.0830)
ξ_8	(HH oxen)	−0.3073	−0.3017
		(0.0925)***	(0.0925)***
	cutpoint 1	1.646	1.631
		(0.409)***	(0.307)***
	cutpoint 2	3.539	3.532
		(0.423)***	(0.324)***
	cutpoint 3	5.158	5.152
		(0.434)***	(0.339)***
	Pseudo R^2	0.34	0.34

p-values: $*p < 0.1$; $**p < 0.05$; $***p < 0.01$.

household i's kinship and community grain resources, which determine the potential advantage from risk pooling, by dividing the cultivated land in i's network and community by the arable land of i.

5.2. Discussion of results

The results of this ordered probit analysis are shown in Table 8. The primary findings are as follows (calculations are again based on the estimates with exponential weight):

(*a*) Altitude does not seem to influence the diversification decision of the household.

(*b*) Orthodox households are significantly more diversified than non-Orthodox households, contradicting the image that the late arrivers in this area are disadvantaged.

(*d*) The coefficient on cultivated land ξ_6 confirms the very strong incentive, already visible in Table 7, to diversify as cultivated land increases. However, this tendency to diversify is proportional to T^2, and hence much stronger than predicted by the above analysis of risk attitude with either constant absolute or constant relative risk aversion. This indicates that there are benefits to crop variation that extend beyond the incentive to reduce the variability of harvest fluctuations. Possible reasons for this tendency to raise multiple crops may be dietary considerations, improvements in soil fertility by rotation of crops, or prestige. Yet, intuition suggests that these reasons induce level effects (i.e., changes in the leading constant) in Eq. 15 rather than the slope effects that would explain the coefficient on land of $\xi_6 = 2.14$. At the moment, this strong desire to diversify remains puzzling to us and deserves further research.

(*e*) Household labor has a negligible effect on the number of crops grown by the peasant. This is consistent with the low productivity we attribute to labor once cultivated land is given. Very tentatively this coefficient alludes to a coefficient of risk aversion that is increasing in expected consumption.

(*f*) Availability of household oxen tends to lower the variety of crops of a household, although the role of oxen in production is minor once cultivated land is given. Again, we can primarily speculate on the reasons of this behavior. Given the importance of oxen in the production of cultivated land and their overall scarcity in the economy, draft animals may constitute a valuable 'asset' that secures long term output. This security may induce households with many oxen to engage in higher yield, higher variability agriculture to a larger extent than predicted by the theoretical analysis.

(*g*) The coefficients ξ_4 and ξ_5 indicate the effect of kinship networks and close community on the diversification decision of the household. If related households engage in risk pooling or if there is some form of ex-post harvest exchange among community households, then these coefficients are negative. However, this hypothesis is rejected by the regression results. The proximity of either relatives or other households tends not to reduce the number of crops grown by a peasant household; to the contrary, model 4 (bell-shaped weight) even indicates that the close community tends to increase the diversification.

These findings confirms our presupposition that in 1698 the region was inhabited by relatively autarchic peasants consuming mainly their own output, and it indicates that even kinship links were not sufficient to overcome impediments of ex-post harvest exchange. It remains puzzling, however, why kinship networks in an area with high emphasis on lineage do not provide mutual insurance against harvest fluctuations, in particular, since these households interact by exchanging the most scarce production factor, oxen.

Two possible explanations come to mind. First, the incentive and moral hazard problems that exist across households are too severe and prevent an effective insurance arrangement in grain even among related groups. The analysis gives indication that problems of asymmetric information prevent risk-pooling arrangements in output, even among families of the same lineage. The mutually beneficial exchange of production factors may still have been possible because problems of compliance with the terms of rental contracts are considerably less severe than the respective problems in mutual crop insurance. The second explanation for the non-existing insurance effect across household borders is based on correlation of risks. Yet, correlation of risks across crops primarily reduces the number of crops grown by the household (there is little incentive to diversify if output variability does not decrease due to high correlation, see Eq. 9) and it leaves unaffected the advantageous effect of cooperation with other households. Hence only incentive and monitoring problems remain as the main obstacles to risk-pooling arrangements. It is beyond the scope of this paper to investigate the deeper social structures that lead to this 'inefficiency' of kinship networks in reducing households' risk.

