Economic Analyses of Prehistoric Greece

Economic Analyses of Prehistoric Greece:

From the Neolithic to the Bronze Age

By

Donald Jones

Cambridge
Scholars
Publishing

Economic Analyses of Prehistoric Greece:
From the Neolithic to the Bronze Age

By Donald Jones

This book first published 2023

Cambridge Scholars Publishing

Lady Stephenson Library, Newcastle upon Tyne, NE6 2PA, UK

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN (10): 1-5275-2809-X
ISBN (13): 978-1-5275-2809-3

TABLE OF CONTENTS

List of Tables ix

Preface x

Part I: Neolithic

Introduction to Part I 2

Chapter 1 4
Transformations from the Neolithic to the Bronze Age in Greece:
Part I. A Model of a Household in an Egalitarian Neolithic Village
1.1 A Model of a Household in an Egalitarian, Greek Neolithic Village 6
1.1.1. The Model 9
1.1.2. The Archaeological Setting 14
1.1.3. The Archaeological Setting 15
1.2. Influences on the Egalitarian Ethic 16
1.3. Saving and Saving Behavior 26
1.4. Influences on Leisure 29
1.5. Conclusion 32
Appendix 1. Definitions and Explanations of Variables and Parameters 34
Appendix 2. Technical Matters 38
Some Details on the Solution Method 38
Numbers in and Numbers out 39
Appendix 3. Components of Changes to Saving Behavior 41
References 43

Chapter 2 47
Transformations from the Neolithic to the Bronze Age in Greece:
Part II. Greek LN/FN Neolithic Households in Settlements and How They Might Have Chosen to Govern Themselves: *Praxis* at the Household and Settlement Levels
2.1. Background and Goals of the Current Research and Roadmap to the Interim Presentation 48

2.2. Time Scales: Human, Economic, and Archaeological 52
2.3. The Household's Intertemporal Economic Behavior in Its Settlement Setting 53
2.4. Innovation 60
2.5. More on the Second Time Period 61
2.6. Governance and Mechanism Design 62
2.7. The Settlement's Public Goods 67
2.8. Activity at the Settlement Level 70
2.9. Back to the Operation of Mechanism Design Theory 71
2.10. The Determinants of Household Differentiation: Household Factor Endowments 73
2.12. Formalizing Household and Settlement Changes over Time 75
References 78

Part II. Prehistoric Crete

Introduction to Part II 84

Chapter 3 87
Concepts in Urbanization and Early State Formation:
The Case of Minoan Crete
3.1. Urbanization 90
3.1.1. Agricultural Productivity and Transportation Technology 91
3.1.2. Financing the Architecture 93
3.1.3. Growth Rates of Ancient Populations 94
3.1.4. The Full Economic Basis of Urbanization 98
3.2. Early State Formation 101
3.2.1. Control and Power 102
3.2.2. Monopolization 104
3.2.3. Imports 106
3.3. Evolution and Revolution 106
3.3.1. Time as a Causal Variable 107
3.3.2. Rapid Developments: How Rapid? 112
4. Synthesis: Fitting the Components Together 118
References 123

Chapter 4 134
Agency and the Growth of Complexity in the Archaeological History of Crete, LN/FN – MM II (16,350)
4.1. The Issues 135
4.2. Complexity 137

4.3. Structuration and Agency Theory for the Practical Archeologist Studying Change 143
Intermezzo: The Train of Thought Thus Far and How It Will Proceed 151
4.4. Antecedents and Consequences of the Rise of Palatial Government 152
4.4.1 Public Finance: An Apparent Fact Looking for Explanations 153
4.4.2 Population Growth: Not an Explanation 155
4.4.3 Agriculture 156
4.4.4 Settlements 158
4.4.5 Archaeological Reflections of Social Development in Mortuary Remains 162
4.5. Hypothetical Applications of Complexity and Agency to Minoan Crete 164
4.5.1 Complexity 164
4.5.2 Agency 166
4.6. Conclusions 171
References 172

Part III. Bronze Age

Introduction to Part III 180

Chapter 5 182
What Happened to the Therans?
5.1. Fatal Assumptions and Modeling 183
5.2. Unpacking the Archaeological Evidence 184
5.3. Theran Artistry in LM IB Ceramics 188
5.4. Pulling Together Absent Corpses and Extant Vase Painting 193
References 194

Chapter 6 199
The Western String Revisited
6.1. The Demographic Background 202
6.2. Non-Western String Shipping Routes 204
6.2.1. Apparent Short-Haul Routes 205
6.2.2. North Beyond the Western String 206
6.3. Modeling Trade, Product Production and Port Service Provision 207
6.3.1. Background 207
6.3.2. The model 208

6.4. Testing the Hypothesis 210
6.4.1. Akrotiri 212
6.4.2. Ayia Irini 212
6.4.3. Phylakopi 215
6.5. Conclusion 217
References 218

Part IV. The Bronze Age Ends

Introduction to Part IV 232

Chapter 7 233
There Be Pirates!
7.1. Pirates and Piracy 234
7.2. Sea Peoples 240
7.2.1. An Excursus on Events on Crete 247
7.2.2. Extrapolation, Conflation, and Usual Suspects 249
7.3. Pulling the Strands Together 250
7.4. Hitchcock and Maeir on the Sea Peoples as Pirates 252
References 257

