*Technical Innovation and Economic Progress in the Ancient World**

By M. I. FINLEY

It is a commonplace that the Greeks and Romans together added little to the world's store of technical knowledge and equipment. The Neolithic and Bronze Ages between them invented or discovered, and then developed, the essential processes of agriculture, metallurgy, pottery, and textile-making. With these the Greeks and Romans built a high civilization, full of power and intellect and beauty, but they transmitted to their successors few new inventions. The gear and the screw, the rotary mill and the water-mill, the direct screw-press, glass-blowing and concrete, hollow bronze-casting, the dioptra for surveying, the torsion catapult, the water-clock and water organ, automata (mechanical toys) driven by water and wind and steam – this short list is fairly exhaustive, and it adds up to not very much for a great civilization over fifteen hundred years.

Paradoxically, there was both more and less technical progress in the ancient world than the standard picture reveals. There was more, provided we avoid the mistake of hunting solely for great radical inventions and we also look at developments within the limits of the traditional techniques. There was less – far less – if we avoid the reverse mistake and look not merely for the appearance of an invention, but also for the extent of its employment. Food-processing offers a neat illustration of each. In the two centuries between 150 B.C. and 50 A.D. (in very round numbers) there was continuous improvement in the wine and oil presses used on the Roman latifundia. I am not referring to the screw-press, but to such advances as refinements in the shape of the mill-stones and their cores, by which craftsmen made presses more efficient and more manageable.[1] Somewhere in this same period the water-mill was invented, and this must rank as a radical invention permitting the replacement of muscular power, human or animal, by water power. But for the next three centuries its use was so sporadic that the total effect was very slight.[2]

In agriculture there was an accumulation of empirical knowledge about plants and fertilizers. But there was no selective breeding (of plants or animals), no noticeable change in tools or techniques, whether of ploughing or exploiting the soil or harvesting or irrigating. There were repeated shifts in the uses of

* A first draft of this paper was read, at Professor Postan's suggestion, at the annual conference of the Economic History Society in Liverpool on 1 April 1960. I have retained the original title in the wording which was the theme of the conference. Valuable suggestions were made in the discussion that evening, and subsequently by Mr Keith Hopkins of the London School of Economics and Politics.

[1] A. G. Drachmann, *Ancient Oil Mills and Presses* (Copenhagen, 1932).

[2] L. A. Moritz, *Grain-Mills and Flour in Classical Antiquity* (Oxford, 1958), ch. XVI; R. J. Forbes, *Studies in Ancient Technology*, II (Leiden, 1955), pp. 86–95.

land, of course, but these were responses to political conditions or to changing consumer fashions (notably the insistence that status was commensurate with the whiteness of one's bread) or to rudimentary economic pressures. Neither increased productivity nor economic rationalism (in Max Weber's sense) was ever achieved in any significant measure, so far as we can tell. Someone in Gaul invented a rude ox-powered mechanical reaper which was used on the latifundia in the northern districts of that province, but it neither inspired landlords elsewhere in the Empire to imitation nor inspired anyone to seek labour-saving devices in other branches of agriculture.[1] By contrast, an English translation of the fourth-century Latin writer Palladius, who gave a brief description of the Gallic device, was the direct stimulus for the invention of 'Ridley's stripper', which had a useful and profitable career in Australia for forty or fifty years (at least to 1885).[2]

In mining, room for invention is in a sense very constricted. The few tools needed were already developed long before the Greeks, and little improvement was possible until the invention of explosives. Where there was much to be done, however, was in the areas of prospecting, engineering, and refining, and the ancient world reached its maximum achievement very early, in the Athenian silver mines of the fifth and fourth centuries B.C. The tunneling, ventilating, and lighting in those mines, the washing, crushing, and smelting in the near-by mills and furnaces, and the utilisation of by-products were all as competent and efficient as anything to be found in the next thousand years, and better than most.[3] The geology of the Laurium district saved the Athenians from the most serious challenge, that of drainage. Others were less fortunate, notably in the western and northern provinces of the Roman Empire, and once again there was a failure of effective invention. 'The cost and inefficiency of ancient drainage machinery made it difficult to mine below the ground-water line'.[4] Apart from the so-called Archemedian screw, for which there is only scattered evidence, reliance was placed either on hand bailing or on a water-wheel operated by a foot-treadle. So technically simple a device as the chain-pump with animal power is unattested.

