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Gabriel Jover-Avellá



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Gabriel JOVER-AVELLÀ*

Population, Subsistence Crisis and Agrian Change in the Island of Majorca, 1560-1650**

Abstract. The studies on the relationships between population and subsistence have established that the decrease in the intensity of fluctuations in harvests and prices of wheat, and the easing of demographic fluctuations are strong indicators of economic and social changes in pre-industrial societies. The aim of this study is to conduct an initial analysis of the relationship between demographic variables, prices and the production of food in the Majorcan Island in the sixteenth and seventeenth centuries. The question that I will try to answer is whether the economic transformations that occurred in the seventeenth century in the Majorcan Island led to an attenuation of the fluctuations in prices and food production, and a lower frequency and intensity of crises of subsistence.

Résumé. Population, crises de subsistance et révolution agraire à Majorque, 1560-1650

Les études portant sur la relation entre population et subsistance ont établi que la diminution de l'intensité des fluctuations des prix et récoltes, et l'atténuation des fluctuations démographiques sont de bons indicateurs des changements économiques et sociaux dans les sociétés pré-industrielles. L'objectif de cette étude est de procéder à une première analyse de la relation entre les variables démographiques, les prix et la production de céréales dans l'île de Majorque aux ^{xvi}^e et ^{xvii}^e siècles. La question à laquelle je tenterai de répondre est de vérifier si les transformations économiques qui ont eu lieu au ^{xvii}^e siècle dans l'île ont conduit à une atténuation des fluctuations des prix et de la production alimentaire, et à une plus faible fréquence et intensité des crises de subsistance.

* Centre de Recerca en història Rua, Universitat de Girona, Departament d'Economia, Campus de Montilivi, Girona, 17071. E-mail : gabriel.jover@udg.edu

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The relationship between population and subsistence in preindustrial societies has been subjected to two types of research. On the one hand, a traditional historiography has dealt with the study of the nature and dynamics of subsistence crisis, especially the relationship between famine and mortality¹. This argument has been reviewed recently based on the study of contemporary famine². On the other hand, the relationships between demographic variables and prices in the long term have been studied. The objective was to elucidate which factors attenuated historical price volatility, fluctuations in production and the demographic crisis associated with them, especially the crisis of mortality related to famine. These studies have established that the regularity of harvests, decrease in the intensity of fluctuations in prices and the easing of demographic fluctuations are strong indicators of economic development and social welfare in preindustrial societies³.

The literature on changes of behavioural demographic variables to commodity price fluctuations is abundant. In general the studies show a high inversed correlation between baptisms (births or conceptions) with prices. This inverse relationship between fertility and prices was explained on the basis of biological (amenorrhea, increase in diseases related to malnutrition) and social factors (various forms of fertility control), or a combination of both. However, it was impossible to establish to what extent each of these factors helps in explaining the phenomenon. This inverse relationship has also been well established between prices and nuptiality, however the behaviour of nuptiality presents more pronounced differences between regions and countries than those registered in the behaviour of birth. While the crises of subsistence keep discouraging any conclusion of new marriages after poor harvests, the behaviour might be more complex when the famine coincided with mortality. The response of marriage above death could be more complex: the first response could result in a postponement of marriages, but with one or two years of delay, marriages could be increased with the rebuilding of previously destroyed homes. The relationship between famine and increased mortality is not as evident as in conceptions and marriages. It is difficult to separate deaths directly caused by hunger and those induced by the spread of disease in populations weak-

1. MEUVRET, J., 1971; DEL PANTA, L. & LIVI BACCI, M., 1979; WALTER, J. & SCHOFIELD, R., 1989; PÉREZ MOREDA, V., 1982.

2. These studies have expanded on the explanation of the causes of the crisis, from strictly ecoclimatic factors to others of economic or institutional character. DREZE, J., 1999; O'GRADA, C., 2007; 2008.

3. PEARSON, K. G., 1999; EPSTEIN, S., 2001; CHEVET, J.-M. & SAINT-AMOUR, P., 1992; O'GRADA, C. & CHEVET, J.-M., 2002.

ened by malnutrition. The analysis of historical data has shown a positive correlation, albeit low, between increases in prices, and mortality in many regions, and an increasing weakening of these relations from the middle of the eighteenth century⁴.

The subject of our communication links with the latter general observations. The question that I will try to answer is whether the economic transformations that occurred in the seventeenth century in the Majorcan Island led to an attenuation of the fluctuations in prices and food production, and a lower frequency and intensity of crises of subsistence⁵. This communication has been structured in the following sections: the first section describes the sources and methods used to study the relationships between demographic and economic variables; in the second section the timing and sub-periods of the economic and demographic changes that took place between 1570 and 1660 are established, and the sub-periods from which our analysis will be structured, after which we will study the relationship between prices, yields and demographic variables and finally it is completed with some general observations.

1. The space, the data and the methods

Until recent times most of the historiography on the island of Majorca has argued that the frequency and intensity of famines from the sixteenth to the eighteenth century was the result of backwardness agriculture, and that policies intended to mitigate its effects (import of grains, the taxation of price, distribution of wheat, etc.) caused huge losses to the public finances of the kingdom and jeopardized their economic growth⁶. However, recent studies on the demographics and economy of the seventeenth to nineteenth centuries present a different scenario. Firstly, the demography studies have argued an early decrease in infant mortality rates and a reduction in the intensity of the demographic crisis throughout the eighteenth century⁷. Moreover, studies on economy have showed some changes in agrarian and commercial sectors in the seventeenth and eighteenth centuries. On the one hand, the crisis in the manufacture of wool exports; and on the other hand

4. MEUVRET, J., 1971; DEL PANTA, L. & LIVI BACCI, M., 1979; WALTER, J. & SCHOFIELD, R., 1989; PÉREZ MOREDA, V., 1982; PERRENOUD, A., 1979; FLINN, G., 1989.

