PART VI

THE EARLY ROMAN EMPIRE

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CHAPTER 20

THE EARLY ROMAN EMPIRE: PRODUCTION

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I INTRODUCTION

The basic issues in evaluating the performance of the Roman economy in the early imperial period are to determine the extent of economic growth in aggregate and to assess the effects of economic change on various groups within Roman society, including wealthy aristocrats, urban residents, and peasant farmers.[1] The growth of the city of Rome and of other cities in the Roman empire created a demand not only for agricultural products but also for manufactured goods, including luxury items.[2] From the time of Augustus to the Antonine period, the population of the empire increased by about one-third, from some 45 to 55–65 million people, and much of this growth took place in the many cities of the empire.[3] The populations of Rome's largest cities exceeded those of the largest cities of Europe until the industrial revolution and were matched only in mediaeval China. Under Augustus, the city of Rome had, on most estimates, between 750,000 and one million inhabitants, while the early imperial period saw the rise of several provincial capitals with populations measured in the hundreds of thousands, including Alexandria, Antioch, and Carthage, as well as many more urban areas with much more modest populations.[4] At the same time, the maintenance of relatively peaceful conditions in the Mediterranean world and the development of a more uniform legal system under Roman rule fostered commerce for these products by lowering transaction costs.[5]

The task of supplying the Roman empire's urban population involved both the state and private producers in a complex network of exchange. Rome was fed with grain imported from Africa and Egypt. As the physical evidence of amphoras indicates, wine produced on Italian estates in the late Republic and early principate supplied Rome as well as markets in Gaul and in other provinces. Soon Rome's demand for wine was met by production from Spain, which also produced olive oil in large quantities for export to Rome and other destinations. Beginning in the second century

[1] Millett 2001. [2] Hopkins 1995/6: 57–63. [3] Frier 2000: 811–16.
[4] Morley 1996: 33–54; cf., for a much lower estimate of Rome's population, Storey 1997.
[5] North 1981.

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and increasingly in the third century, north Africa emerged as a major producer of olive oil, which was exported from that region to markets all over the Mediterranean. Indeed, the same regions could both produce and export agricultural products and at the same time import them. For example, Africa emerged as a major producer of olive oil for export, but it also imported some oil from Spain. The evidence of amphoras alone does not allow us to reconstruct the mechanisms of this exchange. For example, the distribution of Spanish oil amphoras could indicate the operations of the free market. But it is also possible that other mechanisms were at work, such as the efforts of upper-class landowners to import to Rome and other cities the products of their own estates to meet their own domestic needs.[6] But the amphora evidence does point to substantial surplus production for the market.[7] This exchange of agricultural products also created a need to invest in the ships needed to transport foodstuffs as well as in the other infrastructure supporting commerce.[8] The evidence for substantial long-distance trade in agricultural surpluses, moreover, should not obscure the volume of exchanges of surplus foodstuffs on a much more local level as well.[9]

If the Roman imperial peace created opportunities for economic growth, it is still very difficult to assess the overall scale of the Roman economy. The urban economy in the Roman empire was to a large extent fueled by a transfer of wealth from the countryside, especially in the form of rents exacted by the landowning elite, whose economic and social dominance depended on their ability to exact a large share of the agricultural surplus produced in the countryside. In the "consumer city" model, much of the economic activity in the cities resulted from the elite's spending the wealth they gained from agriculture.[10] Since the growth of the urban economy was so closely linked to agricultural production, the possibilities for economic growth were limited.[11] One way to assess the scale of the Roman economy is to estimate the Gross Domestic Product of the Roman empire (GDP) as a multiple of the minimum subsistence of the empire's population. If the empire simply produced enough food to feed its population and nothing more, Hopkins calculates that the GDP would be on the order of nine billion sesterces (9,000 million), given a population of 60 million and a minimum subsistence requirement of 250 kg. wheat equivalent (worth about 120 sesterces). In all likelihood, in Hopkins' view, the GDP was substantially higher, perhaps 1.3 or 1.5 times the minimum subsistence,

[6] For this view of Roman trade, see Whittaker 1985. [7] Peacock and Williams 1986.
[8] Hopkins 1995/6: 59. [9] Horden and Purcell 2000: 205–9.
[10] For discussion of Rome and other ancient cities as "consumer cities," see now Erdkamp 2001, as well as Morley 1996: 13–32; Jongman 1988a: 15–62, especially 52–5; and, on the division of labor between town and countryside, Wrigley 1978, and Hopkins 1978b. Cf. also above, Chapter 3.
[11] Saller 2002.

resulting in a GDP of 12–15 billion sesterces, but it is not likely to have exceeded twice the subsistence level.[12] From this perspective, the earlier estimate by Goldsmith of a GDP of approximately 20 billion sesterces seems overly optimistic, since it assumes a per capita domestic product of three times subsistence.[13]

To approach this issue from another perspective, it seems clear that the scale of the Roman economy rivaled that of mediaeval Europe, to judge by the empire's production of silver. The relative level of silver production in the Roman empire can be assessed by measuring historical levels of atmospheric lead pollution, since lead is a major by-product of silver smelting. Atmospheric lead pollution in ice cores in Greenland began to rise substantially around 500 BC, reaching its peak around the first century AD. This increase seems to be the result of expanding silver production in the Greco-Roman world, especially in Spain. After a decline in silver production in late antiquity, atmospheric lead pollution levels begin to rise again around the year 1000 AD, as a result of increased mining activity in central Europe, but atmospheric lead pollution only matches its Roman levels in the Industrial Revolution.[14] This hypothesis of increased silver production in the Roman empire is confirmed by the level of atmospheric lead pollution measured in Sweden in the sediment at the bottoms of lakes, in peat bogs, and also in forest soils, as well as in peat bogs in Switzerland.[15]

The impressive level of silver production in the Roman empire raises the question whether the development of Rome's urban culture engendered growth in the economy beyond what can be accounted for by population increase alone. This economic growth would have resulted from an increase in the overall productivity of labor, both in agriculture and in manufacturing, which in turn would have required the development and dissemination of new technologies, as well as substantial investment.[16] The question is to what extent the transfer of wealth from the countryside to the cities in the Roman empire resulted in the development of urban manufacturing and commercial sectors that produced and exchanged goods with the countryside and other cities and so generated substantial wealth in their own right. In this scenario, the Roman economy would have shared many features with the economies of early-modern Europe, distinguished from the later

[12] See Hopkins 1995/6: 45–7. The value of the minimum subsistence is based on a price of 3 sesterces per modius (= 6.55 kg.). This model further assumes a fourfold agricultural yield, so that one-fourth of the yield would have to be set aside as seed.

[13] See Goldsmith 1987: 35: based on a population of 55 million at the death of Augustus, and per capita product of 350–400 sesterces. Hopkins 1995/6: 67 n. 29 criticizes Goldsmith's estimates as too optimistic.

[14] See Hong et al. 1994.

[15] For Sweden, see Renberg et al. 2000; 1994; for Switzerland, Shotyk et al. 1998.

[16] Hopkins 1995/6.