The sheer craftsmanship of the work in the Athenian mines requires comment because it introduces a necessary distinction into the discussion. There was a precision, a perfection of measurement, and hence an aesthetic quality, about the gallery walls and the steps – to give but two examples – which were never duplicated in antiquity. For parallels one must turn not to other mines, but to the contemporary temples and public buildings of Athens. The quality is psychological, so to speak, not technological. The artisans of fifth- and fourth-century Athens, whether free or slave, had a tradition of craftsmanship which imposed itself even in the most 'unlikely' places, such as the galleries of the

[1] M. Renard, *Technique et agriculture en pays trévère et rémois* (Brussels, 1959); J. Kolendo, 'La moissoneuse antique en Gaule romaine', *Annales*, XV (1960), 1099–1114.

[2] E. A. Thompson, *A Roman Reformer and Inventor* (Oxford, 1952), pp. 80–1.

[3] E. Ardaillon, *Les mines du Laurion dans l'antiquité* (Paris, 1897), remains basic; cf. S. Lauffer, *Die Bergwerkssklaven von Laureion*, I (Akad. d. Wiss. u. d. Literatur, Mainz, *Abhandlungen d. Geistes- u. Sozialwiss. Klasse*, 1955, no. 12), pp. 1125–46.

[4] O. Davies, *Roman Mines in Europe* (Oxford, 1935), p. 24.

silver mines. But this factor must not be confused with technical progress. Nor must increasing mastery of materials, an inevitable corollary of pride and virtuosity. I do not underestimate the significance of these qualities, or of the quality of the products which they created. Within fairly broad limits, however, limits which the pre-Greek civilizations of the eastern Mediterranean had already reached, such considerations of quality are irrelevant in an analysis of technological and economic growth. The unmatched beauty of Greek coins, after all, contributed nothing to their function as money (except to modern collectors, of course, which transfers the question to an altogether different realm of discourse).

Painted pottery is the best instance, one which takes on special significance from the fact that it is the only ancient industry whose history we can write (or will some day be able to write). The potter's wheel is a very ancient invention, and the Aegean world of the Bronze Age already knew all about the properties of clays, how to fashion a variety of pleasing shapes, how to colour and fire and produce a sheen. The heights to which the Greeks then carried this art is evident in museums all over the world. Yet these advances were all accomplished without any technical innovation, by greater mastery of the already known processes and materials, and, above all, by greater artistry. Then, in the course of the fourth century B.C., the taste for fine painted pottery disappeared, almost abruptly, and at once there was a sharp decline in quality. But people continued to need pots, and rich Greeks and Romans continued to demand better pots with some sort of decoration. Moulded decorations replaced painting and therefore a new technique was introduced in the industry, the only one in its history throughout classical antiquity. That is to say, the long-familiar technique of casting in a mould was adapted from metal to clay in order to produce commodities in the new style. Experts seem to be agreed that neither the speed nor the cost of production was significantly changed as a result. A new fashion was met by the transfer of an old technique. Fourth-century Greeks were not Neanderthal men and we need not hail this particular step as a brilliant accomplishment.

There is admittedly a danger, in pursuing this line of argument, of falling into the trap of assuming that certain values are always and necessarily paramount. The idea that efficiency, increased productivity, economic rationalism and growth are good *per se* is very recent in human thinking (although it seems to take hold in a most remarkable way once it gets an effective start). *We* might consider the Pont du Gard a fantastically expensive way of bringing fresh water to a not very important provincial town in southern Gaul; the Romans in Gaul ranked fresh water and the demonstration of power higher on the value-scale than costs. That was a rational view, too, though not economic rationalism.

Granted that, the ancient world still presents us with a big question, one that is forced on us by at least two facts. The first is that the ancient world was very unambiguous about wealth. Wealth was a good thing, a necessary condition for the good life, and that was all there was to it. There was no nonsense about wealth as a trust, no subconscious guilt feelings, no death-bed restitutions of

usury. The other fact, which I have already mentioned, is that, intellectually (or scientifically) speaking, there was a basis for more technical advance – in production – than was actually made. Why did productivity then not advance markedly, if the interest, the knowledge, and the necessary intellectual energy would seem to have been present? The question cannot be dismissed simply by pointing to alternative values, not, at least, when one of those was a very powerful desire for wealth and for large-scale consumption.

But first do we in fact know that productivity did not advance? Do we know anything about productivity at all? In a sense which can be expressed quantitatively, the answer must be that we do not. The chronic handicap of the ancient economic historian is lack of figures. Even reasonably reliable population statistics are so rare that the basic question of population growth or decline in a given area within a particular period of time can really never be answered with any assurance. But there are some population figures; there are none for production. Ancient writers never considered the matter and archaeology cannot be expected to fill this particular gap adequately. We are therefore driven to oblique approaches, to indicators rather than indexes, to arguments from attitude and inference and silence, all admittedly tricky and even suspect methods. Yet in the end I am satisfied that I have got the question right.