5. JOVER-AVELLÁ, G., 2002; JOVER-AVELLÁ, G. & MANERA, C., 2008.

6. JUAN VIDAL, J., 1976; 1980; 1999; CASANOVA, U. DE, 2005.

7. MOLL, I., SEGURA, A. & SUAU, J., 1983; SEGURA, A. & SUAU, J., 1984; SUAU, J., 1991; BUJOSA, F., MOLL, I. & SUREDA, B., 2000.

the increasing intensification and diversification of agricultural production at local level, as well as the specialization of olive-oil production and export. These studies have contradicted the alleged « unchanged » early modern Majorcan economy and to relate agricultural changes to the demographic ones⁸. The aim of this communication is to conduct an initial exploration of the origins of these changes from the analysis of the relationship between demographic variables, prices and the production of food.

To analyze the relations between population and subsistence at this stage the series of parish registers of births, marriages and deaths, cereal prices in the city of Palma and the series of cereal production will be used. The crops series comes from the records of the cereal harvests collected by the authorities of the island since the Middle Ages. These records estimated the harvest of cereals and pulses with a multipurpose, first to gather the information necessary to prevent possible shortages, the other was used to set the starting price at auction for the lease of the tithes and other taxes on production⁹. The prices of cereals came from the mercurial of de Palma¹⁰. The city prices were affected by several factors. First, for the urban demand which was more inelastic than the rural one; second for the cost of transporting grain from the villages to the city, third for the role of wheat imports and finally for the political economic of authorities¹¹. We do not know what differences there were between city and rural prices or how the city prices influenced rural ones. However, city prices are a reference for the entire island¹². Because, the city was the largest market and main manufacturing center of the island where the bulk of agrarian rents and surplus for urban consumption and export converged¹³.

The construction of a homogeneous sample representative of the demographic variables (births, marriages and deaths) for the period studied has raised some problems. Our initial aim was to make a single homogeneous sample, representative of different agro-ecological districts of the island. Despite the large number of villages that have parish records, many

8. DEYÁ, M., 1995; 1998; BIBILONI, A., 1995; MANERA, C., 1990; 2001.

9. JUAN VIDAL, J., 1976; 1978; SUAU, J., 1979; VAQUER-BENNASSAR, O., 1987.

10. These prices were collected by the authorities of the Kingdom and published in the eighteenth century in the Bulletin of the *Sociedad de Amigos del País de Palma de Mallorca* (SUAU, J., 1979; VAQUER-BENNASSAR, O., 1987).

11. These factors mean that the relationship between process and crops could change over time.

12. JUAN VIDAL, J., 1978; SUAU, J., 1979; VAQUER-BENNASSAR, O., 1987; MANERA, C., 2001.

13. JUAN VIDAL, J., 1978; SEGURA, A. & SUAU, J., 1984.

contain gaps and in others the series are not continuous, particularly the last third of the sixteenth century. The problems are particularly acute in the series of mortality records. The death registers are not continuous until the beginning of 1580, and there are no records of infantile deaths until the end of the seventeenth century¹⁴. These circumstances have obliged us to operate with three samples which are not homogeneous and are relatively small, however continuous for the period addressed. Samples of the demographic variables produced are as follows.

The conception sample included the parishes of Binissalem (Llose-ta), Selva (Mancor), Valldemossa, Montuïri and Manacor, and the sample of marriages includes the parishes of Binissalem (Lloseta), Valldemossa, Montuiri, Petra (Vilafranca) and Felanitx. These two samples are continuous from 1567 to 1656 and represent 20% of the total population of the island and 26% of the rural population. Both incorporate municipalities representing all districts of the island and agroecological populations which are higher than 1,000 inhabitants.

For mortality there are continuous series for the parishes of Binissalem, Montuïri, Sineu (Lloret), Petra (Vilafranca) and Felanitx, this sample represents approximately between 15% and 19% of the island's population. The major disadvantages are that it begins in 1583, and is less representative as it excludes any olive growing parish districts in the Sierra de Tramuntana, and only reflects the mortality of adults.

For treatment of the series we used simple statistical methods: the coefficients of variation (CV) and correlation coefficients (R). The first indicator provides us with statistical information on changes in the intensity of fluctuations of different variables for each of the periods studied. The second, as is known, provides the concordance between two variables, but does not prove causal links between them. However, they can be established from other information. For the calculation of the CV and R we have primarily used crude data from the series. The main reason is that the detrend (removing the trend) of demographic data would incur an important loss of part of the information for the period studied, and therefore affect the final third of the sixteenth century, a key period for our study. However, we performed the same exercises to eliminate the tendency for these series. We have converted raw data (X) in the percentage deviations from the average of thirteen years moving around the years referred to ($X\% = XMM13$)¹⁵.

14. MOLL, I., SEGURA, A. & SUAÚ, J., 1983.

15. GALLOWAY, P. R., 1988; ROEHNER, B. M., 1990.

The result does not significantly improve the results to eliminate the trend of transforming the data series¹⁶. Finally, as suggested by most studies on the impacts of changes in crop/prices on demographic variables, we incorporated time lags of 0 to 3 years; and we have converted births to conceptions, because it is a more accurate way of capturing the possible preventative strategies of fertility, and it is used for the analysis of relations between the variables in the agricultural year.

2. The economic and demographic changes in the sixteenth and seventeenth centuries

In the sixteenth early modern times the Kingdom of Majorca had a population of between 95,000 (1585-1593) to 99,190 (1667) inhabitants. One-quarter lived in the city of Palma and the rest were distributed among 32 parishes. Most of the island was under the feudal dominion of king (70% of territory). Below the king there were barons and other feudal lords that had small manors. The feudal jurisdictions couldn't prevent the movement of people or impose barriers to the movement of goods¹⁷. All the feudal burdens (tithes, census, etc.) were mainly economic in nature. The kingdom had a set of political institutions that governed economic policy of the island, and were legally only enforced by the power of the monarch¹⁸.