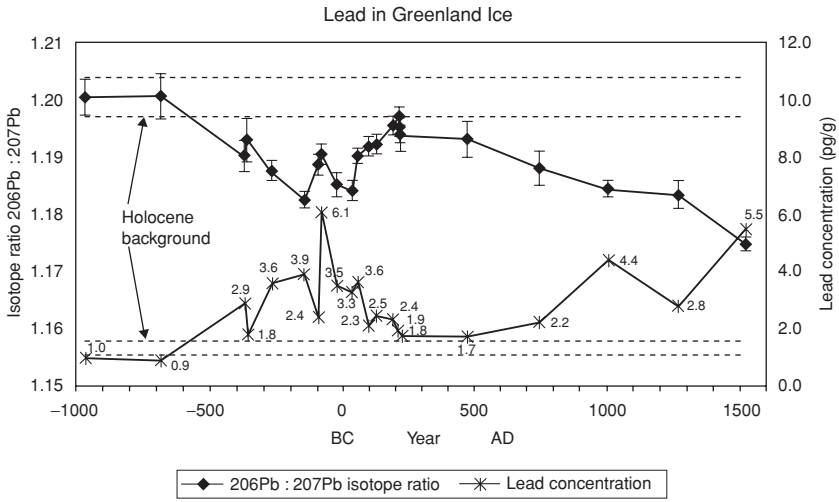

Figure 20.1 Variation over time in concentration and composition of of lead in ice core samples from Summit, Central Greenland
Source: A. Wilson, "Machines, power and the ancient economy," *JRS* 92, 2001: 26, after Rosman et al. 1997

Key: The lower line shows the absolute concentrations of lead in the samples (PG/G) measured against the right-hand vertical axis. The upper line shows the ratios of ^{206}PB:^{207}PB isotopes against the left-hand vertical axis, with upper and lower error limit bars (95% confidence). The dashed bands represent the range of variation in holocene background levels for each series, before anthropogenic activities affected lead deposition.

period mainly by the degree of involvement of the elite in commerce and industry and not by the basic structure of the economy.[17]

Answering this question is difficult, but the likelihood is that the economy of the Roman empire experienced at best a limited structural transformation over the course of the early empire. Throughout this period, agriculture remained the basis of the economy and of the empire's fiscal system. Employing the vast majority of the empire's population, agriculture provided the principal source of wealth of the elite classes.[18] Agricultural wealth was highly stratified and the elite's share only increased throughout the course of the early empire. Thus in the third and fourth centuries, the estates of senators were typically scattered throughout the empire, while several provinces, most notably Egypt and Palestine, saw the creation of large estates and the development of a landowning elite on a scale that had not existed previously.[19] As wealthy as the landowning elite was, its ability to use the wealth from agriculture to transform the economy was limited. Despite the favorable conditions for commerce resulting from the Roman

[17] Pleket 1990. [18] Garnsey and Saller 1987: 64–103.
[19] Vera 1986b; Safrai 1994: 322–64; Hopkins 1995/6.

peace, markets for agricultural products remained highly imperfect. The development of more efficient technologies for processing cash crops, such as the screw and lever olive presses, made it easier for landowners to reap the profits of urban demand for foodstuffs, but even with these developments the private market alone was not able to provide stable supplies of foodstuffs for Rome, Alexandria, and later Constantinople.[20] To protect these cities against the vagaries of the private market, the Roman state devised an elaborate system of reserving for its own use the production of grain, olive oil, and later wine and pork on imperial estates in Italy and in the provinces. In addition, the Roman state supervised the importation of these products into Rome and their distribution there.[21]

The ability of the Roman elite to respond to the opportunities for commercial agriculture was constrained by the "conceptual framework," to adapt a concept from recent research in neoinstitutional economics, within which they engaged in economic planning.[22] To some extent, economic planning in the Roman world was the result of an "embedded" economy, in which social factors, such as the prestige attached to the ownership of land, played a crucial role in influencing economic activity.[23] Certainly a great deal of rigor in management and accounting was possible, as Rathbone has shown in his study of the richly documented estate of Aurelius Appianus. Appianus was a member of the provincial aristocracy in Egypt in the third century and owned an estate in the Fayyum (the ancient Arsinoite nome). The managers of this estate had sufficient information to assess the profitability of various crops and allocate resources efficiently on that basis.[24] But the owner of this estate still faced basic constraints that limited the range of choices in investing wealth that all landowners faced. For upper-class landowners, land represented a resource providing economic security rather than an investment in the modern sense. In managing their agricultural wealth, many landowners were very risk-averse, preferring strategies that maintained economic stability and their social position to ones designed to maximize wealth.[25] In this connection, Simon's concepts of "bounded rationality" and "satisficing" decisions help to explain the economic planning by upper-class Romans. "Satisficing" decisions are ones that do not necessarily make the optimal use of resources – which would be impossible, because of the limits on our knowledge and freedom of action – but instead achieve a desired goal.[26]

[20] For a broad discussion of productivity in Mediterranean agriculture, see Horden and Purcell 2000: 231–97. The widespread view is that technological development in agriculture was slow paced: see Lo Cascio 1991a: 344–7; and Schneider 1992: 52–71. For a more optimistic assessment of the development of technology in the Roman world, see Greene 2000.

[21] Rickman 1980; Sirks 1991. [22] Mercuro and Medema 1997: 130–56.

[23] Veyne 1979; Wallace-Hadrill 1991; cf. Finley 1985; Frederiksen 1975.

[24] Rathbone 1991. [25] Kehoe 1997. [26] Simon 1983: 84–5.

Another factor affecting economic growth in the Roman empire was that much of the wealth generated from agriculture was spent on public building or other forms of conspicuous consumption. Such projects were funded either from taxes or from the savings of members of the elite, often at enormous cost. This type of spending employed large numbers of people and even made fortunes for some of them, but it could not have the same effect on the economy as investing in the development of new technologies that might increase productivity. We can gain a sense of the costs imposed on the Roman economy by public building programs by considering the large-scale quarry operations at the Mons Claudianus and the Mons Porphyrites in the eastern Desert in Egypt.[27] These quarries, which supplied marble and porphyry for monumental imperial building projects in Rome and later in Constantinople, remained under imperial control throughout the period of their exploitation. The task of quarrying granite columns and transporting them overland across the desert to the Nile valley and from there by ship to Rome involved the organization of enormous resources, including the requisitioning of draft animals and drivers on a vast scale.[28] This system of requisitioning must have had a significant impact on the economy of the affected areas in Egypt, since the wages paid by the government provided an infusion of cash. But the larger point is that monumental undertakings like the quarrying of granite columns came at a great cost, since they involved the redistribution of wealth that might otherwise have been invested in other more directly productive purposes.