It will be convenient to start with the intellectual side. And again I begin with a commonplace; the ancient world was characterized by a clear, almost total, divorce between science and practice. The aim of ancient science, it has been said, was to know, not to do; to understand nature, not to tame her. The proposition is true, even if it is commonplace, and attempts to challenge it, which seem to be rather fashionable at the moment, are in my view misguided and certain to fail. Aristotle's verdict holds. At the end of the first section of the *Politics* (1258b 33ff.), he wrote as follows (in Barker's translation): 'A general account has now been given of the various forms of acquisition: to consider them minutely, and in detail, might be useful for practical purposes; but to dwell long upon them would be in poor taste.... There are books on these subjects by several writers... anyone who is interested should study these subjects with the aid of these writings'.[1] Aristotle was the greatest polymath of antiquity, a tireless researcher, and the founder of any number of new disciplines in science and philosophy. His curiosity was unbounded, but 'good taste', a moral category, interposed to put beyond the pale knowledge in its practical applications except when the application was ethical or political.

Mechanics was one of the new sciences first systematized by Aristotle and his school. In a little treatise on the subject written by an unknown disciple, the principles of the lever, wheel, balance, and wedge are explained by illustrations drawn from a significantly restricted range of instruments. The *full* list is this: the sling, the windlass, the pulley, the dentist's forceps, the nutcracker, and the swing-beam over a well. The inference is inescapable, to me at least, that the author deliberately avoided any reference to instruments and machines used in industrial processes, and that when he could not do so

[1] The relevance for this discussion of the practical writers is examined below in a consideration of Vitruvius.

altogether – in the cases of the windlass and the pulley – he made his references as abstract as possible. There is an interesting contrast here with the earlier Ionian philosophers. They were highly speculative thinkers and their concern was cosmology, a subject much more remote than mechanics. Yet they did not hesitate to draw analogies and clues from the potter's wheel, the fulling-mill, the smith's bellows, and other objects of craft and industry.[1] The Pythagoreans, too, for all their mysticism, carried their interest in waves and rhythmic impulses to very practical, and technically significant, consequences.[2] But then a change set in, and the divorce between science and philosophy on the one hand, and the productive processes on the other, can be traced in an unbroken line to the end of antiquity.

The century and a half after Aristotle marked the peak of ancient scientific achievement, and the man who towered over all the others was Archimedes, the greatest and most inventive scientist of the ancient world. And Archimedes was most praised for his refusal to contaminate his science. As Plutarch expressed it (*Life of Marcellus* 17.3–4), he 'had so great a spirit, so profound a soul, and such a wealth of theories which gave him a name and reputation for a sort of divine, rather than human, sagacity, that he did not wish to leave behind him any treatise on these matters, but, regarding mechanical occupations and every art that ministers to needs as ignoble or vulgar, he directed his own ambition solely to those studies the beauty and subtlety of which are unadulterated by necessity'.

Archimedes' practical inventions, I hasten to add, were military and were made only under the extraordinary and irresistible stimulus of the siege of his native Syracuse by the Romans. The ancients had a passion for recording inventions and inventors. This interest goes back to the era of myth-making: Prometheus is the prime example. Eventually it became highly systematized and a considerable literature grew up on the theme, brought to its climax – as with so many other fields – by the Peripatetics. One can still read a fair example in the seventh book of Pliny's *Natural History*. 'Inventions' must be understood as broadly as possible, for the category included laws, customs, ethical beliefs, arts and crafts, as well as artifacts and processes.[3] The crucial point for us is this, that whereas in the other fields the names of individuals are the rule, in the industrial arts they are very rare: usually only the places of invention are recorded, and sometimes not even those. Writing about the screw-press for grapes, Pliny (*N.H.* 18.317) was so precise that he dated its invention (he called it 'the Greek press') to 'within the last hundred years' and a subsequent major improvement even more narrowly, to twenty-two years back. But he knew no inventor's name, though he did know who invented the diadem, the shield, music, prose, and the game of ball. Admittedly he could not attribute so recent an invention to Cecrops or Romulus, but he frequently

[1] B. Farrington, *Head and Hand in Ancient Greece* (1947), pp. 9–11. Aeschylus's Prometheus still shows this lack of 'quelconque réserve à l'égard du technique': J. H. P. Vernant, 'Prométhée et la fonction technique', *Journal de psychologie*, XLV (1952), 419–29, at p. 427.