In the middle of the sixteenth century the economic structure of the island could be described as follows. On the one hand, below the feudal lords, the aristocratic landowners had established extensive estates, organized as large farms which were worked by the abundant wage-labour force¹⁹. The peasant smallholdings encircled the rural villages. The peasant tenancies were intensively cultivated with cereals, vineyards and olive trees²⁰. Throughout the fifteenth and sixteenth centuries the big estates specialized progressively in the extensive cultivation of cereals and sheep farming²¹. From the late sixteenth century and especially in the seventeenth century an important specialized olive production began, in the villages of the mountainous districts of the Tramuntana and Levant. Meanwhile on the plains of

16. See Table 6, analyses with crude data, and Tables 7 and 8 analyses with the date's de-trended.

17. MOLL, I. & SUAÚ, J., 1986.

18. JUAN VIDAL, J., 2000.

19. JOVER-AVELLÀ, G., 2011.

20. JUAN VIDAL, J., 1988; 1989; JOVER-AVELLÀ, G., 1998.

21. MOLL, I. & SUAÚ, J., 1979; JOVER-AVELLÀ, G. & MOREY, A., 2003.

the island, cereal crop specialization was reinforced at the cost of reduction in livestock farming. Furthermore, in the middle of the sixteenth century a powerful manufacturing sector, specializing in the exportation of medium quality cloth was expanded. At the beginning of the sixteenth century the bulk of the manufacturing activity was located in the city of Palma. During the sixteenth century the rural manufactures expanded, especially the spinning and weaving processes. This situation was driven by the need to reduce costs in relation to foreign competition and the undertaking of an increasing number of peasant families with insufficient land to ensure their reproduction²². The strength of this sector was based on the facilities offered by the commercial network woven into the medieval period and under the privileges that the Catalan-Aragonese crown had granted Majorcan cloths to their holdings in Italy²³.

These two sectors were the engines of economic and population growth in the sixteenth century. The studies show an increase in agricultural production, population and prices throughout the second half of the sixteenth century²⁴. However, during the last third of the century, economic expansion would become increasingly difficult, as Figure 1 and Figure 2 indicate. The first shows the evolution of production and wheat prices, and the ratio between the production of wheat and births, an indicator of product per capita; the second shows the evolution of demographic variables. The sets of both graphs are expressed as variable averages over 13 years and have a variable index base from 1589, the first year for which we have a complete series of all variables. Since 1580 a clear deterioration in the relationship between population and wheat production can be appreciated, which in turn is reflected in an increase in cereal prices. In the first decade of the seventeenth century grain production collapsed and remained so until the mid-1630s at levels 20 percent lower than those at the end of the sixteenth century. Wheat prices continued to rise and remained there, varying between 20 and 40 percent above the average for the decade of 1590s until the mid-1630s. As can be seen in graphic 3 these tensions were expressed in a long series of shortages of various kinds and intensities²⁵. Finally, demographic records from 1600 show a stagnation of the curves of conceptions and marriages that lasted for the first third of the seventeenth century, and a sharp increase in mortality in the decades following 1620 and 1630. Population censuses recorded de-

22. DEYÁ, M., 1995; 1998; BERNAT, M., 1995.

23. BIBILONI, A., 1995; VAQUER-BENNASSAR, O., 2001, 2008.

24. JUAN VIDAL, J., 1988; 1989; JOVER-AVELLÁ, G., 1998.

25. JUAN VIDAL, J., 1976; 1978; MOLL, I., SEGURA, A. & SUAÚ, J., 1982; VAQUER-BENNASSAR, O., 1987.

mographic stagnation in the first half of the century. Following the studies on the first half of the seventeenth century this stagnation of population was due to mortality, the frequent military levies and migration into the Kingdom of Valencia²⁶. Only in the decades after 1640 is population growth clearly resumed²⁷.

Figure 1. *Production and prices of wheat, and product per capita (13-year average)*

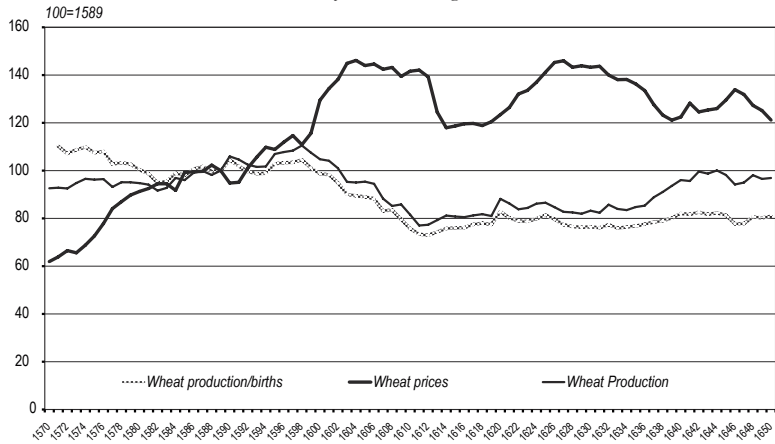
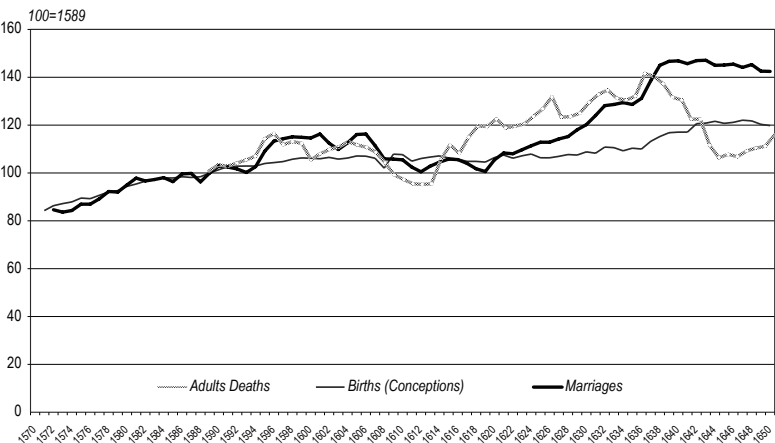


Figure 2. *Evolution of births (conceptions), adults deaths and marriages (13-year average)*



26. SEGURA, A. & SUAU, J., 1984; JUAN VIDAL, J., 1990; CASANOVA, U. DE, 2005.
27. The changes in agriculture and population in seventeenth century are explained in JOVER-AVELLÁ, G. & MANERA, C., 2009.