6. Conclusions

In this paper we have tried to interpret the economically relevant portions of an early census in a frontier area of the Habsburg Empire, with particular attention to the ability of kinship networks to provide substitutes for missing markets in securities and production factors.

The quantitative analysis of agricultural production confirms reports by the census takers that draft animals are the critical constraint to the expansion of agricultural output. It is found that kinship networks provide a substitute for missing rental markets in draft animals: Households are able to increase their efficiency in agricultural production by allocating and sharing scarce oxen across households of the same lineage. At the same time, shortages in human labor seem to be lessened by a form of general neighborhood help, independent of kinship relations. With respect to a provision of mutual insurance against the risks of agricultural production, however, kinship networks apparently fail to lower the variability of output by pooling risk across households.

The inability of kinship structures to overcome the incentive and monitoring problems associated with insurance contracts, and the apparent irrelevance of blood-ties for the exchange of human labor, are surprising in a location where families are usually considered to be of large social significance. These findings shed some doubts on theories that explain the transformation of zadrugas, the dominating form of family organizations in Slavonia, with an economic rationale concentrating on labor and risk reduction.

Some caution, however, is necessary in interpreting these findings in the context of 17th century Slavonia. The fact that crop diversification did not occur where households had network resources does not imply that households did not exchange outputs. It only shows that they did not take what is to us the obvious step of specializing production to achieve economies that could be insured by post-harvest exchange. This could mean that they were not rational, or at least not intelligent. It could also mean that they knew that even if they did specialize there was no way they could improve production by growing fewer crops. The idea that less diversification means higher levels of production is not necessarily correct under the primitive technological circumstances they had. Indeed it actually increases the risk of disease losses, especially across years, as such diseases build up in the soil. There has to be diversification at least through crop rotation.

The fact that post harvest exchange does not seem to happen between related households and that labor exchange does happen between unrelated households does not necessarily mean that the theories about the importance of the extended household and lineage were wrong. First, we are observing these households and lineages at first settlement. The theories about the decline of the zadruga are based on observations of a decay of functionality in the 19th century. It is possible that the zadruga was not so important in the 17th century, but came to be important by the late 18th, and the reasons for the decay in the 19th century are indeed correct. Second, the exchange of human labor may occur easily because there is no supervision problem, so that the absence of emphasis on exchange of human labor between related households may only mean that the negative reasons for restricting oxen exchange to kinsmen are just absent. Also note that exchange of human labor is often part of a cycle of feasting and entertainment and that this has important implications for maintaining social ties. There is not so much reason to strengthen social ties between related persons, because those ties are already strong. It may be more efficient socially to concentrate on exchange with non kin. This is in fact one of the important functions of prohibitions on marrying kin.

Endnotes

1 The division between the Civil and Military zones was not formally established until 1745. Some households were already military in 1698, others expressed a desire to be, and for many households there is no information. We actually do not know anything precise about the feudal dues, only that they were eventually different for the two statuses.

2 We are indebted to Reinaldo Gregori for finding and utilizing the GIS data.

3 There are a few Protestants (Hungarian Calvinists) in villages with Orthodox populations near the Drava.

4 Nominal data linkage for baptismal, marriage, and burial records from 7 Slavonian parishes 1714–1900 shows that even in the earliest records last names of males had crystallized and were quite stable. Occasionally, records linked to a male might show alternative last names; these appear to be the last (not first) names of the maternal and paternal grandfathers. Last names of females were less stable, showing this alternation and also some retention of the maiden name as name of mother in the earliest births for that mother. Our imputation of kinship from last names is for males only. The strongly agnatic nature of migration and residence makes it quite likely that males with the same last name within local areas were related. We will err in imputing kinship to some males with accidentally identical names, but our intuition is that that error is small. We will err in not imputing kinship to some males with different last names, but our intuition is that that error is even smaller.