[2] A. D'Arrigo, *Natura e tecnica nel mezzogiorno* (Florence, 1956), ch. XIV.

[3] A. Kleingünther, *Protos heuretes. Untersuchungen zur Geschichte einer Fragestellung*, *Philologus*, Supplementband XXVI, Heft 1 (1933).

cited conflicting claims and it is evident that in his wide, if most uncritical, reading he found none at all for the screw-press. Several ancient cities laid claim to be the birth-place of Homer. Several Italian cities in the seventeenth century contested with equal vehemence (and with equal baselessness) for the honour of the invention of eye-glasses.[1] That symbolizes the difference in attitude. In antiquity, 'only the tongue was inspired by the gods, never the hand'.[2] And here we have moved from the realm of pure science to that of popular taste and interest among the literate classes of society generally, and of an implicit moral judgment. It was in those circles (including men like Pliny himself) that the ownership of property rested, in other words, to whom the profits of technical improvement would have accrued in large measure, were there any. I shall have more to say about them later, but first we must look at the technicians.

Specifically, what about the writers whom Aristotle dismissed, but from whom, he conceded, one could learn all about the practical arts? He had agronomists in mind, but, rather than deal with them, I prefer to go on at once to the most critical and most advanced of all the fields and to consider Vitruvius. He was both an expert practitioner and a man of extensive and intelligent reading. In his *De Architectura*, written probably in the reign of Augustus and designed as a complete text-book of the subject, Vitruvius drew on his own experience and on the far from negligible body of Hellenistic writing, and he explained scientific principles as well as the best practices. In this work we have the highest example available from antiquity of the knowledge and thinking of a man who was a do-er, not just a know-er, a man, furthermore, who was a first-class engineer as well as an architect. In sequence he dealt with the following topics: architecture in general and the qualifications of the architect, town-planning, building materials, temples, other civic buildings, domestic buildings, pavements and decorative plaster-work, water supply, geometry, mensuration, astronomy and astrology, and, finally, 'machines' and siege devices.

Vitruvius was a discursive writer. He had a great deal to say, for example, about the ethics of his profession, especially in the lengthy prefaces to each of the ten books. The last one, which deals with machines, is introduced by a sermon on the carelessness of architects, a trait which could easily be remedied by universal adoption of a law of Ephesus holding the architect personally responsible for all costs exceeding twenty-five per cent above his original estimate. It is all the more significant, therefore, that in the whole work I can find only one passage which considers the achievement of greater economy of effort or greater productivity. Vitruvius recommends (5.10.1), that in public baths the hot-water room for men be placed next to the one for women, so that they can be fed from a single heat source. It will be conceded that this is not a very impressive instance. By contrast, the description of the water-mill for corn-grinding is astonishingly brief, just one short paragraph (10.5.2), and it is absolutely bare of comment, so much so that only the reader who is so

[1] E. Rosen, 'The Invention of Eyeglasses', *Journal of the History of Medicine*, XI (1956), 13–46, 183–218.
[2] E. Zilsel, *Die Entstehung des Geniebegriffes* (Tübingen, 1926), p. 22.

minded will appreciate the implications for effort and productivity. Vitruvius gives no hint in that direction. All in all, it is correct to say that for Vitruvius the sole aim of technical advance (apart from aesthetic considerations) is the achievement of operations which are otherwise impossible, or possible only by excessive effort. Since, he writes, stage-curtains and other theatrical devices cannot be operated without machines, I thought it desirable to complete my book with a treatise on machines. He defines a machine (10.1.1) as 'a continuous material system having special fitness for the moving of weights', and discusses under that heading such a miscellany as the scaling-ladder, the multiple-pulley and windlass, the wagon and the bellows alongside the water-mill and the catapult.

Scattered in the prefaces there are several stories drawn from the history of inventions. Invariably the circumstance, and therefore the explanation, is either accidental (as in the discovery of the marble quarries at Ephesus when two fighting rams chipped a bit of the hillside) or frivolous (as in Archimedes' discovery of the principle of specific gravity in response to a request for a way in which to unmask a dishonest silversmith). Neither for the past nor for the present nor for the future did Vitruvius conceive of technology as something which could be advanced by sustained, systematic effort. His outlook was altogether utilitarian. Quite the reverse of Aristotle, he discussed only practical matters and referred the reader who wished to bother with 'things which are not for use but for the purposes of our delight' (Ctesibius's automata) to the available literature (10.7.5). Yet on the matter which concerns us, Vitruvius and Aristotle were of one mind. In essence so were all the other writers on such subjects, and it is this unanimity which justifies the argument from silence.