Chapter 8 268
Post-Palatial Greece: Where Did All the People Go?
8.1. Post-Palatial Population Decline 269
8.2. Legendary Evidence of Emigrations 272
8.3. Archaeological Evidence 273
8.3.1. Headed East: Cyprus 273
8.3.2. Headed East: The Philistines 274
8.3.3. Headed East: People Other than the Philistines 276
8.3.4. Headed West: Italy 276
8.4. Linguistic Evidence 277
8.4.1 Across the Aegean to Anatolia 277
8.4.2. East to Cyprus 278
8.5. Why Would People Have Wanted to Leave Greece? 279
8.5.1. Pictorial Evidence 280
8.5.2. Environmental Evidence 282
8.6. Conflicting Trends: Collapse, Rejuvenation, Technological Change, Where? When? 283
8.7. Joining the Legends, the Archaeological Data, and the Economics of Sustained Population Decline 284
References 285

Index 297

LIST OF TABLES

Table 1.1. Effects on Household Contributions to and Participation in Maintenance of Egalitarianism

Table 1.2. Participation in and Contributions to Egalitarian Activities

Table 1.3. Influences on Leisure

Table 1.A1. Definitions of Endogenous Variables

Table 1.A2. Definitions of Exogenous Variables

Table 1.A3. Elasticities of Savings Variables

PREFACE

This is a book about archaeology–Greek archaeology or sometimes called Classical archaeology–if one written by an economist. Accordingly it will not "sound" like one written by an archaeologist, whether that archaeologist was trained as a "Classical" archaeologist in a Classics Department or in an Anthropology or Archaeology Department. That is the point. If I had nothing to say that had not already been said or would be said by one or more of these archaeologists there would be no point to this book. But my own reading and research in the various fields of Greek archaeology and conversations with archaeologists practicing in the Greek or broader "Classical" field lead me to believe that my perspectives could add value to an already vibrant group of fields.

An economist? Physicists, metallurgists, botanists, geneticists, sociologists, linguists, psychologists . . . but an economist?! Satan's handmaiden, if we follow the late David Graeber? Markets? Efficient markets? Competition? Perfect competition? Rational expectations? Rationality? Let's take rationality first, a much maligned whipping boy, even taken to task by Nobel Prize winner in Economics Daniel Kahneman and his predeceased colleague Amos Tversky. As another Nobel Prize winning economist, Gary Becker, showed decades before Kahneman and Tversky made their mark at the interstices of economics and psychology, that non-rationality, or irrationality, can take specific forms, each of which can be studied for its consequences for resource allocation decisions. Consider a specific case that some people might consider irrational: a person wants to give away half of her income each year. That is her goal. She would be irrational if her actions led her to continue accumulating rather than disbursing. Economics relies on a few specific axioms to define rationality for its analyses, but a rough-and-ready definition of rationality targets the relationship between preferences and choices. And beyond rationality, Becker founded the analytical apparatus for studying choice behavior outside of markets.

Archaeologists have reached keen, economic insights about their subjects and material on many occasions, ranging from contractual organization under conditions of uncertainty to time allocation in potting to public choice to industrial organization. I have reported and elaborated on some of these

insights previously, so there is no point in repeating them here. In part I of this volume I have developed models–economic models–of how routine, household behavior over centuries might have paved the way for gradual transition from relatively egalitarian polities to the distinctly non-egalitarian polities of the Bronze in Greece, particularly the later Middle Bronze Age and the Late Bronze Age. Partially successful numerical analysis in the first chapter suggests the relative strength of various external forces on people's work-leisure and wealth accumulation choices. The second chapter extends the individual household theoretical framework into the setting of a settlement in which direct and indirect interactions with other households could have led to changes in preferences for egalitarian values and behavior. I have left to others the transition from various forms of consensus public decision making to the unmistakable monarchies of the Late Bronze Age. This section provides ways of thinking, many of which are not particularly foreign to archaeologists, but are somewhat more codified, but not "answers." It would not be uncharitable to characterize these two chapters as developing hypotheses which ingenuity may be able to probe or even test with excavation material.

The chapters of Part II continue in the spirit of providing a framework for thinking about issues which have riveted archaeologists of Crete for decades–its urbanization, the emergence of what appears to have been one or more states, and the concomitant increase in various aspects of social and economic complexity. They bring together some familiar material–facts, beliefs, working hypotheses–and join them with "moving parts" of individual and group behavior which, presently–archaeologically–visible or not, must have occurred to accomplish the changes observed in the excavated remains. Again, these chapters offer ways of thinking about what is or may become known, not "answers" such as can be provided by metallurgical analysis or mass spectrometry or network analysis.