5 For example, a man baptized as Stefan might have a son baptized as Jovan, who would be known as Jovan Stefanović. Technically, the -ov suffix is creates a possesive adjective, as in Jankova kuća (Janko's house), and the -ić suffix is a diminutive on masculine or neuter nouns, as in nožić (little knife). Sometimes the third name (Stefanov, above) became crystallized as a lineage name and subsequently as a surname, and sometimes the second name (Jovanović, above) became so crystallized. Similar patterns occur in other non-Slavic Indo-European languages, e.g. surnames ending in -son, -sen in the Germanic languages.

6 For a general discussion of the economic conditions prevailing in Europe during this period see de Vries (1976).

7 The iugum, yoke, was probably the amount of land that could be plowed in a day, thus about an acre.

8 'Hayfield' is a guess. The census lists 'currus foeni', which means 'hay cart', and 'falcator', which means 'scythe' or possibly 'reaper.' We assume that these measures mean the amount of meadow that can be scythed in a day, thus functionally equivalent to the yoke.

9 The exception is the famous Lippizaner horses of the Spanish Riding School in Vienna, which originated in the region of Lipica, just west of Slavonia. But these, too, are riding horses, originally bred for military use.

10 Note that alders prefer damp, even swampy ground.

11 We also eliminated one outlier household that was reported as having virtually no grainland but 14 oxen. This entry is probably erroneous.

12 For a discussion of this distinction between 'extent of cultivated land' and 'intensity of cultivation' see also Clark (1991).

13 The functional form of the production function is important for the validity of the econometric inference. Only Cobb-Douglas and other homothetic production functions allow the separation of optimal resource allocation and size of farm on which much of our econometrics is based.

14 The conclusions derived from this maximization problem remain unchanged if one adds an additional area of production (for instance to allow for the inclusion of horticulture) that follows also a Cobb-Douglas production and competes with the resources allocated to the production of T and Y. Since we only have information on grain agriculture, this extension complicates the algebra with no additional insights.

[15] This argument is supported by a comparison with pre-1600 English agriculture which seems roughly comparable in structure and technology to our setting. With CRS we can write rewrite Eq. (4) in terms of output per acre $\frac{Y}{T} = A_Y^* \left(\frac{L}{T}\right)^\beta \left(\frac{B}{T}\right)^\gamma$. Clark (1991) identifies reaping and threshing as the two dominating tasks related to yield per acre. If wages are competitive, the harvest wages paid for these tasks reflect the ability to improve land productivity by more intensive cultivation and shed light on the magnitude of the coefficient β in Eq. (4). Clark finds that around 1300 English agriculture had a yield of approximately 12 bushels of wheat per acre. Reaping one acre required 1.7 man-days, and the wage for reaping was 5.58*d* – equivalent to 0.61 bushels of wheat per acre or 0.36 bushels per man-day. Threshing of the output of one acre required approximately 2.88 man-days and was payed essentially the same wage of 0.37 bushels per man-day. The remuneration of factors according to their marginal productivity implies the equations $12 = A_Y^* \left(\frac{B}{T}\right)^\gamma \cdot (1.7 + 2.88)^\beta$ for output and $0.36 = \beta A_Y^* \cdot \left(\frac{B}{T}\right)^\gamma \cdot (1.7 + 2.88)^{\beta-1}$ for harvest wages. Solving for β results in $\beta = 0.14$. This low coefficient is consistent with the reports of surprisingly low labor productivity in medieval agriculture. This derives from the fact that output is primarily determined by the amount of cultivated land and the scope for improving the productivity of land by increased labor input is very limited. But only these increases in the productivity of land are reflected in (competitive) wages.

We do not have any information on the coefficient γ in Eq. (5) and the wage based inference based on English agriculture is also not available. However, intuition suggests that for harvesting the role of oxen is secondary to that of labor, and therefore γ is likely to be much smaller than β. These two arguments imply that in the constant return to scale environment the coefficient α is close to one, and output is almost proportional to the amount of cultivated land. The rough calculation above confirms our presupposition that the amount of arable land observed by the 1698 census takers can be taken as proxy for household production.

[16] Of course, if a pair r_B and w satisfying Eq. (5) is competitive (i.e., r_B and w equal the marginal productivities at a prevailing labor to oxen ratio $\frac{L}{\bar{B}}$), then by CRS the additional production will be completely paid in rental costs and the peasant is indifferent to not renting any inputs at all. Yet our notion of 'optimality' for $\frac{L}{B}$ remains unaffected since it rests only on the ratio of inputs, not on their absolute level.