I have considered attitudes at such length not only because of the necessity to hunt for clues there, but also because attitudes are the key to the blockage. Obviously there were material limits or hindrances to technical advance as well. Ctesibius tried to make a torsion catapult with metal springs and he also produced a compressed-air catapult, but he had to give them up as a bad job.[1] Inadequate metallurgical knowledge and lack of precision tools rendered these inventions ineffective. It may be, to take another case, that the delay in the utilization of the screw-press can be explained by its inefficiency until a proper screw-cutter was invented. But what material conditions prevented men who could make very complicated weather-vanes from getting the idea of the wind-mill? Or from linking the lever and the wheel to make a wheel-barrow?

Above all, what about the water-mill? Potentially it was a technical revolution in itself: 'it was able', writes Forbes, 'to produce an amount of concentrated energy beyond any other power resource of Antiquity'.[2] Its use was in the one process, corn-grinding, in which there had been a reasonably continuous history of technical advance, a process of immense importance to society, one in which the Roman state, in particular, was immediately concerned. Every 'rational' argument suggests quick and widespread adoption, yet the fact is that, though it was invented in the first century B.C., it was not

[1] On Ctesibius, see A. G. Drachmann, *Ktesibios Philon und Heron* (Copenhagen, 1948).
[2] *Op. cit.*, p. 90.

until the third century A.D. that we find evidence of much use, and not until the fifth and sixth of general use. It is also a fact that we have no evidence at all of its application to other industries until the very end of the fourth century, and then no more than one solitary and possibly suspect reference (Ausonius, *Mosella* 362–4) to a marble-slicing machine near Trier.[1]

A common 'defence' – I choose the word deliberately because it symbolizes a not infrequent false approach to the whole problem – is that use of the water-mill was checked by the absence of swift-running streams. This is no defence at all. Among a number of counter-arguments it is enough to point out that some of the best attested mills were powered from aqueducts, of which there was no shortage in the Roman Empire. Even Athens had such a mill in the fifth century A.D., and Athens ranks near the bottom of the world's cities when it comes to running water. But the city of Rome had none, or hardly any, until the late fourth century. In the year 39 or 40, the emperor Caligula created a bread shortage in the capital when he commandeered the mill-animals to carry his Gallic booty.[2] By then, beyond a doubt, water-mills were not only known but were functioning effectively. The *Greek Anthology* includes a short poem written about a half century before Caligula, which celebrated the new invention in these words:

> Oh stay your busy hands, ye girls that grind at the mill;
> Let not the cock that heralds dawn disturb your sleep.
> The river-nymphs are bidden by Demeter's will
> To do your work; and on the topmost wheel they leap
> And turn the axle's winding spokes, upon whose coil
> Concave Nisyrian's millstone's weight revolves anon.
> A golden age has come again; for free from toil
> We learn to taste what fruits from Mother Earth are won. [3]

One cannot press a Greek poet too far, but is it altogether fanciful to suggest that unconsciously he had put his finger on the essential point? Freeing slave-girls from toil (or animals, either, if one wishes to be more precise than the poet) was not a powerful enough incentive.

It is also necessary to eliminate the argument that lack of capital was a decisive consideration. In the century following the conquest of Egypt by Alexander the Great, the Ptolemies carried through a massive transformation, all in the interest of the royal revenue. They reclaimed great quantities of land, improved and extended the complex irrigation system, brought in new crops and better species, introduced iron on a scale which Rostovtzeff said was 'almost tantamount to a revolution',[4] and made administrative and managerial changes. But everything they achieved – and they were prepared to expend great resources – they did by utilizing the instruments and processes of the Greek world from which they stemmed. Only the *sakiyeh* for raising water and

[1] See Lynn White, Jr., *Medieval Technology and Social Change*, (paperback ed. 1964), pp. 82–3.
[2] Suetonius, *Caligula* 39.1.
[3] *Anth. Pal.* 9.418, translated by L. A. Moritz, *op. cit.*, p. 131.
[4] *The Social & Economic History of the Hellenistic World* (Oxford, 1941), I, p. 363.

the screw-pump were genuine innovations, and their use was severely restricted.