The difficulties of cereal production were added to the growing problems facing the export of cloth. The studies on woollen manufactures suggest that climate was achieved in the decade following 1610, and after that time there was an acute drop in the production and export of cloth. The causes of this « manufacturing crisis » have been explained from the loss of its monopoly in the markets of Southern Italy, a trade and tax policy unfavourable to the development of the island cloth manufacturing, changes in the Mediterranean trade, and increasing competition from new cloth imports from across the Atlantic²⁸. The problems of this sector also contributed to the complication of the policies of supply of wheat by the authorities and traders on the island. So, to cover the growing cereal deficit, wheat was regularly imported from markets in the western Mediterranean, especially southern Italy, the same markets to which they exported the bulk of the cloth from the island. The decline in the export volume of cloth to affect the financial capacity to guarantee the purchase of grains resulted in growing political and financial burden for the authorities of the kingdom²⁹. During the first third of the seventeenth century the convergence between the crisis in cereal production and the decline in manufacturing provoked a tension in all market and economic mechanisms, and social institutions that should have been able to prevent the subsistence crisis³⁰.

The economic and demographic changes described above permit the establishment of three terms as a basis for studying the vital variables, prices and grain production. The first period covers the last third of the sixteenth century, the last stage of demographic and productive growth, and when the island was still a major producer and exporter of cloth (1567-1596); the second period covers the first quarter of seventeenth century, coinciding with the demographic stagnation, the crisis of cereal production and the manufacturing decline (1597-1626); and finally the third period (1627-1656) reflects the first signs of recovery in agricultural production and population, and the now full definition of the new export model based on the production of olive oil.

28. DEYÁ, M., 1998; BIBILONI, A., 1995.

29. BIBILONI, A., 1995; CASANOVA, U. DE, 2005.

30. According to the estimates of authorities of the Kingdom during these years the needs of wheat for population consumption rose to an estimated average of 11% of the wheat harvest in mid-1579, to 18% from 1600/09, to reach their peak in the decade of 1610-19 to 28% in respect of the total production of the island. In those years the debt burden grew dramatically. Dates collected for O. VAQUER-BENASSAR, 1987, U. DE CASANOVA, 2005, and C. MANERA, 2001.

3. The subsistence crises.
An analysis on the production and prices of cereals, 1530-1714

This section will focus on our questions, first, as to whether there were changes in the intensity levels of fluctuation and correlation between fluctuations in production and prices from 1600 onwards. If that were the case, and if constant, we would have evidence of socioeconomic transformations. Mitigating fluctuations could be the result of complex changes in the agricultural sector, the functioning of markets and public policies on the supply of food. Table 1 and Table 2 summarize the coefficients of variation (CV) and Table 3, Table 4 and Table 5 correlation coefficients (R), prices and grain production for each of the sub-periods into which the sixteenth and seventeenth centuries have been divided.

Table 1. Fluctuations in the prices of cereals (CV)

	<i>Wheat</i>	<i>Barley</i>	<i>Oats</i>	<i>CVt-CVc</i>
1530-1564	41,51	40,81		0,70
1565-1596	41,00	40,67		0,33
1597-1626	30,90	26,80	24,66	4,10
1627-1656	23,79	28,87	21,35	-5,08
1657-1686	22,77	26,58	26,98	-3,81
1687-1716	23,41	24,69	22,78	-1,28

Table 2. Fluctuations in the production of cereals (CV)

	<i>Wheat</i>	<i>Barley</i>	<i>Oats</i>	<i>CVt-CVc</i>
1530-1564	28,60			
1565-1596	23,91	23,40	44,82	0,51
1597-1626	26,54	28,85	33,31	-2,31
1627-1656	21,38	28,34	34,80	-6,96
1657-1686	25,14	33,19	32,08	-8,05
1687-1716	25,16	22,94	29,72	2,22

Table 1 shows that the prices of wheat and barley have the highest CV in the second half of the 16th century. During the periods of 1530-1564 and 1567-1596 CV ratios reach above 40%, with minimal differences between wheat and barley. Fluctuations in wheat prices are always higher than those of barley. In the period 1597-1626 there was an initial decrease in the intensity of fluctuations in prices, which will continue throughout

the century. The decrease in CV was accompanied by a significant change in the difference in the amplitude of the oscillations of wheat and barley (column $CV_T - CV_C$). Production fluctuations in Table 2 show a more complex evolution. The pattern is similar to that described for the price, but with a significantly lower level of oscillation and with some variations³¹. Throughout the second half of the seventeenth century the CV of wheat remained around 25%. Fluctuations in the production of barley and oats, throughout the seventeenth century, show a greater variability in the intensity of fluctuations. A joint assessment of the CV of prices and production for the period suggests, that price fluctuations were more intense than those of production in the second half of the sixteenth century (1530-1565 and 1567-1596: about 17-19%). These differences between price fluctuations and production of wheat were reduced in the first quarter of the seventeenth century (1597-1626: about 5%).

From 1626-1657 the difference between the average intensity of fluctuations in production and in wheat prices are very low (2-3%), despite the differences between the CV of price and production in barley and oats being more than in wheat, the fluctuations in the production of these items tended to be higher than the prices.

We can say that throughout the seventeenth century there was a gradual damping of the fluctuations in the prices and harvests of cereals, and that the evolution of the fluctuations in the production of other cereals was more complex, as will be seen through the evolution of production and wheat prices.