The chapters of Parts III and IV provide "answers," to the extent that indisputable "answers" can be derived for many periods and events in prehistory. The chapters of Part III deal with two problems of Bronze Age prehistory. The first, what happened to the residents of Thera, or at least some of them, after the volcanic eruption that covered the port town Akrotiri and much of the island with volcanic sediment. The economics remains in the background but guides the hypothesized behavior of certain elements of the Theran population. It might be considered a "light touch" of labor economics. The second chapter deals with Thera and two other Cycladic islands–Melos with its settlement Phylakopi and Kea with its settlement Ayia Irini–before and after the effective destruction of Thera for a

millennium. Some of the remains of both settlements have given the appearance of affluence, which has in turn fueled a wide range of speculation for its emergence. The chapter develops a hypothesis and uses published excavation data to test it.

Part IV continues to offer "answers" to long-standing questions of Greek–and broader East Mediterranean–prehistory: what were the Sea Peoples and what happened to the population of mainland Greece after the collapse of the Mycenaean palatial system? Rather than produce another speculation on what some or all of the Sea Peoples were, I endeavor to demonstrate conclusively that they were not pirates, a supposition into which too many fine archaeologists land without serious thought. In the final chapter, the juxtaposition of the drastic decline in the population of mainland Greece during the period of legendary, mythical or possibly actual, population movements of various scales offers an opportunity to explore "coincidences."

In the concluding contribution to a symposium on the transition from Minoan to Mycenaean Crete, a period a millennium or more later than the times I address in the papers of this volume, Michael Galaty and Jeremy Rutter (2022: 425-426) reflect on the concepts "event" and "process" in archaeology as entry points for exploring and understanding transitions in particular and change in general during prehistoric periods. Archaeology commonly documents events: the construction or destruction by fire of a building, the introduction of a new pottery shape, and such. Processes that lead to these events typically are more difficult to document archaeologically, although remains of household refuse within architectural foundations, and even possibly the occasional remains of feasting such as found in Pit Pi (or Pit 212) at Makriyalos I (Urem-Kotsou and Kotsakis 2007: 228-229, 242-243) which may mark both event and possibly process. Although the importance of archaeological documentation of events cannot be disputed, the chapters of this volume explore processes leading to and sometimes following events.

Altogether I hope these chapters will spark interest in what economics and economists can offer to archaeological, prehistoric scholarship.

References

Galaty, M.L., and Rutter, J.B. 2022. "Event, Process, Transition, Transformation: Concluding Comments and Data Regarding Crete's Monopalatial Period." In *One State, Many Worlds; Crete in the Late Minoan II-IIIA2 Early Period*, SMEA Supplement 2, edited by D'Agata,

A.L., Girella, L., Papadopoulou, E., and Aquini, D.G., Rome: Consiglio Nazionale delle Ricerche: 425-451.

Urem-Kotsou, D., and Kotsakis, K. 2007. "Pottery, Cuisine and Community in the Neolithic of North Greece." In *Cooking up the Past, Food and Culinary Practices in the Neolithic and Bronze Age Aegean*, edited by Mee, C., and Renard, J., Oxbow: 225-246. URL: https://www.jstor.org/stable/j.ctt1cfr8qd.18

PART I:

THE NEOLITHIC

INTRODUCTION TO PART I

The Neolithic of Greece can be seen profitably as part of the Neolithic of the Balkans and the rest of Southeastern Europe, as demonstrated amply in the papers of *First Kings of Europe*, a recent publication of the Field Museum. While hereditary social differences did not emerge over the millennia of the Neolithic, excavated remains indicate both that some differences in wealth and probably prestige developed and remained within single generations and that tensions between communal ethics and household individuality are apparent from the Early Neolithic in some settlements. However, by the end of the Final Neolithic / Chalcolithic in Greece, societies were still another millennium away from the apparent beginnings of monarchies such as represented by the Mycenaean palatial civilization and possibly the earlier Minoan palatial civilization although the prospect of monarchy has not been broached for the Minoan Cretans despite the name of the Throne Room at Knossos.

The chapters of this section construct models of a Neolithic household, first in isolation and next in the context of a settlement composed of other households, with constructs which can be associated with observable, archaeological remains. In both settings, the households possess a preference for an egalitarian ethic, an ethic which competes in the minds of the householders with the necessaries and even frivolities of daily living. The goal of the modeling of these two chapters is to identify ordinary behavior which over generations and millennia could have changed minds–modified preference–in ways that could have created openings for less consensual governance that in turn could have led to small-faction or one-person governance by the Late Bronze Age–without the necessity of resort to invasion.

This modeling effort takes us only part of the way from conflicted egalitarianism to palaces and throne rooms. It offers ways of thinking about the social changes along the way, but not answers. A motivating idea behind the effort is that understanding of physical remains can be enhanced by well-constructed stories ("stories") about how the remains got there, a goal embraced by efforts by archaeologists to introduce agency and its structuration relative into thinking about artifacts. The chapters of Part II

extend this mode of thinking to focus on events on Crete during the very last part of the times of Part I and times shortly afterward.

References

Gyucha, A., and Parkinson, W.A., eds. 2022. *First Kings of Europe: From Farmers to Rulers in Prehistoric Southeastern Europe*. Chicago: The Field Museum of Natural History.