What gives point to this picture is the fact that, simultaneously, the Ptolemies founded and supported the Alexandrian Museum, for two centuries the main western centre of scientific research and invention. There Ctesibius, the greatest inventor of antiquity, was employed in military technology when he was not exercising his ingenuity on mechanical toys. But nothing suggests that his engineering skill was ever directed to agriculture or food-processing or manufacture. From its inception the Royal Society, despite its aristocratic patronage, was assigned problems of practical utility in a wide range of fields. But not the Alexandrian Museum. Why not? Why did neither the Ptolemies nor the Sicilian tyrants nor the Roman emperors systematically (or even spasmodically) turn their engineers to the search for higher productivity, at least in those sectors of the economy which produced the royal revenues? Whatever the answer, it was not lack of capital (or lack of authority). Funds, manpower and technical skills were made available (and wasted) in vast and ever increasing amounts for roads, public buildings, water supply, drainage and other amenities, but not for production. Of course, the effort to increase productivity might have proved unsuccessful – but it was never even attempted. I know of only one exception: it was in the royal factories of Pergamum that parchment was made practicable and mass-produced. This exception may not prove the rule, but it at least proves that we are faced with a legitimate question.

Private capital, it is true, would not have been readily available for the promotion and utilization of many of the possible technical innovations. There were enough individuals who possessed the resources, but not among the men whose interest lay in production (other than agricultural). Wherever one turns in industry and commerce, the picture is the same and always negative: one of failure to take steps to overcome the limits of individual cash resources. There were no proper credit instruments – no negotiable paper, no book clearance, no credit payments. The desperate search of the 'modernizers' among economic historians of antiquity for something which they can hold up with pride against, say, fifteenth-century Toulouse or Lübeck, is sufficient proof. Barring some odd and dubious text here or there, the best they can produce is the giro system for corn payments in Hellenistic Egypt. There was money-lending in plenty, but it was concentrated on small usurious loans to peasants or consumers, and in large borrowings to enable men to meet the political or other conventional expenditures of the upper classes. Only the bottomry loan was in any sense productive, and it was invariably restricted in amount and usurious in rate, as much an insurance measure spreading the high risks of seaborne traffic as a proper credit instrument. Similarly in the field of business organization: there were no long-term partnerships or corporations, no brokers or agents, no guilds [1] – again with the occasional and unimportant exception. In short, both the organizational and the operational devices were lacking for the mobilization of private capital resources.[2] The one exception points up all these

[1] It is necessary to insist on 'no guilds': neither the Greek nor the even more numerous Roman 'corporations professionnelles' performed the economic functions of guilds, often as that word may be mis-applied to them in modern writing.

[2] I have discussed this aspect of the Greek economy in 'Land, Debt, and the Man of Property in Classical Athens', *Political Science Quarterly*, LXVIII (1953), 249–68.

negatives: the Greeks initiated and the Romans carried to a considerable pitch the associations of tax-farmers (*publicani*). Yet this simple idea was not transferred to other economic activities.

Division of labour requires special consideration in this connection. There is a passage in Xenophon's *Cyropaedia* (mid-fourth century B.C.) which is quoted so repeatedly and with such solemnity by modern writers that I must give it in full. The context is the superiority of the meals provided in the Persian palace with its staff of kitchen specialists. 'That this should be the case', Xenophon explains (8.2.5), 'is not remarkable. For just as the various trades are most highly developed in large cities, in the same way the food at the palace is prepared in a far superior manner. In small towns the same man makes couches, doors, ploughs, and tables, and often he even builds houses, and still he is thankful if only he can find enough work to support himself. And it is impossible for a man of many trades to do all of them well. In large cities, however, because many make demands upon each trade, one alone is enough to support a man, and often less than one: for instance, one man makes shoes for men, another for women; there are places even where one man earns a living just by mending shoes, another by cutting them out, another just by sewing the uppers together, while there is another who performs none of these operations but assembles the parts. Of necessity he who pursues a very specialized task will do it best'.

This is an important text, and I shall return to it. But it is no cause for excitement on the subject of division of labour. In the first place, Xenophon is clearly interested in specialization of crafts rather than in division of labour. In the second place, the virtues of both are, in his mind, improvement of quality, not increase in productivity. And in general the whole 'analysis' belongs to that corpus of rudimentary 'economic' statements strewn among ancient writings which Schumpeter put in their proper place when we wrote: 'Classical scholars as well as economists... are prone to fall into the error of hailing as a discovery everything that suggests later developments, and of forgetting that, in economics as elsewhere, most statements of fundamental facts acquire importance only by the superstructures they are made to bear and are commonplace in the absence of such superstructures'.[1]

To be sure, it is not unthinkable that, as one scholar has argued, Xenophon's stress on quality was 'conditioned by the requirements of his comparison. The actual entrepreneur... would likely also have brought into calculation the increase in quantity'.[2] It is not unthinkable – but the fact is that no one has yet discovered a sentence in any Greek or Roman writer which makes such a calculation. Division of labour is not often discussed, but when it is, the interest is exclusively in craftsmanship, in quality.[3] Furthermore, everything we know about ancient production argues against extensive division of labour, or even widespread specialization. It is enough, I think, to point first to the predomi-

[1] *History of Economic Analysis*, ed. E. B. Schumpeter (1954), p. 53.