No money changes may explain the decrease in price fluctuations³². However, we have evidence of market intervention by the authorities. In the years of severe crisis in 1591, 1604-1606, 1613, 1617, 1630-1632 and 1635 as show Figure 3 and Figure 4, the authorities improved facilities to import grain, rose the public control over the supply of grain, and price taxation was established³³.

31. Fluctuations in wheat production were more intense in periods 1530/65 (CV = 28.6%) and 1597-1626 (CV = 26.5%), coinciding with the most serious crisis of agricultural underproduction in the sixteenth century and the first half of the seventeenth century (Figure 3).

32. FELIU, G., 1993.

33. JUAN VIDAL, J., 1976; 1978; MOLL, I., SEGURA, A. & SUAU, J., 1982; CASANOVA, U. DE, 2005.

Figure 3. *Demographic crises.*
Adult deaths, marriages and conceptions in agricultural years.
The percentage deviation of year data referred to 13-year average

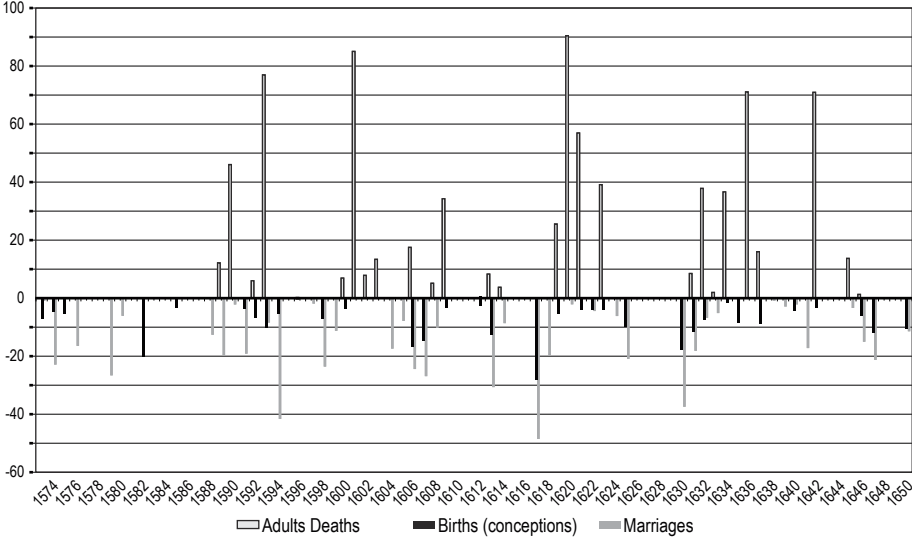


Figure 4. *Subsistence crises.*
Wheat crops and wheat prices fluctuations.
The percentage deviation of year data referred to 13-year average

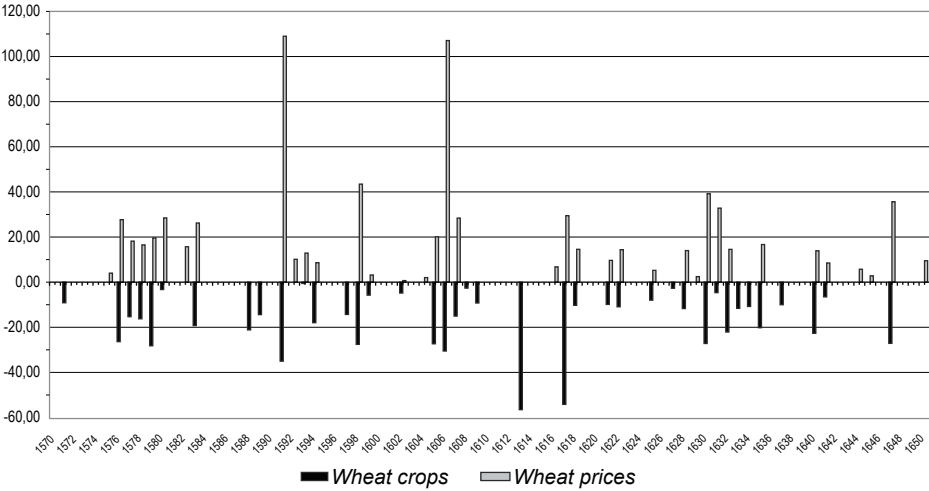


Table 3 shows the R prices in town. In all periods and among all variables, the Rs obtained are very high: the average of R is 0.83 or more (Table 4, column XR) in all periods. There is a high correlation between changes in grain prices throughout the sixteenth and seventeenth centuries. In general, high levels of correlation between the prices of wheat, barley and oats have been interpreted as an indicator of the lack of alternatives with inferior cereals offered to consumers when the price of wheat soared. However, R expresses the correlation in the intensity of the oscillation, but this does not affect the differential in price levels which remained constant, thus replacing the consumption of bread made with wheat, bread made with wheat and barley, or barley alone, which could be an alternative for a section of the population. Table 4 summarizes the correlation indexes between the series production of wheat, barley and oats. The R between the different productions of cereals is lower than the R that offers other series of prices for these cereals. This is probably due to the greater variability of local crops and different farming regimes that were conducted on the island. However, we observe a slow convergence of the upward rates of correlation between wheat, barley and oats throughout this stage (XR column, Table 4): from 0.41 in the first period (1565-1596) to 0.65 in the last period (1687-1716).