Still, fortunes could be made in commerce and manufacturing, which certainly occupied a significant place in the Roman economy. But the chief beneficiaries of the opportunities that the Roman empire offered for generating wealth in these sectors were generally people of more modest social and economic status, from wealthy freedmen to independent artisans.[29] Upper-class Romans tended to be involved in these activities only indirectly. They might lend money, sometimes to their own freedmen, but more generally the involvement of the elite largely derived from their investments in agriculture, as they supplied the raw materials such as clay or wool for urban industries but were not directly involved in the production and marketing of manufactured goods.[30]

II AGRICULTURE

Both large landowners and small farmers depended for their livelihoods on the production of surpluses for the market in the face of substantial risks imposed by the Mediterranean climate. The most significant risk affecting

[27] Maxfield 2001. [28] Adams 2001. [29] Pleket 1983; 1984; 1990.
[30] On lending by aristocrats to freedmen, see D'Arms 1981.

agricultural production was the irregularity of rainfall. Although the average annual rainfall in much of the Mediterranean world was at least 300–400 mm., sufficient to allow for the production of wheat and other basic staples, the annual rainfall averages mask the extreme variability, both in larger areas and in micro-regions, that could allow one region to produce a bumper crop while causing drought and crop-failure in another.[31]

In regions characterized by a Mediterranean climate, the most common method for cultivating wheat, the basic staple crop in Roman agriculture, was the two-field system, sometimes called "dry-farming." This represented an adaptation to the hot summers and rainy winters of the Mediterranean area. In this system, crops would be planted in the fall and harvested in the spring. The soil was worked repeatedly with a light plough (the ard, or *aratrum*). This ploughing created a layer of soil that in more arid regions could absorb water, and in regions with greater rainfall, could help restore nitrogen.[32] After the harvest in the spring, the field would normally lie fallow for more than a year, when it would be replanted with a cereal crop. This type of farming resulted in modest yields, at least when measured in terms of the volume of crops produced from each unit of land. Yields varied considerably depending on rainfall, but a representative figure would be 500 kg./ha., a yield somewhat below those attested for mediaeval and early modern Europe.[33] In Egypt, with a more intensive agricultural system organized around the annual flooding of the Nile, we might expect production on the order of 1,000 kg./ha.[34]

Roman farmers pursued various strategies to avoid risk and enhance their security. These strategies tended to involve the diversification of crops rather than investing labor and resources in improving yields.[35] The most common strategy to reduce risk was to practice "polyculture," that is, mixing the cultivation of olives, vines, or other orchard crops with cereals. Since the harvests for cereals, vines, and olives occurred at different times, polyculture allowed the farmer to make more efficient use of the labor available throughout the agricultural year while at the same time raising the productivity of each unit of land. Vines and olives were costly to cultivate, since both require substantial investment in pressing and storage facilities, as well as time before a substantial crop can be realized. Roman farmers could also raise yields by practicing crop rotation, in particular the rotation of cereal crops with beans and other lupines. The lupine crop could be a source of food or ploughed back into the soil as "green manure" to restore nitrogen.[36]

Livestock-raising was of central importance to agriculture in the Roman world. Plough oxen, though costly to maintain, increased the productivity

[31] Horden and Purcell 2000: 175–203.
[32] Spurr 1986: 23–40; cf. Morley 1996: 118–21.
[33] Sallares 1991: 374–5; Spurr 1986: 82–8.
[34] Rathbone 1991: 242–3, 465.
[35] Horden and Purcell 2000: 175–230.
[36] Spurr 1986: 103–19.

of farmers, and the ability to maintain draft animals was surely crucial to a farmer's prosperity and independence in the Roman world.[37] In some circumstances, individual farmers might form partnerships to manage the costs of maintaining them.[38] The raising of livestock also allowed farmers to diversify their sources of income. Sheep, for example, could be raised for their wool, but raising livestock for meat allowed farmers to produce food from land that otherwise could not be used for agriculture, such as hillsides or marshlands, where cattle and sheep could be pastured, or forests, where pigs could be allowed to forage.[39] The problem was that it was difficult to integrate livestock-raising fully into agriculture. The dung from livestock represented an important source of fertilizer, but in many regions, livestock were kept in pastures separate and even at some distance from the cultivated area. Indeed, some landowners in Italy, including the imperial government, practiced an extreme form of this economy when they maintained large flocks of sheep that moved seasonally from lowland winter pastures to upland summer pastures in an annual pattern of transhumance.[40] Mediterranean dry-farming is to be contrasted with the three-field system that characterized the later agricultural revolution in northern Europe. This system made it possible to integrate livestock raising more fully into agriculture by cultivating oats or other fodder crops in rotation with cereals, but it required summer pasture not available in the areas of the empire characterized by a Mediterranean climate.[41]

The most important technological change affecting agricultural productivity involved the dissemination of olive and wine presses throughout the Mediterranean. Olive presses were quite expensive items, and, since they are not needed to produce olive oil in modest amounts, their presence in many regions of the Roman empire indicates investment on a substantial scale to produce olive oil for the market.[42] For example, the dissemination of the heavy and expensive lever-press in north Africa allowed landowners to produce and bring to the market much larger amounts of olive oil than would have been possible with less technologically sophisticated methods of pressing the olives.[43] As Mattingly argues, the impressive olive-pressing installations in north Africa suggest that cultivators there had the capacity to press olives well in excess of what could have been an average yield. This extra capacity allowed them to take advantage of occasional bumper crops to make substantial profits that would carry them through leaner years. Because of the frequency of drought, regions could be suppliers and exporters of basic staples more or less at the same time.[44] This

[37] Foxhall 1990. [38] Lirb 1993. [39] Horden and Purcell 2000: 197–200. [40] Frayn 1984.
[41] There is a range of views for how successful Roman agriculture was in developing more productive methods of farming than implicit in the Mediterranean two-field system: see Morley 1996: 115–21. Kron 2000 argues that the Romans integrated livestock and agriculture to a significant degree.
[42] Peacock and Williams 1986: 29–35. [43] Mattingly and Hitchner 1993. [44] Mattingly 1993.

intensification of agriculture in response to market forces continued in late antiquity in some areas. For example, in Syria, archaeological evidence indicates the development of olive orchards in the fourth and fifth centuries.[45]

At the same time, the speed with which such technology was disseminated should not be exaggerated. The introduction of a new technology did not necessarily supplant the old one. For example, the lever-press continued to be used for decades and even centuries in many locations after the more advanced screw-press was introduced.[46] Another invention that suggests the limited role of technological development in increasing productivity in agriculture is the Gallic reaping machine, or the *vallus*. The *vallus* made it possible to harvest wheat much more quickly than was possible by hand. But this device does not seem to have been adopted on a widespread basis; it was especially useful in Gaul, apparently, because the variety of wheat cultivated there, *siligo*, had to be harvested quickly to avoid spoiling.[47]

Investment in irrigation could also raise productivity substantially. But irrigation could be expensive, since it was costly to raise water from a source to an irrigated field at a higher elevation.[48] In Egypt, where agriculture was dependent on the annual flood of the Nile, artificial irrigation was generally limited to intensively cultivated vineyards, orchards, and gardens, which produced a higher income for each unit of land than land cultivated with cereal crops. The principal means of irrigation were the shaduf, a simple water-lifting device involving a container mounted on a pivot, and the saqiya, a water-wheel.[49] In other parts of the empire, underground passages, or *cuniculi*, might be used to channel water from springs into irrigated fields. In more arid regions, such as the pre-desert areas in north Africa, farmers would irrigate their crops by cultivating them in terraces or in wadi beds (seasonally dry streams) with elaborate systems to capture water from occasional but often violent rainstorms. The techniques for this type of irrigation had been disseminated in north Africa before Roman rule, but it seems clear that farmers in Roman times used them to establish flourishing agricultural communities in such arid areas as the frontier region in southern Africa Proconsularis and in Tripolitania.[50]

III PRODUCTION FOR THE MARKET AND THE ESTATE ECONOMY

Landowners in the Roman world developed various strategies to achieve marketable surpluses in response to these geographical and technological constraints. One strategy was to invest heavily in slave labor to produce cash crops. This is the approach toward investment that characterized the