CHAPTER 1

TRANSFORMATIONS FROM THE NEOLITHIC TO THE BRONZE AGE IN GREECE: PART I. A MODEL OF A HOUSEHOLD IN AN EGALITARIAN NEOLITHIC VILLAGE*

Abstract

A model of a Neolithic Greek household is developed and used to investigate factors affecting the household's contributions to and participation in activities that generate an egalitarian distribution of income and wealth in a village and factors and events influencing savings behavior, both planned and opportunistic. Many external influences on egalitarian activities are found, but the most distinct is the depressing influence of larger village size on these activities. While many technological changes have small and moderate influences in both directions on savings and the concomitant accumulation of wealth, larger village size depresses planned savings but appears to be outweighed by additional opportunitistic savings of both agricultural and manufactured goods which could well have had idiosyncratic and differing impacts across households in a village or region. Both sets of activities offset both large and visible and small and difficult-to-discern changes in behavior that could have contributed to the transformation from relatively egalitarian Neolithic society to more hierarchical, and eventually palatial, Bronze Age society in Greece.

*Re-published with permission of Peeters Publishers Leuven from *The Earliest Economic Growth in World History; Proceedings of the Berlin Workshop* (Leiden, 2022).

Keywords: egalitarianism, Gini index, households, leisure, production, savings

Multifaceted changes transformed Neolithic village society into societies with palatial administrations at their apex. These changes spanned political, economic, settlement, intellectual, and possibly religious spheres. No single model could account coherently for the full array of developments. Since the transformations occurred over at least two thousand years, and probably longer, there would have been numerous "stages" which could be identified, at least conceptually, as possible modeling targets: "from stage Blue to stage Green," to avoid implications of numerical designations and associations of descriptive names with the plethora of theories extant in various literatures. An alternative to such a "point-to-point" approach is modeling of routine social processes which, interacting with technological changes, could lead to erosion of earlier societal norms or organization of particular types of activities. Individual process models could focus on a variety of activities which are believed to have undergone reorganization as part of the Neolithic-to-Bronze transformation.

The basic problem that this paper addresses is how "more equal" societies of the Neolithic became the "more unequal" societies of the Bronze Age, culminating in Greece in the Mycenaean palatial society. The model posits particular pathways that might have operated over time to redistribute resources among households such that eventually a much smaller proportion of households possessed a much larger proportion of resources. The standard measure of such equality or inequality is the Gini coefficient, itself derived from the Lorenz curve. The Gini coefficient is a single-number measure of the degree of inequality of some variable measured on a sample of individuals or percentiles of a population. As such, it is a measure of a distribution. The model developed in this paper deals with the activities of a single household which would affect the equality of distribution of wealth within a village of households. Consequently, there is no need to measure the Gini coefficient, since a single household is observed at a single, initial point in time and at a single, temporally displaced point in time. What the model does employ, however, is a generalized Gini measure as a function of several variables which would be expected to affect its value. A common formula for the Gini coefficient is $G = \Sigma_{i=1}^{n} \sum_{j=1}^{n} |x_i - x_j| / 2n \sum_{j=1}^{n} x_j$, where x is the measure of the variable distributed over individuals i and j, where there are n individuals. The Gini coefficient is the sum over all of the magnitude-ordered individuals of the shortfall from equal shares of the cumulative magnitude of that variable up to each individual in the distribution, divided by the greatest value possible at that point, with complete inequality. The value of a Gini coefficient generally ranges from

zero, indicating complete equality, to one, indicating complete inequality–one individual holding all of the variable under measure.

Returning to the employment of a Gini function in this model, the actions of any household can result in either increased or decreased wealth, with other households unchanging. Of course, in any Neolithic village, many, if not most, households would undertake actions that could change the village's distribution of wealth, and entries and exits of households also could affect that distribution, but one household's behavior is likely to generalize, while the concept of an "open" village–open to emigration and immigration–raises forces beyond those incorporated here.

The first model developed here is such a process model. It addresses how an apparent, egalitarian ethic could have been reduced and possibly largely eliminated over time by the force of small changes affecting the resources required to maintain rough equality of wealth across a village community. As Blake and Clark (Blake and Clark, 1999, 57; Clark and Blake, 1994) endeavored to achieve in their work, the approach here reverses the question of "how did inequality emerge," to "how did egalitarianism weaken or disappear?" As the force of egalitarianism weakened, village sizes and settlement systems may have changed, both introducing additional forces weakening the application of an egalitarian ethic. The model here does not advance into those subsequent changes, although they remain interesting topics for further modeling.

1.1. A Model of a Household in an Egalitarian, Greek Neolithic Village

This model studies the behavior of a household that has multiple members who devote their efforts to maximizing the well-being of their household subject to constraints on the household's resources as well as to the norms of the village where they live. The household members produce an agricultural good–their food–and manufactured goods, which could range from stone, bone, and wood tools to ceramics and clothing. One thing the household values in addition to consumption and leisure is a measure of equality of wealth across households in the village, but maintaining any given level of equality requires the household to devote resources to that effort, resources which come out of their own consumption. However, the degree of equality across households in the village depends on the expenditures of all the households on the equality maintenance activity, making the degree of equality achieved a public good.