Table 3. *Coefficients of cereal prices correlation (R)*

	<i>Wheat/barley</i>	<i>Wheat/oats</i>	<i>Barley/oats</i>	<i>XR</i>
1530-1564	0,93			
1565-1596	0,94			
1597-1626	0,82	0,74	0,92	0,83
1627-1656	0,91	0,86	0,96	0,91
1657-1686	0,90	0,87	0,95	0,90
1687-1716	0,81	0,78	0,91	0,83

Table 4. *Coefficients of cereal production correlation*

	<i>Wheat/barley</i>	<i>Wheat/oats</i>	<i>Barley/oats</i>	<i>XR</i>
1530-1564				
1565-1596	0,40	0,36	0,46	0,41
1597-1626	0,49	0,74	0,33	0,52
1627-1656	0,41	0,68	0,48	0,52
1657-1686	0,65	0,73	0,39	0,59
1687-1716	0,54	0,72	0,69	0,65

Finally, Table 5 summarizes the correlation between prices in the city and the total production of cereals. The evolution of R for each product is negative; therefore we could foresee the price formation in the city was affected to some degree by fluctuations in the harvests of the island, although there are significant variations during the sixteenth and seventeenth centuries. The concordance between prices and production of wheat is high in the growth stage of the second half of the sixteenth century ($R = -0.6$). In the first third of the seventeenth century the R production/ wheat prices decreased to -0.47 . The serious and repeated shortfall of wheat crops during this period were not translated into proportional inverse price increases to the production severity of crop shortfalls. Perhaps the high quantities of wheat imports, consumption of inferior cereals (barley, oats) and measures taken by the authorities play an important role in the attenuation of correlation between crops and prices in this period. In subsequent periods the correlation increases to $-0.77 / -0.79$ situated above the levels of the sixteenth century. This close relationship is broken in the period 1686-1716 as a result of price rises due to the serious crises of subsistence in 1689 and 1711 and the distortions caused by the long War of the Spanish Succession (1705-1717). The R in prices and production of barley are more fickle (= in-constant). Although the three sub-periods into which we have divided the period 1567-1656 maintained an inverse relationship between R wheat, the periods 1657-1686 and 1687-1716 both have a very similar evolution.

Table 5. *Correlation co-efficients between the production and the prices of cereals*

	<i>Wheat</i>	<i>Barley</i>	<i>Oats</i>	<i>XR</i>
1530-1564	-0,62			
1565-1596	-0,60	-0,42		-0,34
1597-1626	-0,47	-0,77		-0,41
1627-1656	-0,79	-0,44		-0,41
1657-1686	-0,77	-0,73	-0,66	-0,72
1687-1716	-0,35	-0,38	-0,36	-0,36

The information furnished by CV and R proposes, as expected, more questions than answers. The high fluctuations in production and cereal prices that characterized the long sixteenth century took place, first during a period of economic expansion. It is possible that the high CV of prices and production reflected cultivated marginal land, the pressure of population growth, more dependence from cereal imports, and the first dif-

ficulty in manufactured exports. The decrease in R between production and prices between 1530-1564 and 1597-1626 suggests increasingly that prices in the city became more dependent on increased global demand and rising imports of wheat from abroad rather than from domestic production. Moreover, during this period Rs between the production of wheat and barley (Table 4), and the evolution of R in prices and production of barley (Table 5), as described above, suggest that this cereal could be a complement or substitute for wheat in times of crisis.

From the second third of the seventeenth century onwards the decline in CV of prices started. The stability of the CV of production, the growing convergence R of production and the increase in R between the price and production of wheat could be related to a set of economic changes closely interrelated. The first being the significant decrease in imports of wheat³⁴. This decline in imports could have been achieved thanks to a moderate increase in both urban and rural population³⁵, to boost grain production from the decades of 1630 and 1640 (Figures 1 and 4), and thanks to the mitigation of wheat crops shortfall (Figure 3). Also, chronologically, these changes coincide with agricultural transformations that were produced in dry farming cereal systems, characterized by greater intensification of work, improved rotation systems with the introduction of pulses (= legumes, especially dry beans) from the decade of 1630³⁶, the abandonment of land less suitable for grain and the expansion of the vine³⁷, and the great expansion of production and trade specialization in olives trees among the hilly villages³⁸. However, we should recognize that the connections between these different processes have been poorly studied.

34. Import requirements according to authorities estimates of wheat in the decades of 1630 and 1640 accounted for 11% of the harvest, and were below 7% of the total production in the decades of 1640 and 1650. Dates collected for O. VAQUER BENASAR, 1987, U. DE CASANOVA, 2005 and C. MANERA, 2001.

35. Which is evident in the population census of the seventeenth century (SEGURA, A. & SUAÚ, J., 1984) and the evolution of baptisms (Figure 2).

36. The information collected about legumes production started in 1620, but it is only continuously collected from 1650 (JUAN VIDAL, J., 1978).

37. CASANOVA, U. DE, 1987; BINILONI, A., 1995; MANERA, C., 1988.

38. BINILONI, A., 1995; MANERA, C., 1988; JOVER-AVELLÁ, G., 2002; JOVER-AVELLÁ, G. & MOREY, A., 2003; JOVER-AVELLÁ, G. & MANERA, C., 2009.

4. The demographic responses to short falls crops

What were the responses of demographic variables to the frequent and intense fluctuations in production and prices that occurred on the island of Majorca during the early modern era? Which dominated, *preventive checks* or *positive checks* (or compulsory checks)? Did the demographic patterns change at the same rate as the price fluctuations and production? In Table 6, we have systematized the R between the critical variables, price and production. Each panel corresponds to a period of time it takes for the lagged R of demographic variables from 0 to 3 years in respect to prices and production for the year 0. In Tables 7 and 8 we have performed the same exercises, which eliminate the tendencies of these series. We have converted raw data (X) in the percentage deviations from the average of thirteen years moving around the years referred to ($X\% = XMM13$), and we calculated the R of series with the new data.