[2] A. Rehm, 'Die Rolle der Technik in der griechisch-römischen Antike', *Archiv f. Kulturgesch.*, XXVIII (1938), 135–62, at p. 153.

[3] Cf. Augustine, *De civ. dei* 7.4. See J. H. P. Vernant, 'Travail et nature dans la Grèce ancienne', *Journal de psychologie*, LII (1955), 18–38, at pp. 29–33.

nance of the *autourgos*, the man who works for and by himself, or of the smalf establishment with four, five, or six men, throughout ancient history; secondl to the extensive evidence of the public-works accounts recorded in inscriptions, with their incredible fragmentation of the operations, revealing the poverty o, entrepreneurial resources and the low level of specialization on the part of most workers. It is not only the opening analysis of *The Wealth of Nations* which is fifteen hundred or two thousand years ahead in the future, but the pin factory itself.

Richard Baxter said, 'If God show you a way in which you may lawfully get more than in another way (without wrong to your soul or to any other), if you refuse this, and choose the less gainful way, you cross one of the ends of your Calling, and you refuse to be God's steward'. Aristotle would have been appalled at this, although he conceded (*Politics* 1256b 38 ff.) that there were men who thought wealth was boundless. Old Cato, on the other hand, would have rubbed his hands in glee, adding a cynical grin at the parenthesis, 'without wrong to your soul or to any other'. But he, too, would quickly have parted company from Baxter when he came to such a sentence as, 'God hath commanded you some way or other to labour for your daily bread'.[1] That was neither the way to wealth nor its purpose. Cato's gods showed him a number of ways to get more; but they were all political and parasitical, the ways of conquest and booty and usury; labour was not one of them, not even the labour of the entrepreneur.

Impossible as it is to lump the whole of ancient society into one generalization, it would not be far wrong to say that from the Homeric world to Justinian great wealth was landed wealth, that new wealth came from war and politics (including such by-products as tax-farming), not from enterprise, and that whatever was available for investment found its way into the land as quickly as it could. There was never a time, so far as I know, when the large landholders of antiquity did not prosper as a class. Agrarian crisis was chronic among the little men, but even in the worst days of the third century, or the fifth, the magnates drew large rents and profits from their estates.[2] In most periods they were absentee urban-dwellers, who left the management and operation of their estates either to tenants or to slaves and slave bailiffs. In either case their psychology was that of the rentier, and hence neither their material circumstances nor their attitudes were favourable to innovation. They were not so stupid or so hide-bound that they could not abandon grain production for olive and vine cultivation or pasture when circumstances pressed them, or that they could not (sometimes) tell a better landed investment from a poorer one. But essentially their energies went into spending their wealth, not making it, and they spent it on politics and the good life. In this respect Cato represented a minority point of view, that of the sumptuary legislation which repeatedly cropped up in antiquity – attempts to prevent the aristocracy from conspicuously wasting its resources, always a failure precisely

[1] *Christian Directory* (1678), I, pp. 378b, 111a, respectively, quoted from R. H. Tawney, *Religion and the Rise of Capitalism* (Penguin ed., 1947), pp. 201–2.

[2] See A. H. M. Jones, *The Later Roman Empire 284–602* (Oxford, 1964), II, ch. XX.

because, whatever the fate of any given individual, the class had a continuous income which even Petronius's Trimalchio could not outrun.

Cato hated to spend money on his farms, and his *De Agricultura* is filled with minute advice about that, advice which can be summarized under two headings. First, do not waste labour time or equipment; acquire exactly as much of both as you need, no more and no less, and think up ways to keep them occupied all the time. Second: sell, do not buy; produce and make on the estate whatever you can to meet its consuming needs. All this is cheese-paring; it is not economic rationalism. His advice – to quote Schumpeter again – 'that the landowner should sell aging slaves before they become useless and that he should show himself as hard a taskmaster as possible when inspecting his estate is no doubt very revealing in many respects but it does not involve economic analysis'.[1] In a very literal sense, Cato was unable to determine which operation was profitable, which not, and the relative advantages of one against another.[2] Such calculations as he offers are fundamentally unintelligible, and there is his most famous omission, his failure to consider distance from the centres of consumption. Later writers – Varro and Columella – corrected him on this particular point, a matter of common sense, but they, too, if I may be permitted a very old-fashioned expression, lacked the spirit of capitalism.