The household can save some proportion of both their agricultural production and their manufactured production and at any given time may have some wealth in the form of accumulated savings. These physical savings can deteriorate over time, so they are not permanent, and the household may have dipped into its savings at different dates in the past. Since intra-village, and even interregional, trade was long established in the Neolithic, the household can consume some imports, which it pays for with its own exports of agricultural and manufactured goods. If the household does dip into its savings during the period modeled, it can spend those savings on either goods produced by other households in the village or imports. The ability to spend accumulated savings on exports breaks the requirement that the value of imports equal the value of exports.

The household uses both labor and capital equipment in its agricultural and manufacturing activities. Some of the equipment may be left over from previous periods, according to a depreciation rate, and may be refurbished with the use of some labor in the model period. Similarly with housing: the household consumes housing, some of which remains from the previous period but is subject to maintenance or upgrading with the use of labor time. The household can receive a rate of return on previous savings, which could be achieved by loaning out some of the equipment or agricultural inventory to other villagers, although the same is not true of housing. The household need not live a life of working drudgery but can choose some leisure time as well.

In numerical solutions, the household can take on a continuum of activities through the initial specification of labor allocation between agriculture and manufacturing. The specification used in the results presented here depicts the household as primarily an agricultural household, with some modest manufacturing activities, with 35 percent of household time devoted to agriculture, 13 percent to manufacturing activities, 30 percent to leisure, 10 percent to repair and production of agricultural and manufacturing tools, 7 percent to ritual activities, and 5 percent to housing maintenance, repair and upgrade. These percentages could be altered to represent a household more specialized in manufacturing activities, possibly exchanging those products for all of its food. (I owe consideration of this point to Vagia Mastrogiannopoulou.)

The valuations–prices by another name–that the household faces are all given to it. That is, the return to applications of labor is the same across households and may well be the same in other villages. The valuations of goods and capital equipment also are not affected by any household's

actions. Intra- and inter-village trade (exchange) determines the prices of goods, which may also be the same across the entire array of villages in the region.

The model contains a number of avenues for change. First, households can accumulate wealth, which will affect their supply of labor to various activities. Second, changing labor allocations will alter patterns of production within households and can in turn make contributions to maintenance of equality across households less attractive, without any change in the fundamental preference for equality. Third, depreciation rates on productive equipment, housing, and stored inventories (physical wealth) could decrease through technological change, freeing household members' maintenance and repair time to be used in other activities, including leisure. Fourth, prices could change, possibly beginning with the price of imports, which could increase or decrease relative to prices of locally produced items. While the model leaves prices exogenous to activities by this household, changes in the activities of many households in a village–and in other similarly affected villages–could begin to affect prices of goods and of factors of production–labor time and equipment. Fifth, technological change could affect the production functions and even introduce new products. These changes could be neutral in their effects on the productivity of time and equipment or could enhance one or the other more.

As with Sahlins' vision of the "domestic mode of production" (1972, Chapters 2-3), endorsed by Halstead (1999, 89-90), the household developed here engages in exchange with other households but also accumulates wealth even while engaging in activities aimed at leveling wealth. The model developed here is closer to Chayanov's "peasant economy" model in its focus on alternative household activities, although with considerably less detail on the intricacies of agricultural operations. The agricultural household model has been developed extensively within economics in recent decades as well (Barnum, 1979; Singh, 1986; Nakajima, 1986; Key *et al*., 2000; Jones, 2014, 414-423; Jones, 2021, Chapter 2), and the model presented here follows the broad outlines of that approach.

The present model shares an emphasis on agents' pursuit of their own interests with a model of the emergence of hereditary inequality by Blake and Clark, who emphasize ". . . the emergence of rank, or institutionalized inequality, [as] a long-term, unexpected consequence of many individuals pursuing their own short-term interests" (Clark and Blake, 1994: 17; Blake and Clark, 1999, 57). While the model developed here stops short of establishing social rank or political power or leadership, it does provide

several short-term mechanisms which contain longer-term implications for wealth inequalities, which do seem to be at the heart of rank and leadership.

Proposals for processes that may have led from egalitarian societies of the Neolithic to the more hierarchical ones of the Bronze Age have tended to emphasize political negotiations as well as subsidiary economic developments (Clark and Blake, 1994; Blake and Clark, 1999), and looking forward in time a bit (Earle, 2010). Clearly the intra-village, and certainly at some point, inter-village or intra-town, negotiations and decisions regarding authority, both temporary and hereditary, must have played an important role in the transformation from Neolithic village and town societies to the palace societies of the later Middle and Late Bronze Age in Greece. The present model focuses on some economic underpinnings of those negotiations, but does not address the more general issue of social complexity.[1]

1.1.1. The Model

A household's utility is a function of its consumption of food, F_C, manufactured goods, M_C, imports, I, housing, H, leisure, ℓ, wealth, W, and the degree of wealth equality among the village population, V(G), where G is the Gini index, which takes a value of 0 for complete equality and 1 for complete concentration in one household.