Table 6. Correlation analysis of complete data

1567-1596				1597-1626				1627-1656			
T-0	CAA-1 DAA-1 MTA-1			T-0	CAA-1 DAA-1 MTA-1			T-0	CAA-1 DAA-1 MTA-1		
CCA-1	1,00			CCA-1	1,00			CCA-1	1,00		
DAA-1	-0,32	1,00		DAA-1	0,04	1,00		DAA-1	-0,40	1,00	
MTA-1	0,55	-0,15	1,00	MTA-1	0,60	0,31	1,00	MTA-1	0,62	0,04	1,00
PROBL	0,09	0,29	0,51	PROBL	0,62	0,35	0,72	PROBL	0,60	0,05	0,55
PREBL	0,31	-0,04	-0,07	PREBL	-0,44	-0,12	-0,38	PREBL	-0,42	-0,34	-0,55
1567-1596				1597-1626				1627-1656			
T-1	CAA-1 DAA-1 MTA-1			T-1	CAA-1 DAA-1 MTA-1			T-1	CAA-1 DAA-1 MTA-1		
CCA-1	1,00			CCA-1	1,00			CCA-1	1,00		
DAA-1	-0,32	1,00		DAA-1	0,01	1,00		DAA-1	-0,38	1,00	
MTA-1	0,55	-0,15	1,00	MTA-1	0,62	0,29	1,00	MTA-1	0,62	0,07	1,00
PROBL	0,11	-0,17	0,02	PROBL	0,22	0,00	0,38	PROBL	-0,08	-0,05	0,23
PREBL	0,40	0,20	0,27	PREBL	-0,26	-0,06	-0,27	PREBL	-0,03	-0,06	-0,39
1567-1596				1597-1626				1627-1656			
T-2	CAA-1 DAA-1 MTA-1			T-2	CAA-1 DAA-1 MTA-1			T-2	CAA-1 DAA-1 MTA-1		
CCA-1	1,00			CCA-1	1,00			CCA-1	1,00		
DAA-1	-0,28	1,00		DAA-1	-0,02	1,00		DAA-1	-0,42	1,00	
MTA-1	0,52	-0,13	1,00	MTA-1	0,61	0,25	1,00	MTA-1	0,62	0,02	1,00
PROBL	0,01	-0,51	-0,09	PROBL	-0,09	-0,11	-0,04	PROBL	0,41	-0,44	0,19

PREBL	0,41	0,57	0,35	PREBL	0,04	0,14	-0,09	PREBL	-0,29	0,12	-0,45
1567-1596				1597-1626				1627-1656			
T-3	CAA-1	DAA-1	MTA-1	T-3	CAA-1	DAA-1	MTA-1	T-3	CAA-1	DAA-1	MTA-1
CCA-1	1,00			CCA-1	1,00			CCA-1	1,00		
DAA-1	-0,30	1,00		DAA-1	-0,03	1,00		DAA-1	-0,40	1,00	
MTA-1	0,55	-0,13	1,00	MTA-1	0,63	0,22	1,00	MTA-1	0,63	0,02	1,00
PROBL	0,15	0,34	0,14	PROBL	0,01	-0,22	-0,14	PROBL	0,42	-0,21	0,11
PREBL	0,45	-0,33	0,19	PREBL	0,04	0,18	0,16	PREBL	-0,23	0,00	-0,37

Notes. CCA1: sample of conceptions in agricultural year; DAA1: sample of adult deaths in agricultural year; MTA1: sample of marriages in agricultural year; PROBL: wheat production of Majorca; PREBL: Wheat prices of Palma. T-0, T-1, T-2 and T-3 time lags.

Tableau 7. Correlation analysis with de-trended series, 1590-1650

T-0	PROB	PREBL	DAA1	CAA1	MTA1
DAA1	0,21	-0,18	1,00		
CAA1	0,61	-0,47	-0,19	1,00	
MTA1	0,66	-0,51	0,17	0,55	1,00
T-1	PROBL	PREBL	DAA1	CAA1	MTA1
DAA1	-0,14	0,12	1,00		
CAA1	0,10	-0,26	-0,20	1,00	
MTA1	0,13	-0,20	0,18	0,56	1,00
T-2	PROBL	PREBL	DAA1	CAA1	MTA1
DAA1	-0,38	0,42	1,00		
CAA1	-0,06	-0,10	-0,19	1,00	
MTA1	-0,23	-0,04	0,17	0,57	1,00
T-3	PROBL	PREBL	DAA1	CAA1	MTA1
DAA1	-0,18	0,18	1,00		
CAA1	-0,01	0,02	-0,20	1,00	
MTA1	-0,21	0,06	0,18	0,56	1,00

Note. The raw data (X) in the percentage deviations from the average of thirteen years moving around the years referred to ($X\% = XMM13$).
CCA1: sample of conceptions in agricultural year; DAA1: sample of adult deaths in agricultural year; MTA1: sample of marriages in agricultural year; PROBL: wheat production of Majorca; PREBL: Wheat prices of Palma. T-0, T-1, T-2 and T-3 time lags.

Tableau 8. *Correlation analysis with de-trented series for the periods established, 1590-1650*

<i>1570-1596</i>	<i>PROBL</i>	<i>PREBL</i>	<i>DAA1</i>	<i>CAA1</i>	<i>MTA1</i>
PROBL	1,00				
PREBL	-0,81	1,00			
DAA1	0,19	-0,17	1,00		
CAA1	0,05	-0,27	-0,38	1,00	
MTA1	0,56	-0,37	-0,16	0,32	1,00
<i>1597-1626</i>	<i>PROBL</i>	<i>PREBL</i>	<i>DAA1</i>	<i>CAA1</i>	<i>MTA1</i>
PROBL	1,000				
PREBL	-0,552	1,000			
DAA1	0,267	-0,212	1,000		
CAA1	0,645	-0,507	-0,044	1,000	
MTA1	0,712	-0,531	0,328	0,598	1,000
<i>1627-1652</i>	<i>PROBL</i>	<i>PREBL</i>	<i>DAA1</i>	<i>CAA1</i>	<i>MTA1</i>
PROBL	1,000				
PREBL	-0,650	1,000			
DAA1	0,039	-0,171	1,000		
CAA1	0,600	-0,577	-0,326	1,000	
MTA1	0,454	-0,506	0,058	0,587	1,000

Notes. The raw data (X) in the percentage deviations from the average of thirteen years moving around the years referred to ($X\% = XMM13$).