[45] Horden and Purcell 2000: 274–5; Pollard 2000: 13, 201–2.
[46] Mattingly 1988b: 158. [47] Sallares 1991: 355; Morley 1996: 115–16.
[48] Horden and Purcell 2000: 237–57. [49] Bagnall 1993: 17–18, 311–12.
[50] Shaw 1984; Mattingly 1988c.

development of the villa-economy of late Republican and early imperial Italy, which saw the spread of a unique type of agricultural enterprise in the Roman world throughout the coastal regions of Campania, central Italy, and Etruria.[51] The villas developed as an increasingly wealthy landowning class responded to the opportunities for commercial agriculture represented by the growth in the city of Rome and its increasing power in the western Mediterranean. These estates, such as the carefully excavated Villa Settefinestre at Cosa, were relatively modest in size, comprising perhaps several hundred ha.[52] They regularly included a *pars urbana*, an often lavishly adorned farmhouse that was to serve the needs of the landowner during his or her visits on the estate. The agricultural part of the estate, or the *pars rustica*, included facilities for pressing grapes and, to judge by the evidence of the Villa Settefinestre, buildings that could have served to house a substantial workforce, which in most cases consisted of slaves, managed by a slave-bailiff, or *vilicus*. Archaeological remains of presses indicate that wine was generally the principal cash crop. These estates were organized in such a way as to take the greatest advantage possible of careful management and intensive cultivation. The relatively modest sizes of the estates helped landowners keep the size of the slave staff under control. The evidence provided by the writings of the Roman agronomists, in particular Cato, suggests that we should expect to find on the order of fifty to one hundred slaves working on an estate comparable in size to the Villa Settefinestre. The chief advantage that landowners achieved by employing slaves in large numbers was to have a workforce that they could employ intensively as they saw fit and avoid the need to compete for labor. But employing slaves can only be advantageous for the landowner if they can be kept busy year round. Thus it seems likely that most villas produced a variety of crops, including wheat, which could be used to feed the staff but was also sold on the Roman market.[53] Indeed, the seasonal nature of much agricultural work meant that it was impractical for landowners of large slave-based estates to use slaves to perform all agricultural tasks, and such estates hired additional labor at the busiest times, such as the harvest.

The owners of Roman villas in this period were able to generate substantial wealth by marketing wine in Rome, in other Italian cities, and, to a lesser extent, in Gaul. Roman villas were generally located in close proximity to the coast, which made it possible to ship their products by sea at relatively low cost to Rome and to other coastal cities. The archaeological remains of Dressel-1 amphoras, the vessels in which wine from Italy's Tyrrhenian coast was transported, indicate that wine from this region was marketed not only in Rome but also in Gaul beginning in the last third of the second century BC. From the time of Augustus the Dressel 1 amphoras

[51] Morley 1996: 108–58; Purcell 1985. [52] Carandini 1989a. [53] Scheidel 1994b.

were supplanted by Dressel 2–4 amphoras, which continued to be shipped to Rome and to Gaul.[54] The villa system became a dominant form of agriculture in early imperial Italy, employing numerous slaves.[55] At the same time it must be recognized that this form of agriculture was largely confined to coastal regions, and that other forms of production, including small-scale peasant agriculture, coexisted with villa agriculture. The labor hired on a casual basis could be recruited from small-scale peasant cultivators in the vicinity or also from farm tenants.[56]

By the beginning of the second century AD, however, this type of estate organization in Italy was giving way to another type, one that was probably more representative of the empire in general. At this time, the Dressel 2–4 amphoras that attest the wide distribution of wine produced on these estates fade from the scene, while the archaeological record of the villa estates in Italy changes considerably. During this period, most of the sites identified by archaeologists as villas were abandoned or transformed. Many richly adorned villas were replaced by far more modest residences. The intensive concentration on viticulture apparently was succeeded by a more mixed regime with cereal culture and livestock-raising playing more prominent roles. One factor contributing to the apparent decline of viticulture on these estates seems to have been competition from other parts of the empire. To judge by the evidence of amphoras found at Ostia and Rome, Spain and later Gaul became important producers of wine for Rome, while Spain and Africa exported olive oil on an increasing scale to Rome. But the decline of the villa system in Italy is not likely to have been the product of a "crisis" in the slave mode of production, with the numbers of slaves gradually exceeding the capacity of Roman landowners to supervise them effectively. Rather, the increased competition from the provinces and changes in the rural population in Italy eroded the comparative advantage that Roman landowners gained from employing large numbers of slaves in a concentrated fashion. Simply put, the profits that could be made from producing wine on these intensively cultivated estates no longer justified the costs of maintaining and supervising large numbers of slaves.[57] Indeed, the decline of Italian viticulture should not be overstated; Rome and other Italian cities continued to be consumers of wine, and vineyards in Italy, now organized in a different manner, in all likelihood continued to provide much of this wine, especially the ordinary wine for the broad market. Some of this wine may have been transported in wooden casks or in other containers that leave no trace in the archaeological record.[58]

From the second century onward, it seems likely that estates in the areas of Italy characterized by intensive villa agriculture increasingly resembled

[54] Tchernia 1986. [55] Harris 1980b; 1999. [56] Scheidel 1994a: 153–224.
[57] Patterson 1987; Morley 1996: 133–42. [58] Tchernia 1986.

estates that were coming into being in other parts of Italy and in the provinces. The estates were typically much larger than the classical villa. Typically these estates, or *latifundia*, were not unified or contiguous holdings, but rather represented agglomerations of individual farms pieced together over the course of time through bequest or purchase.[59] Landowners commonly solved the problem of overseeing the cultivation of fragmented and scattered estates by leasing the individual farms out to tenants. It must be emphasized, however, that farm tenancy and the use of slaves are not mutually exclusive. Even after the decline of the villa economy of Italy in the second century AD, slaves continued to constitute an important element in the labor force on Italian estates.[60]

In the provinces, upper-class landowners also took advantage of the commercial opportunities offered by the Roman empire by investing in the cultivation of cash crops such as vines and olives, and the production of these crops for the markets on a large scale helped to generate the wealth that supported elite landowners in Gaul, Africa, and Spain.[61] In Gaul, during the first century AD, villas inspired by Italian models dotted the landscape.[62] In Africa, substantial oil factories with large presses have been discovered in such diverse locations as the Kasserine plain and the Gebel region of coastal Tripolitania, in particular, in the extensive territory of Lepcis Magna.[63] The hinterland of Lepcis Magna was marked by substantial investment in olive culture. There are numerous rural sites with multiple olive presses, some of which were among the largest discovered in north Africa. Olive oil was certainly a major cash crop in this region, which supplied Lepcis Magna and markets overseas. It is likely that the production of olive oil provided much of the wealth of the elite of Lepcis Magna, as is suggested by stamps on oil amphoras from the late second and early third centuries.

The nearest analogue in the provinces to the intensively cultivated and rigorously managed villa is the estate of the third-century Egyptian magnate Aurelius Appianus. The organization of this estate was a product of the peculiar economic geography of Roman Egypt, where land was divided up into relatively small parcels. As is indicated by the evidence from the Heroninos archive, the portion of the estate of Appianus in the Fayyum consisted of a series of divisions, or *phrontides*, organized around individual villages. The *phrontides* themselves were comprised of a diverse array of parcels of varying sizes devoted to the cultivation of a wide range of crops, including principally wine, wheat, and fodder. The individual divisions of the estate were under the management of *phrontistai*, who reported to the central administration of the estate, located at the nome capital.