[17] For a discussion see for instance Binswanger and McIntire (1987).

[18] The short period of settlement after the defeat of the Ottoman Empire may therefore explain the low number of oxen per worker that prevails in this period.

[19] See Sect. 3.2 for the calculation of B_i^{NW}, L_i^{NW} and B_i^{NNW}, L_i^{NNW}.

[20] For the correlation across fields a decay with distance is more realistic. However, since we take land and its distribution as given and focus on crop choice this would only complicate the algebra without providing additional insights.

References

Binswanger HP, McIntire J (1987) Behavioral and material determinants of production relations in land-abundant tropical agriculture. *Economic Development and Cultural Change* 36:73–99

Čapo J (1995) Comments on 18th–19th Century agriculture in Croatia. Personal communication

Chayanov AV (1986) *The Theory of Peasant Economy*. University of Wisconsin Press, Madison. Originally published by Agricultural Economics Scientific Institute, Moscow, 1925

Clark G (1991) Labour productivity in English agriculture, 1300–1860. In: Overton M, Campbell BMS (eds) *Land, Labour and Livestock: Historical Studies in European Agricultural Productivity*, Manchester University Press, New York, pp. 211–235

de Janvry AM, Fafchamps M, Sadoulet E (1991) Preasant household behavior with missing markets: Some paradoxes explained. *The Economic Journal* 101:1400–1417

De Vries J (1976) *The Economy of Europe in an Age of Crisis, 1600–1750*. Cambridge University Press, Cambridge

Fafchamps M (1992) Solidarity networks in preindustrial societies: Rational peasants with a moral economy. *Economic Development and Cultural Change* 41(1):147–174

Hammel EA (1972) The zadruga as process. In: Laslett P, Wall R (eds), *Household and Family in Past Time*. Cambridge University Press, Cambridge

Hammel EA, Wachter K (1996a) Evaluating the Slavonian census of 1698. Part I: Structure and meaning. *European Journal of Population* 12(2):145–166

Hammel EA, Wachter K (1996b) Evaluating the Slavonian census of 1698. Part II: A micro-simulation test and extension of the evidence. *European Journal of Population* 12(4):295–326

Hirshleifer J, Riley JG (1992) *The Analytics of Uncertainty and Information*. Cambridge University Press, Cambridge

Jančula J (1980) *Povijest Cernika i cernička samostanska kronika*. Grafička Radna Organizacija "A. Tajkov", Slavonska Požega

Marczali H (1910) *Hungary in the Eighteenth Century*. Cambridge University Press, Cambridge

Mažuran I (1988) *Popis naselja i stanovništava u Slavoniji 1698. Godine. Vol 2: Radovi Zavoda za Znanasveni Rad u Osijeku*. Hrvatska Akademija Znanosti i Umjetnosti

Mosely, PE (1940) The peasant family: the zadruga, or communal joint-family in the Balkans, and its recent evolution. In: Ware CF (ed) *The Cultural Approach to History*. Kennikat Press, Port Washington, N.Y.

Rosenzweig, MR (1988) Risk, implicit contracts and the family in rural areas of low-income countries. *The Economic Journal* 98:1148–1170

Rothenberg GE (1960) The Austrian Military Border in Croatia, 1522–1747. *Illinois Studies in the Social Sciences* 48

Salaman RN (1949) *The history and social influence of the potato*. Cambridge University Press, Cambridge

Singh I, Squire L, Strauss J (1986) *Agricultural Household Models*. John Hopkins University Press, Baltimore

Skok P (1972) *Etimološki rječnik hrvatskoga ili srpskoga jezika. Vol 2.* Jugoslavenska Akademija Znanosti i Umjetnosti, Zagreb

Tomasevich J (1955) *Peasants, Politics, and Economic Change in Yugoslavia*. Stanford University Press, Stanford

Townsend RM (1993) *The Medieval Village Economy: A Study of the Pareto Mapping in General Equilibrium Models*. Princeton University Press, Princeton