$$U = U(F_C, M_C, F_E, M_E, I, H, \ell, W, V(G), \theta_F, \theta_M, \theta_I),$$

in which $U_j > 0$ and $U_{jj} < 0$ for all arguments. Exports of the agricultural and manufactured goods, F_E and M_E, are used to purchase imports I; since increasing F_E and M_E reduces consumption, equality maintenance and savings, $U_i < 0$ and $U_{ii} < 0$ for these two choices. ($U_j > 0$ means that as one of the arguments in the utility function U, e.g., H, increases in magnitude, utility increases. $U_{jj} < 0$ means that additional increases in U get smaller as argument j continues to increase. This notation is developed as subscripts subsequently when that notation is clearer, e.g., $g_{F_G} > 0$.) The θ_i are drawdowns from wealth to finance consumption of the three goods–the agricultural good, the manufactured good, and the imported good. Θ_F and $\theta_M \gtreqless 0$, with negative values indicating sales of those goods within the community and saving the proceeds. $\Theta_I \geq 0$, since the household cannot sell

[1] For which see, e.g., the papers in Price and Feinman (1995) and Price and Feinman (2010).

imports; however, a reduction in θ_I is possible, indicating a reduction in drawdowns from savings to purchase imports.

The value of the Gini index is a function of all households' contributions to equality and accordingly is a public good:

$$G = G\left(\sum_i^n g_i\right), g = g(F_G, M_G, L_G), g_{F_G} > 0, g_{M_G} > 0, g_{L_G} > 0, g_{M_G M_G} < 0, g_{F_G M_G} > 0, and\ G_{\sum g} < 0$$

where n is the number of households in the village.

Food produced by a household, F, is allocated to consumption, C, maintenance of equality, G, and savings, S:

$$F = F_C + F_G + F_S + F_E \text{ and } M = M_C + M_G + M_S + M_E,$$

where subscript S designates savings and subscript E designates exports outside the village of food and manufactures. Production of housing services involves maintenance labor applied to the structure as it existed at the end of the previous period, where the subscript t indicates the time period:

$$H_t = (1 - \delta_H)H_{t-1} + H(L_{Ht}),$$

where δ_H is the depreciation rate of housing stock. Strictly speaking, H_t and H_{t-1} are stocks of housing at the two dates, while H in the utility function is a flow of housing services proportional to the stock of housing. This maintenance labor may actually increase the housing stock.

Liquid wealth at the beginning of any time period t is the accumulated value of savings in terms of the two goods subject to storage:

$$W_t = \sum_{t=0}^{t-1}\left[(1 + r_f - \delta_F)(1 - \theta_{Ft})F_{St} + (1 + r_M - \delta_M)(1 - \theta_{Mt})M_{St}\right],$$

where the r_j are interest rates that can be obtained on the respective, stored goods, δ_j are the depreciation or deterioration rates, and θ_{jt} are withdrawals at previous dates t. Total wealth includes the values of physical assets such as housing and capital equipment, plus or minus current-period drawdowns:

$$W = W_t(1 - \theta_F - \theta_M - \theta_I) + P_H H + P_{K_F} K_F + P_{K_M} K_M + P_T(\alpha(n)T_F + \gamma(n)T_H) + F_S + p_M M_S,$$

where $\alpha(n)$ and $\gamma(n)$, $\alpha_n < 0$, $\gamma_n < 0$, represent crowding effects of additional households in a village on farm and house land respectively. The P_i, i = H, K_F, K_M, and T, are the prices of the respective assets, which are, of course, considerably larger than their current rental prices, the p_i. The P_i are related to the p_i as:

$$P_i = \frac{p_i}{r_i}\left[1 - \frac{1}{(1+r_i)^{N_i}}\right],$$

where, for example, $p_i \equiv r$ for K_F and K_M and k for T, r_i is the own-discount (or interest) rate for the particular asset, and N_i is the anticipated economic life of the asset. The N_i and r_i are inversely related to each other but are not simply inverses of each other. It has been found that contemporary consumers display strikingly different discount rates for different kinds of assets, particularly that consumers discount the value of energy efficiency in household appliances at rates well above consumer borrowing rates (Hausman, 1979; Dubin and McFadden, 1984). Whether to interpret these divergences as representing irrationality of consumers or their possession of information not available to researchers has been decided generally in favor of the latter.

The household's technologies for producing food and manufactures are contained in production functions. For food production, or farming:

$$F = \tau_F F(L_F, \alpha(n)T, K_F), F_i > 0, F_{ii} < 0, F_{ij} > 0,$$

where τ_F represents the productivity of the technology, L_F is labor time, T is land sown, and K_F is services of capital equipment used. Land, T, is affected by the number of village households, represented by $\alpha(n)$ $\alpha_n < 0$, reflecting the effective reduction of land available to all households as an increasing number of households forces greater travel distances to fields for at least some households.

For manufacturing, production technology is represented by:

$$M = \tau_M M(L_M, K_M)$$

where τ_M represents the manufacturing technology, L_M and K_M are labor time and services of capital equipment used in manufacturing. Capital equipment used in farming and manufacturing is produced by the household:

$$K_{jt}(1 - \delta_{Kj})K_{j,t-1} + H\left(L_{K_{jt}}\right), j = F, M$$

where δ_{K_j} is the depreciation rate of capital equipment used in the previous period as upgraded by repair or maintenance with labor in the present period, $H\left(L_{K_{jt}}\right)$. Factor-specific technological change could be modeled with additional τ_k terms, but I have opted to avoid the additional notational clutter.