[59] Vera 1995a; 1995b. [60] Vera 1992–3. [61] Mattingly 1988b; Hitchner 1993.
[62] Woolf 1998: 148–68. [63] Mattingly 1988c.

The key to the profitability of Appianus' estate, and the advantage that he enjoyed over smaller-scale landowners, was achieving economies of scale by organizing the cultivation of a vast array of individual parcels under one unified system of management and sharing resources.[64] These economies depended on the careful management of labor and other productive resources, in particular, draft animals, which were maintained by the central management of the estate and shared out among the divisions. The labor force in each village-based division of his estate was provided by a relatively small number of permanent laborers, termed *metrematiaioi* and *oiketai*, as well as by numerous people hired on a daily basis. The management of this estate involved considerable costs, since careful control had to be maintained over labor costs and over the allocation of centrally maintained livestock and other resources.

IV TENANCY

The type of management associated with early imperial villas or the estate of Appianus depended on the coincidence of a number of factors: the ownership of a critical mass of land in one area to make the sharing of resources feasible, and the availability of a labor force that could be organized and employed on a daily basis. When such circumstances did not obtain, many landowners used the institution of farm tenancy to organize the management and labor on their estates. These considerations applied equally to the Roman state, which was by far the largest landowner in the Roman empire. State or imperial property included estates that were originally the private property of the emperors but that, with the changing of regimes, became incorporated with other state-owned properties under the general administration of the imperial treasury, or Fiscus. Imperial properties also included lands that were always classified as "public," including the *ager publicus* of the Republic. In the empire, state-owned land was an especially important feature of the Egyptian agrarian economy, where two categories of state-owned land, namely, public land, or *ge demosie*, and royal land, *ge basilike*, were to be found in virtually every location and in some nomes may have represented as much as half of the total land.[65] The portion of land controlled by the state surely grew in the course of the early empire, since property confiscated from those condemned for criminal offenses or for failure to pay taxes fell under the administration of the Fiscus, as did the property of people without heirs.[66] State lands in Egypt and in Africa, and probably in other parts of the empire as well, were typically leased out to small-scale tenants.

[64] See Rathbone 1991; and Kehoe 1992: 92–117.
[65] Rowlandson 1996: 70–101. [66] Crawford 1976.

Farm tenants on private and imperial land represented a wide range of economic and social statuses, including large-scale tenants who took upon themselves the task of managing entire estates. But the vast majority of tenants were small-scale cultivators, and even in this group, the range of resources that the tenant brought to the farm could vary considerably. Some tenants provided important resources, including draft animals, and even slaves. These tenants, who were more likely to be economically independent, were recruited to some extent from the small-scale landowners in the vicinity of the estate. This is not possible to document in most parts of the empire, but it does seem to have been the case in Egypt, where the lines between landowners and tenants were often blurred.[67] Other tenants, lacking these resources, were more or less laborers, economically dependent on their landlords.[68] Another important factor affecting the bargaining power of tenants was their access to the legal institutions of the state to protect their rights. Tenants with leases enforceable in Roman courts enjoyed much greater protection than those who cultivated the estates of landowners who, by virtue of their superior social and economic standing, could effectively dictate terms of tenure. Perhaps the best evidence for the bargaining power that some tenants enjoyed can be seen in the apparently successful efforts of tenants on imperial estates in Africa and Asia Minor during the late second and the third centuries AD to petition for redress against abuses by the large-scale tenants who collected their rent, imperial tax officials, landowners from neighboring towns, and soldiers.[69]

Tenants performed a crucial service for landowners when they invested their own resources in the cultivation of the land. This type of investment could be especially important with capital-intensive crops such as vines and olives, which were important cash crops but which also required considerable long-term investment of resources and labor. The Roman government relied on small-scale tenants to engage in this type of investment on state-owned properties. This can be seen in the case of the imperial estates in the Bagradas valley in Africa. There, on the basis of two regulations, the *lex Manciana* and the *lex Hadriana de rudibus agris*, the imperial government encouraged small-scale sharecroppers, or *coloni*, to engage in polyculture, in particular the cultivation of olive trees in tandem with grain.[70] It seems likely that many private landowners depended on the production of tenants much as the imperial government did.[71]

The extreme stratification of wealth in the Roman empire should not disguise the difficulties that landowners encountered in profiting from their estates. Many landowners depended on the efforts of numerous small-scale

[67] Rowlandson 1996: 124.
[68] Foxhall 1990; cf. Lo Cascio 1993; Capogrossi Colognesi 1992–3: 206–21; 1995: 220–45.
[69] Hauken 1998. [70] Kehoe 1988a; Kolendo 1991; de Ligt 1998/9; De Vos 2001.
[71] Kehoe 1988b.

cultivators to produce the cash crops that provided their incomes. The achievement of the Roman landowning elite was not so much to establish more efficient and productive methods of agriculture, but to extend their holdings so as to extract a modest income from a multiplicity of sources. But the constant problems that private landowners and the state encountered in keeping their land cultivated meant that the demand for food on the part of the empire's urban population was probably never fully met, with the resulting hardship and perhaps even intermittent starvation.

V URBAN AND RURAL INDUSTRIES

The next question to be answered is to what extent wealth generated from agriculture contributed to an expansion of production in the non-agricultural sectors of the Roman economy. To answer this question, we need to evaluate the economic role of cities in the Roman empire and their relationship with the countryside.

Certainly, the dominant role played by the upper classes in the rural economy meant that one important economic function of towns and cities was to meet the consumption needs of local landowners, who spent there much of the income that they derived from their estates. This is the economic model that Jongman has developed for Pompeii.[72] But it is unlikely that this was the only significant dimension of the urban economy. One stimulus to growth in the urban economy was the need of the landowning elite to market their surplus from the countryside. This created opportunities for generating wealth in supporting industries, most obviously in the production of ceramic vessels, but also in less obvious things such as shipbuilding or the construction of market facilities and other infrastructure to support commerce. At the same time, the aggregate demand of small landowners, tenants, and other agricultural laborers provided a stimulus to manufacturing. A key factor affecting the development of manufacturing, both in cities and in the countryside, was the level of wealth in the hands of small landowners and tenants. If these farmers produced a substantial surplus over and above what they had to pay as rent and taxes, then they would have income to spend that would support the development of industries. Thus Engels, in his analysis of the economy of Roman Corinth, develops the concept of the "service city," whose economy revolved around producing goods and providing services for a rural workforce that had much greater spending power than is generally assumed.[73]

The stimulus that agricultural production provided to manufacturing can most readily be traced in the ceramic industries that supported agriculture. A great deal of what we might term as industrial production is

[72] Jongman 1988a: 187–203. [73] Engels 1990.

associated with rural rather than urban sites, including *vici* and estates.[74] For example, the production of olive oil as a cash crop for export became increasingly important for Africa in the third century AD, when African olive oil began to be exported all over the Mediterranean. During this same period, ceramic production increased substantially in the countryside in which the olive oil was produced. Thus rural kiln sites indicate the production of amphoras on a substantial scale, to be used as containers for the oil to be sold on the market. At the same time, the production of fine ceramic wares for the local market shifted from the cities in north Africa to the countryside.[75] It seems likely that many of the same workshops producing amphoras also took advantage of the increased purchasing power in the countryside resulting from the production of olive oil by producing consumer goods as well.