CCA1: sample of conceptions in agricultural year; DAA1: sample of adult deaths in agricultural year; MTA1: sample of marriages in agricultural year; PROBL: wheat production of Majorca; PREBL: Wheat prices of Palma. T-0, T-1, T-2 and T-3 time lags.

Studies on Majorcan demography have highlighted that during this period (1560-1660) the island was not affected by serious epidemics. The only two phenomena known are the plague epidemic of 1652 that affected a very limited geographic area, and a crisis of infantile mortality in 1610³⁹. To link mortality and famine, the R of adult's deaths should provide a positive relationship with prices and a negative one with production. As shown in Table 6 (and Tables 7 and 8) the R indicates only a weak relationship between famine and deaths. Only in two periods, and with a delay of two years (T 2), there are some relationships between variables. In the first period (1583-1596) only a positive relationship between mortality and prices (0.57) ap-

39. VAQUER BENASAR, O., 1987; MOLL, I., SEGURA, A. & SUAUE, J., 1982; CASANOVA, U. DE., 2005.

pears and a negative one related to production (-0.57). In the second period (1626-1656) there is a very slight positive relationship between mortality and price (0.12), and more intense with production (-0.44). Although there is no overlap between the years of strong increases in mortality and food shortage, these results suggest that in some times mortality occurred years after the severe or several subsistence crises. Figures 2 and 3 show that there was a sustained increase in adult mortality in the decade of 1590, and a new and intense increase in the decades of 1620 and 1630, both increases in mortality are after periods of severe and prolonged death⁴⁰. Probably the link between scarcity and mortality at this stage is expressed mainly in the deterioration of the population's access to a diet adequate in quantity and quality. The scarcity and the increase in wheat prices could be due to the combination of frequent harvest shortfalls and commercial and financial difficulties for providing grain from exterior markets (increased prices). In these circumstances, a reduction of the quantities of wheat consumed and a substitution (in the diet of much of the greater part of the population) of wheat bread by another made with cereals of inferior quality could be produced. Under these conditions, the morbidity of the population could increase and make them more vulnerable to diseases related to the digestive system and respiratory systems⁴¹.

The behaviour of conceptions and marriages is more consistent with the information but with some nuances. On the one hand, the relationship between marriages and conceptions with prices and production is more intense than that described for deaths, except for the first period. Secondly, the effect of price and production on marriages and conceptions occur in the same year and in the months following the poor harvests. Delays dilute the levels of correlation between economic and demographic variables, except for the period 1626-1657⁴². In the first period (1567-1596) and at T-0 only marriages show a significant relationship with production, and the rest of R between conceptions, production and prices, and marriages and prices is barely significant. The relationship between conceptions and prices, and to a lesser extent also for married couples, is positive but weak in delays T-1, T-2 and T-3 (0.40-0.45). Some questions arise from this data: is this behaviour due to the fact that decisions were made relying on other social

40. Especially in the second period, the famine years were 1613, 1617, 1626-27, 1630-32, 1636-38 and 1647. MOLL, I., SEGURA, A. & SUAU, J., 1982.

41. O. VAQUER BENASAR, 1987, in his study on the Felanitx parish, established this relationship for the subsistence crises of the first half of the seventeenth century.

42. In these years there is a significant correlation between fluctuations of marriages and conceptions, and production and prices, in the delays t-2 and t-3, which coincide with what was observed for mortality during the same period.

and economic factors other than crops? Did the extension of rural manufacturing as a supplementary income carry any weight in the demographic behaviour?

The behaviour of marriages and conceptions in the seventeenth century contrast with the last third of the sixteenth century. In the second (1597-1626) and third (1627-1656) periods the relationship between conceptions and marriages with respect to economic variables becomes more intense. Faced with shortages (rising prices and falling production) both marriages and conceptions decrease. As is seen, this behaviour takes place mainly in the months following a poor harvest (T-0), weakening the impact in subsequent years.

*

From the beginning, the hypothesis was that between the end of the sixteenth century and the first half of the seventeenth century there were a number of important changes in the economy of the island of Majorca. The purpose was to identify the dynamics of these changes by an exploration of demographic variables and prices, and wheat production for which we had quantitative, rich and relatively homogeneous information. The analysis of the correlation (R) and variation coefficients (CV) of price and production of cereals suggests that during the first third of the 17th century some other changes tended to mitigate the fluctuations observed. We couldn't determine with certainty the nature and scope of these changes, but we could instead suggest some insights.

Firstly, the information provided by the indicators and the studies suggests that agricultural changes took place in that period: expansion of legumes, vineyards, olive-trees.

Secondly, there is an open field to study the role played by the authorities regarding the control of prices and market interventions during extremely difficult years.

Thirdly, the commercial adjustments which were made in the first half of the seventeenth century are not explained either. They involved much more than the replacement of manufacturing exports by oil exports, because they also constituted a change in trade routes and places of exchange (from the Mediterranean to the Atlantic), and the creation of a new system of changes that would allow the purchase of the cereals required in some

ports (the Mediterranean) different from those where the oil was sold (the Atlantic).

Finally, a rough outline of the analysis of the relationship between population, production and prices (CV and R) is not too far from the analysis of other regions and countries. The correlation indexes suggest that conceptions and marriages were more sensitive to fluctuations in crop yields and prices of cereals. In contrast, mortality had a more tenuous and complex relationship with shortfall crops. It might be that the major change took place in the first third of the seventeenth century, when the relationship between conceptions and marriages, and crops and prices was strongest. How could we explain this reinforcement of the relationship between conceptions and prices and crops? Could we suggest that after the wool manufacture crisis the rural population was more dependent on agricultural income than before? Our findings indicate that a more accurate analysis of the entire seventeenth century is needed.

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