Because savings can be tapped for current expenditures, a household's disposition of either good can exceed or fall short of its own production, even after allowing for exchange among other households within the village, an effect captured by terms $\theta_i \gtreqless 0$, I = F, M, I, shares of liquid wealth at the beginning of the period that are spent on consumption goods:

$F^d = F_C + F_G + F_S + F_E + \theta_F W_t$ and $M^d = M_C + M_G + M_S + M_E + \theta_M W_t$

The household's full supply of labor time is allocated across the various productive activities and leisure:

$$L = L_F + L_M + L_H + \sum_j L_{K_j} + \ell$$

The household's income is derived from the following sources:

$$Y = w\left(L_F + L_M + L_{H_t} + \sum_j L_{K_{jt}} + \ell\right) + r(K_F + K_M) + kT + p_H(1-\delta_H)H_{t-1} + \sum_{i=F,M} \theta_i W_t,$$

where θ_i is the proportion of the household's wealth that it spends during the period. The household's expenditures, including its saving, equal its income:

$$E = F_C + F_S + p_M(M_C + M_S) + p_G g + p_H H + p_I I + \sum_{i=F,M} \theta_i W_t,$$

where I is imports, $p_F = 1$, and the other p_j terms are prices (valuations) of the other goods in terms of the agricultural good.

Allowing unbalanced trade, or a balance-of-payments deficit or surplus, since a store of value exists,

$$p_I I = F_E + p_M M_E + \theta_I W_t$$

The model clearly contains a large number of endogenous variables, 26 in all, although happily six of them, excluding constraint multipliers, can be substituted out using adding-up relationships. The household has a fixed amount of time, of which leisure ℓ can be eliminated as the residual of the fixed total household time L minus the time spent in other activities. V(G), H, and W can be substituted out of the utility function with their components, and the two categories of capital equipment, L_F and L_K, can be eliminated with the use of their residual stocks from the previous period and time allocated to their maintenance or supplementation during the current period.

These eliminations of endogenous variables still leave a large model, since 5 constraints remain to be imposed, each with its endogenous Lagrange multiplier, which add another five variables and equations to the model. The budget constraint, with its Lagrange multiplier λ_1, equates household income and expenditure. The magnitude of the multiplier tells the value of a marginal increment in the budget constraint. The second and third constraints characterize the agricultural and manufacturing technologies. The fourth constraint represents the transformation of goods and time allocated to activities maintaining an egalitarian ethic into a value of the Gini coefficient and the structure of the subsequent valuations of those values, V(G). The fifth constraint is the trade balance, allowing effectively for an imbalance of payments with θ_I.

The Lagrangean is

$$
\begin{aligned}
Max\ \mathcal{L} = U(F_C, M_C, F_E, M_E, I, H, \ell, W, V(G), \theta_F, \theta_M, \theta_I) \\
+\ \lambda_1\{w(L_F + L_M + L_H + L_{K_F} + L_{K_M} + \ell) \\
+ r(K_F + K_M) + kT + p_H(1 - \delta_H)H_{t-1} - F_C - F_G - F_S \\
- p_M(M_C + M_G + M_S) - p_H H - p_I I\} \\
+ \lambda_2\{F - F(L_F, \alpha(n)T, K_F) - \theta_F W_t\} \\
+ +\lambda_3\{M - M(L_M, K_M) - \theta_M W_t\} \\
+ \lambda_4\left\{G\left(\sum_i^n g_i(F_{G_i}, M_{G_i}, L_{G_i}) - G\right)\right\} \\
+ \lambda_5\{p_I I - F_E - p_M M_E - \theta_I W_t\}
\end{aligned}
$$

The next modeling steps, detailed further in Appendix 2, involve, first, differentiation of the Lagrangean with respect to each of the endogenous variables under the control of the household. This procedure yields the configurations of variables that will maximize the utility of the household, given the external constraints it faces–known as "first-order conditions" for

maximization. The second step is to differentiate totally (i.e., with respect to all variables, endogenous and exogenous) the first-order conditions. A third step converts the coefficients of the equations resulting from the second step into elasticities–the percent change in an endogenous variable caused by a one-percent change in an exogenous variable. The fourth and final step in the calculations arrays the coefficients of the third-step equations as a matrix and solves for the determinants of alternative versions of the basic matrix of coefficients. From this step emerge elasticities of the endogenous variables with respect to changes in each of the exogenous variables and parameters, which provide the narratives told below.