The same forces that promoted industrial production in the countryside could also create opportunities in cities, especially in ports and other cities that served as entrepots for commerce in agricultural products. For example, a recent study of Leptiminus, a port city of modest size on the eastern coast of the Roman province of Africa, indicates the potential for industrial production in an "entrepot" city.[76] This city was a place in which olive oil produced in its hinterland was loaded onto ships and transported to more distant markets. A survey of the city reveals a number of kiln sites producing ceramic products, especially amphoras in the Africana I–II series, dated from the second to the fourth centuries. In addition, some sites indicate iron working, again on an apparently substantial scale, in close association with the production of amphoras. In early imperial Gaul, commercial agriculture also stimulated the development of a manufacturing sector. During this period, Gallic workshops supplanted Italian workshops as the major producers of fine ceramic ware, *terra sigillata*, for the western empire. *Terra sigillata* represents one of the basic consumer goods that a broad range of the population of the Roman empire purchased. What is striking about the production of Gallic terra sigillata is the diffusion of the centers of production, which is to be contrasted with the earlier more centralized production of Italian terra sigillata at Arretium. The principal centers of production included smaller towns or villages, such as La Graufesenque, Bram, and Montans, as well as the larger town of Narbonne.[77] Presumably, these production sites were associated with sources of clay.

At the same time, growth in the manufacturing sector of the Roman economy was limited by the reluctance of the upper classes to invest in it on a large scale. The initiative and rewards for investing in manufacturing went to people of much more humble social rank, including freedmen.

[74] Whittaker 1990. [75] Peacock et al. 1990.
[76] Mattingly 2001. [77] Guéry 1990; Woolf 1998: 190.

Industries tended to be organized on a modest scale, with independent artisans working in relatively small workshops. Upper-class investment in industries was limited primarily to the provision of raw materials, including clay, wool, linen, timber, and other commodities, in fact, most of the products used in construction or manufacture, with the likely exception of metals. In fact, upper-class involvement in the production of building materials confirms the dominant role of agriculture in the Roman economy, since bricks and timber were products of rural estates and represent production in the rural economy much like foodstuffs.[78]

We can appreciate the limited involvement of upper-class Romans in industry by considering the organization of brick production in the Roman empire. The humble brick was a basic material in the building industry in the Roman empire, and we can trace some of the steps in the production and distribution of this commodity from the stamps that various people involved in these processes placed on them. With the exception of certain notable cases, the ownership of the clay resources and the organization of the brick-making industry were separate. The upper-class landowner typically owned the land that provided the raw materials for making the industrial product, while another party, economically independent of the landowner, organized the actual production, providing the management and taking on the risk associated with it. The evidence for this comes from Helen's study of a sample of 9,000 stamped bricks from excavations at Ostia during the first two centuries AD.[79] Especially important for our purposes are the so-called binomial stamps, common in the second century, that record the name of the producer of the bricks, or the *officinator*, as well as the owner, or *dominus*, of the *figlinae*, which Helen convincingly identifies as the source of the clay used in the making of the bricks rather than the actual place of their production (although these might in fact be identical).

The evidence of the brick stamps indicates that the wealthy Romans who owned estates with important clay pits generally exploited this resource by leasing out the rights or otherwise alienating them to a third party, the *officinator*, who took the clay, produced the bricks, and sold them for construction projects. The brick industry involved members of the highest ranks of the aristocracy, including, in the second century, the emperor, members of the imperial family, and associates of the court, such as the praetorian prefect Plautianus, the father-in-law of the emperor Caracalla, who was also a large landowner and producer of olive oil in the region around Lepcis Magna.[80] But it is not likely that these people were directly involved in the building-supply industry. In some instances, the *officinatores* were freedmen of the owners of the clay pits. For example, the wealthy

[78] Cf. Horden and Purcell 2000: 182–6.
[79] Helen 1975; cf. Aubert 1994: 217–44.
[80] Mattingly 1988c.

brothers Cn. Domitius Lucanus and Cn. Domitius Tullus employed their own freedmen as *officinatores* in the late first century, but generally the pattern seems to have been for the *officinator* to have been independent from the owners of the *figlinae*. Sometimes the *officinatores* were of relatively high social rank, such as the Calpentani of the first century, or L. Faenius Rufus, who was praetorian prefect under Nero. But more often the *officinatores* were of lower rank than the *domini*. They were often independent entrepreneurs, who took upon themselves the task of securing the sources of clay to make the bricks and to supply them for the building projects.[81]

It is difficult to determine how the production of amphoras and fine ceramics was organized. The example of the rural sites in Africa suggests that rural estates may have provided the setting for the production of amphoras serving commerce in olive oil, but this is not certain. Certainly, we should expect that some landowners engaged in olive production also produced their own amphoras, as was the case in the late Republic with the Sestii, who owned wine-producing estates at Cosa, or the Laecanii, a senatorial family that produced amphoras on a large scale in the first century AD to support olive oil production in Istria.[82] But to judge by the evidence for ceramic production from Egypt, the production of amphoras was largely carried out by artisans who were independent of the estate producing olive oil or wine. The exact mechanism for this production may be suggested by a series of three leases for potteries on vineyard estates in third-century Oxyrhynchus in Egypt.[83] In these labor contracts, the lessees received wages and allowances of wine in exchange for delivering large numbers of wine vessels, some of which may have been sold to other estate owners in the area. In other cases, it is apparent that estate owners relied on skilled craftsmen in the community to produce wine and oil containers.[84] Thus the estate of Aurelius Appianus made payments to potters working as independent contractors; this was part of a general policy to rely on independent artisans involved in other trades rather than to retain them as permanent employees of the estate.[85]

Our knowledge of the organization of terra sigillata production is very sketchy, but again, such evidence as exists suggests that it was organized by independent artisans, and that the role of the elite was largely to provide the raw materials, and, possibly, the kilns used for firing the ceramic wares. Stamps and signatures on the terra sigillata provide some evidence for the organization of the ceramic industry at Arretium in the late Republic and in the early empire.[86] There the pottery industry was controlled by a group of seemingly autonomous workshops, generally operating on a modest

[81] Helen 1975: 131–50. [82] Bezeczky 1995. [83] Cockle 1981.
[84] Ruffing 1999: 104–6. [85] Rathbone 1991: 154, 167, 174.
[86] Pucci 1973; Guéry 1990; Aubert 1994: 276–302; Fülle 1997.

scale. These workshops were not pre-industrial "manufactories," that is, shops in which most of the work was done by hand, with a minimum of mechanization, but with some economies of scale realized from labor specialization. Rather, the basic producing unit was the small workshop, in which much of the labor was provided by skilled slaves.[87] Although it is very difficult to be certain on this point, the proprietors of these workshops were not members of the elite but rather skilled artisans themselves, in some cases, freedmen who had proved themselves by their skill in producing fine ceramics. To be sure, there were some artisans who had as many as fifty or sixty artisans of slave or freed status working with them, but there seem to have been few economies of scale.[88] Under this circumstance, many of these slaves and freedmen were probably socially dependent but economically independent artisans who leased workshops from their owners or patrons. The master artisan, then, would run his own workshop, but he could make additional money by training artisans who would eventually set out on their own, providing their owner or patron with some financial consideration for helping to establish them in business.[89]