1.1.2. Stories of the Neolithic

The model contains 25 endogenous variables and 24 exogenous variables and parameters–and more of each when the endogenous variables that are substituted out of the model are accounted for, detailed in Tables 1.A1 and 1.A2 of Appendix 1–so there is a plethora of "stories" that the model can tell. I call these results "stories" because I do not know whether they are true or accurate, which requires a combination of evaluating the logical plausibility of each result and comparing the theoretical prediction with empirical material from Neolithic Greece. Not all of these stories need be told in the same manner. In some cases, interest dwells in the consequences for one or more endogenous variables of changes in a range of exogenous variables. The prime example of this type of story is the influences on egalitarianism, represented by changes on the household's resources allocated to maintenance of an egalitarian ethic as represented by the value of the village Gini coefficient. Others are the influences on determinants of household savings and influences on withdrawals of savings for particular expenditures. The other principle type of story–or set of stories–to be told is from the perspective of a particular exogenous variable, for example the depreciation rate of the housing stock, which has widespread and strong impacts on many of the endogenous variables, most of which are only indirectly affected by that variable.

Readers may be accustomed to two major predictions from economic analyses of consumers and producers: that consumers are expected to purchase fewer units of a product when its cost to them, or price, is higher; and that producers are expected to produce more units of a good when its sale price is higher. The current model is a household model, however, and households are both producers and consumers, facing cost or price incentives in both directions. Consequently, some of the resource allocation responses emerging from the model may seem counterintuitive initially,

although with some further reflection, the intuition behind the responses emerges. The five constraints also can push allocative forces beyond the variables initially affected by exogenous changes, such that responses sometimes appear in unexpected corners of the household economy. That said, the model is large enough to contain intricacies that I simply do not understand myself, although the great majority of understandable responses increases my confidence in the model more than in my full understanding of all its workings. Appendix 2 addresses some technical matters which some readers may value more than others.

1.1.3. The Archaeological Setting

Considerably more could be said regarding what is known about the society(ies), villages, and households of Neolithic Greece than I will report here. The findings I cite here offer some background to the structure of the model presented above and the findings reported below.

First, trade (or exchange, if one prefers that term) occurred among villages, including long-distance trade from the Early Neolithic (Perlès, 2001). Second, by later in the Neolithic, it has been established that specialized production existed at the level of the household, at least for pottery and stone tool manufacture (Souvatzi, 2008) and I suspect also for some stages of clothing production and building construction. This specialization, even if only relative and not absolute, implies some exchange or trade at least among households within a village, which Halstead has concluded must have existed (Halstead, 1995). Fourth, in the Near East, the lack of common storage facilities is taken as evidence making it seem clear "that households held property separately from the community", as Hole concludes was probably largely true for the Levantine and Anatolian early Neolithic (Hole, 2000, 206).

Fifth, the constancy of village size over the Neolithic, particularly toward later centuries, appears to be a matter of current question. Halstead has presented evidence suggesting year-round occupancy for settlement sites (Halstead, 1999). Several models of village splitting with time and population growth have been put forward (Carneiro, 1987; Jones, 1999; Bandy, 2004; Bandy, 2008), and a number of authors have cited the implied requirement for governance structures as village sizes increased (e.g., Halstead, 2005).

Sixth, the egalitarian ethic has been widely deduced or otherwise proposed (e.g., Kantner, 2008; Souvatzi, 2008), but the timing of its disappearance

has been widely dated (Kuijt, 2002; Orrelle and Gopher, 2002; Wright, 2004). Alongside the suggestion of egalitarianism, and apparently peaceful life, skeletal evidence from both Neolithic Greece and the Neolithic Near East reveals what may have been a fairly extensive record of personal violence, in the forms of fractured facial bones from frontal injuries (Papathanasiou, 2005) and more extensive, non-warfare injuries (Whittle, 2003, 39). Clearly interpersonal conflict existed.

1.2. Influences on the Egalitarian Ethic

The egalitarianism constructed in this model requires that households allocate resources to maintaining its extent as measured by a Gini coefficient. Those resources–some of the agricultural good(s) and some of the manufactured good(s), combined with household members' time–may go into feasting, ceremonies, construction and maintenance of shrines and other monuments, and so on. I do not model direct redistribution as a separate consumption item although feasting probably could be so considered. Nevertheless, the egalitarian consequences, V(G), enter the household's utility function. But recall that the value of the village's Gini coefficient, or the degree of the village's egalitarian distribution of income and wealth, is the result of the actions of all households in the village, so each household contributes only a portion of the effort but receives the full results–i.e., egalitarianism or the distribution of income and wealth is a public good. While the model contains only a single household's contributions to this public good, in a Nash equilibrium of strategic interactions across households in the village, which is a plausible condition, all the households would behave as the one under study.

The model presents two principal perspectives on the progress of egalitarianism in the face of external changes: the resources allocated directly to its maintenance and their consequences, and the value the household places on an increase in achievable egalitarianism, represented by the Lagrange multiplier on that constraint, λ_4. Table 1 reports the larger elasticities of external influences on the household's contributions to egalitarianism. As explained above, the very large elasticities should not be taken at face value but rather as reflecting higher degrees of sensitivity.

Table 1.1 reports the elasticities of the household's allocations of the agricultural and manufactured goods, as well as their own time, to the activities that maintain egalitarianism in the village, as well as the effects on the household's valuation of a marginal increment in a more equal distribution of wealth and income. In the case of each influence other than