Outside of Italy, the production of ceramics was likewise in the hands of individual workshops, but slavery seems to have played less of a role in production. In Gaul, the producers were in all likelihood individual artisans of free status, although they might also employ slaves in more menial tasks.[90] Some workshops producing goods for both local and distant markets would establish branch or satellite workshops in new locations that produced more or less the same wares. For example, the "Ateius" workshop producing terra sigillata at Lugdunum seems to have been established from a "parent" workshop in Arretium.[91] This example could be multiplied many times in the diffusion of the products of both the Arretine and the Gallic workshops. The same phenomenon is apparent in the terracotta lamp industry, the organization of which can be traced to some extent on the signatures in the bases of common lamps, or "Firmalampen," which were a common household item throughout the Roman empire.[92] Generally in the ceramic industry, there was probably little institutional supervision of quality or prices. Rather, such associations or *collegia* of potters that did exist served primarily religious or social functions.[93] In Africa, the production of African red-slip ware, or Terra Sigillata Africana, was likewise dispersed among a number of production centers, both in cities and in rural settings. This pottery was marketed all across the Mediterranean world beginning in the second century AD. The identity and the status of the producers of this pottery are uncertain, but it is noteworthy that the dominance of African

[87] Fülle 1997. [88] On the number of workers, see Pucci 1973: 266–7.
[89] Fülle 1997. [90] Pucci 1993; Guéry 1990. [91] Guéry 1990: 141.
[92] Harris 1980a; Aubert 1994: 303–18. [93] Pucci 1993.

red-slip ware coincides with the emergence of Africa as a major producer of olive oil and at the same time as a major contributor to the ruling class of the Roman empire.[94]

The entrepreneurial activity involved in organizing the production and marketing of ceramics was often distinct from the ownership of the raw materials. This can be traced in the terra sigillata industry at La Graufesenque, one of the major centers of production in southern Gaul. There, we gain some understanding about the organization of the industry from a series of lists of potters associated with a major kiln complex.[95] This complex had some ten kilns used in the firing of terra sigillata, and it had the capacity to produce hundreds of thousands of pieces in a given season. To judge by the parallel from the Egyptian lease contracts, it is likely that the individual potters at this site were specialized artisans who leased the right to have the kilns at their disposal for varying periods of time. The whole kiln complex, according to this reconstruction, was owned by another party, presumably a landowner who also owned the land that supplied the clay as well as the wood fuel for the kilns. It has been argued that this hypothetical owner organized the individual potters and marketed the terra sigillata ware that they produced.[96] But it seems more likely that the potters themselves were the ones who actually organized the production and distribution of ceramic products. The role that the owner of the kilns played in the ceramic industry was to invest in equipment that allowed him or her to derive revenue from a resource associated with an estate. In this sense, the owner of the kilns at La Graufesenque would be much like the owners of clay pits for bricks. But as was the case in the brick industry, the people who were actually involved in ceramic production were of a more humble social status.

The textile industry, in particular, the production of woolen and linen clothing, reveals a similar separation of the ownership and production of raw materials and the organization of manufacturing characteristic of other industries. The textile industry was certainly one of the very most important and ubiquitous industries in the Roman world. As we have seen, the raising of sheep was a basic aspect of agriculture both in Italy and the provinces, and providing the raw materials for the textile industry, an important source of income for landowners, including the imperial government, as well as for pastoral groups.[97] Even if there were no cities in the Roman empire dominated politically and socially by a commercial class deriving its wealth from textiles, it is still likely that textile production was a basic component of the economic life of many ancient cities.[98] The clothing prices in Diocletian's price edict indicate the existence of certain cities

[94] Carandini 1983b. [95] Strobel 1987: 100–13.
[96] Strobel 1987. [97] Frayn 1984. [98] Van Minnen 1987.

famous for the production of some high-cost clothing items; for example, Tarsus, Laodicea, and Alexandria were well known for the production of high-quality linen garments.[99] Indeed, about two centuries earlier, Dio of Prusa commented on the large number of linen workers at Tarsus and the political unrest resulting from their exclusion from full participation in civic life.[100] But many more cities and villages were involved in the production of more common items of clothing that could be purchased by a much broader buying public, much like the ceramic ware that is found all over the empire. To be sure, much of this clothing was produced domestically, but independent artisans were economically significant.[101] The archaeological evidence for fulling and dyeing works at Pompeii indicates the presence of a thriving wool industry in that city, even if the scale of production should not be overestimated.[102] In a recent study of the archaeological remains of Timgad, a city in the frontier zone in Numidia whose population included numerous veterans, Wilson detects a substantial concentration of fulling and dyeing workshops in the northeast quadrant of the city. These establishments, concentrated in one part of the city presumably because of the malodorous nature of their work, suggest the existence of a textile industry that turned local agricultural products into marketable manufactured goods.[103] The example of Timgad can be multiplied many times throughout the empire.

The basic unit of production in the textile industry was the individual workshop. This was certainly the case in Roman Egypt, where documentary papyri preserve contracts involving textile production as well as documents connected with the associations, or "guilds" of weavers and other artisans.[104] The major capital outlay for this industry, the purchase of a loom, was relatively modest, and it seems likely that many weaving establishments consisted of little more than a space within a private house. The typical weaving establishment in Egypt, then, might consist of between one and four highly skilled artisans, each with his or her own loom.[105] The artisans themselves were usually of free status, but they might also be slaves. Supplemental work was provided by family members, including women, skilled slaves leased out for that purpose or working independently, salaried workers, and apprentices. The other crafts associated with the textile industry, including fulling and dyeing, required specialized workshops and so demanded greater investment.[106] Clearly many of the people involved in weaving in the countryside also gained income from other sources, including agriculture. Skilled weavers and other artisans were likely to have been

[99] Jones 1960. [100] Dio Chrys. *Or.* 34.21–3.
[101] For the importance of domestic production, see Foxhall *apud* Mattingly and Salmon 2001a.
[102] Jongman 1988a: 155–203. [103] Wilson 2001a. [104] Wipszycka 1965; van Minnen 1987.
[105] Wipszycka 1965: 81 ff. [106] Wipszycka 1965: 58–73.

concentrated in much greater numbers in the cities than in Egypt's villages, and it is in cities where we should expect to find weaving workshops organized on a larger scale. Thus the proprietor or manager of a weaving establishment at Alexandria could be styled as the "manager of a workshop of linen weavers having many workers in the workshop."[107] Another possible way to organize textile production was on the so-called Verlagssystem or "putting-out system," in which a large-scale merchant would provide individual artisans with materials and pay them for each garment that they produced. In this system, the artisan would have no contact with the customers and would not play any role in the acquisition of raw materials. There is not much evidence for this type of arrangement in Egypt, although we might expect to find it in large commercial centers such as Alexandria or Tarsus. Weavers and other artisans were organized into associations, called *collegia* or *synodoi*, a term that is often translated as "guilds." These associations served social and religious purposes, often functioning as burial societies, as is indicated by dedications preserved on inscriptions in many parts of the Roman empire. In Egypt, at any rate, these associations do seem to have played some role in regulating trade and prices.[108]

The papyri provide little evidence of large-scale, "vertical" organization of the textile industry, with large landowners supplying wool or flax to their own weaving establishments. Rather, the production of the raw materials for the textile industry was generally distinct from the manufacturing process. For example, the estate of Appianus and those belonging to other landowners in his circle had large flocks of sheep, which were often leased out to shepherds in exchange for cash rents. These shepherds were responsible for securing pasture land and for shearing the sheep and marketing the wool.[109] Large estates in Egypt might include weaving workshops along with the other facilities involved in rural production, such as olive pressing facilities, mills, and even bathhouses. But these facilities were often leased out, as they were on the estate of Appianus, and so were not integral to the agricultural side of the estate.[110]

VI MINING

Mining was an industry significant to the Roman economy. Archaeological evidence indicates that mining was conducted on a widespread basis in many regions of the Roman empire, and mining generated significant revenues for the state and for private individuals. The principal products of Roman mining included precious metals such as gold and silver, as well as lead, copper, tin, and iron. The importance of mining to the Roman

[107] *P.Oxy.* XXII 23410, 192 CE; Jones 1960; van Minnen 1987: 47.
[108] Van Minnen 1987: 60 ff.
[109] Rathbone 1991: 202–9.
[110] Rathbone 1991: 196–9.

economy is suggested by the measurement of historical pollution levels of lead, a by-product of silver production (see above).

Roman mining involved some application of technology, especially in the use of devices to remove water, but more importantly, the organization of vast amounts of labor and resources, in particular, water and wood. The organization of such resources was crucial to both of the major forms of mining in the Roman world, surface and shaft mining. In the former, the ore is located close to the surface of the earth, often in alluvial deposits. The simplest method of surface mining involved panning river beds for precious metals such as gold. To mine deposits that were not in river beds, more elaborate methods had to be devised, which all involved using tremendous amounts of water. Ore deposits could be uncovered by a method called "hushing." This method involved storing large amounts of water in reservoirs, which might be supplied by aqueducts. The water would then be released in a torrent, which would wash away the earth and expose the ore. A similar method, called "ground-sluicing," involved washing the surface with a continuous supply of water to expose the ore. The ore might be gathered from collection boxes, or "long toms," which were basins with wooden cross-pieces, or riffles, on the bottom to catch the heavier ore as water washed the material over them.[111] When the supply of ore from surface deposits was exhausted, shaft-mining techniques might be used, which involved digging vertical shafts below the surface of the earth. In this method of mining, vertical shafts were dug to reach the level of the ore deposit, while horizontal tunnels or galleries would be excavated to follow the ore deposit and expedite its removal. Often tunnels, or "adits" were dug into a mountain side to provide a means to approach the vertical shafts. Adits and galleries would often be hundreds of meters in length but at the same time quite narrow, generally 1–2 m. in diameter, just large enough to allow access to workers and to pass the mined ore out by hand. Enormous amounts of wood were required to build supports for the tunnels as well as to provide fuel for the furnaces used in the smelting of the ore.[112] The extraction of ore was extremely labor intensive. The work was done by hand, with iron and copper shovels, axes, and buckets. The main application of technology was in the extraction of water, which tended to accumulate in subsurface mines. This could be accomplished by a series of Archimedes' screws or by water-wheels, which would be turned by human workers.[113] The systems of pumping out water that the Romans developed allowed them to mine at depths down to 200 m. below the water table.[114]

Mining was one industry that could have been practiced by the elite on a large scale, since it involved the application of existing technologies

[111] Woods 1987: 625–33; Shepherd 1993: 1–46. [112] G. B. D. Jones 1980.
[113] Woods 1987: 613–24. [114] Greene 2000: 38.

to extract ores for which there was apparently steady demand. Perhaps to protect its own control over precious metals, however, the state maintained direct control over the most important mining areas and exploited them in a kind of partnership with private enterprise. During the Republic, mines in Spain were sometimes in private hands, but many more were owned by the state and leased out to private individuals or to partnerships, *societates publicanorum*. In the empire, this situation gradually changed as the imperial Fiscus increasingly took over mines and maintained ownership over them.[115] It seems likely that some mines were worked directly by the Fiscus, but generally the task for actually digging for ore in the individual mines was divided among numerous smaller-scale operators. This is at least the pattern that emerges from the mining regulations from Vipasca in the province of Lusitania, where two bronze tablets from Aljustrel in Portugal attest the workings of mines in some detail.[116] In this district, the Fiscus would lease the rights out to individual contractors, or *coloni*, in exchange for one half of the ore that they produced. The imperial administration's role in exploiting the mines was not simply to regulate the *coloni*, since the inscription also includes provisions for the Fiscus to dig exploratory shafts that would later be assigned to *coloni*. In addition, the Fiscus raised additional revenues by selling off for cash payments mines that had once been worked but were no longer in operation.

The system of mining attested at Vipasca does not seem to have involved elite investment on a large scale. The Fiscus retained control over the productive resources, and it shouldered some of the most important capital costs, in particular, those connected with the smelting of the ore. It is difficult to determine what level of resources the *coloni* brought to bear in covering the costs of exploiting the individual mines. The main expenses that the *coloni* bore were to provide labor, which may have included many slaves, and to build supports for the galleries and shafts. Because these costs were considerable, the *coloni* might pool resources by forming partnerships.

VII CONCLUSION

Our evidence for the organization of manufacturing in the Roman world is limited, but it nevertheless seems possible to place it within a broader context of the Roman economy. The modest economic growth that characterized the early imperial period created an increasing demand for basic manufactured goods such as ceramic wares and textiles. This demand, in turn, created two types of economic opportunities. On the one hand, large landowners gained additional sources of revenues by supplying the raw materials for this production, including clay for ceramics and wool or flax

[115] Domergue 1990: 227–386. [116] Flach 1979; Domergue 1983: 115–80.

for the textile industry. But for the most part, the involvement of the Roman elite was limited to supplying raw materials, and it was left in the hands of artisans and workers recruited from more humble levels of society to undertake the actual production of manufactured goods. So it does not seem that the Roman empire experienced the development of a class of entrepreneurs engaged in manufacturing on a sufficient scale to rival the political and social ascendancy of the landowning elite. Recently Drinkwater has made the case that the textile industry did provide the basis of wealth for families accomplishing precisely this, such as the third-century Secundinii from Trier.[117] This Gallo-Roman family included large-scale merchants who organized a lucrative business involving the production of fine textile wares. They purchased raw materials from local and distant sources and organized a specialized workforce of weavers and dyers in and around Trier to manufacture garments that they could sell for immense profits in distant markets. Despite its wealth, however, the family never took its place among the elite in Gaul. It is difficult to know how common entrepreneurial families such as the Secundinii were, but it is likely that there were many such people who could take advantage of the business opportunities that Roman rule created. But the dismay of the linen weaver from Alexandria mentioned above (see at n. 107) over being nominated for a civic liturgy normally filled by a landowner suggests both the degree of wealth obtainable from manufacturing and the limits that this wealth could represent. Clearly it was not common for people whose primary income was from manufacturing to take their place alongside a town's landowners in performing the basic civic liturgies. Perhaps the wealth associated with such enterprises was too fleeting, dependent on an individual entrepreneur's organizing the skills of a highly trained labor force. An income that ultimately depended on the production of a lasting asset, such as land, was far more stable for the long term, and the Roman upper classes never shifted their resources away from the land. For elite landowners, the production of raw materials for manufacturing was economically more attractive than the actual production and marketing of manufactured goods.

[117] Drinkwater 2001.