The objection will be raised that I have looked in the wrong place, among the landed magnates. I accept that, though I cannot refrain from noting that the two centuries covered by Cato, Varro, and Columella were the most fertile in the invention of agricultural machinery – the Gallic reaper, the screw-press, and the water-mill – and that all three manuals seem totally oblivious to what was happening in this field. I then add that there is no other place in which to look. There were, to be sure, prosperous shippers in such centres as Cadiz, Alexandria, and Ostia, who amassed considerable wealth despite their very primitive business organization. There were men with large investments in mining and industry; but when we scrutinize them more closely – men like the Athenian general Nicias or the Italians who exploited the Spanish mines following the Roman conquest of that peninsula – it turns out that more often than not they, too, were rentiers, obtaining their rents from slaves in mines and mills, rather than from slaves or tenants in the fields. And they were a very small minority, without influence on the shape or the direction of the economy. The stress is not on 'minority' – beginnings are usually small – but on the lack of influence. Even in the Roman Empire the quantitative contribution of trade and manufacture was tiny, their social position low, their future without interest.[3]

There is a story, repeated by a number of Roman writers, that a man – characteristically unnamed – invented unbreakable glass and demonstrated

[1] *Op. cit.*, p. 70.

[2] G. Mickwitz, 'Economic Rationalism in Graeco-Roman Agriculture', *English Historical Review*, LII (1937), 577–89.

[3] A. H. M. Jones, 'The Economic Life of the Towns of the Roman Empire', *Recueils de la Société Jean Bodin*, VII (Brussels, 1955), 161–94; cf. his *Later Roman Empire*, II, ch. XXI, and especially his account of how (p. 841) 'the state, and to a lesser extent great landlords, ... cut a considerable sector out of the market by supplying their own needs directly'.

it to Tiberius in anticipation of a great reward. The emperor asked the inventor whether anyone else shared his secret, and was assured that there was no one else; whereupon his head was promptly removed, lest gold be reduced to the value of mud. I have no opinion about the truth of this story, and it is only a story. But is it not interesting that neither the elder Pliny nor Petronius nor the historian Dio Cassius was troubled by the point that the inventor turned to the emperor for a reward, instead of turning to an investor for capital with which to put his invention into production? [1] I do not doubt that he could have found the capital, but ancient writers, when they thought about the subject at all, saw little but the threat of over-production. The extremely low level of demand and its inelasticity – that is the important theme of the passage from the *Cyropaedia* which I have already quoted. In small towns there is so little demand that a man must be jack-of-all-trades, and even then he can scarcely earn a livelihood. In big cities, however, there are more people, and therefore more demand. But even in big cities, Xenophon tells us elsewhere, demand will not stand up to pressure. About 350 B.C. he produced a pamphlet, the *Ways and Means* it is usually called in English, in which he proposed that the Athenian state should itself become a rentier, investing in slaves to be leased out to private individuals who held concessions in the silver mines. His scheme envisaged so large an increase in mining that every citizen would eventually draw full maintenance from the rental of the state-owned slaves. He argued carefully, meeting possible objections, including the following (4.4–6): 'Of all the activities I know, this [silver mining] is the only one in which expansion arouses no envy.... If there are more coppersmiths, for example, copper-work becomes cheap and the coppersmiths retire. The same is true in the iron trade.... But an increase in the amount of the silver ore ... brings more people into this industry'.

Here and in the *Cyropaedia* passage Xenophon thinks of manufacture only for the local market; otherwise there would be no point at all to his remarks. Xenophon was fundamentally right; it is our modern writers who are wrong when they exaggerate ancient export trade, as they often do, to enormous proportions. Export – I use the term to refer to trade out of a city or region, not merely in the narrow sense of trade with foreign nations – was economically significant only in the basic foodstuffs (corn, wine, olives), in slaves, and in luxury goods. For this statement there is ample evidence. And luxuries, though they may have been lucrative to a few merchants, were small and insignificant on the production side. Neither the potters of Athens nor the linen weavers of Tarsus, to take two examples from different periods of local trades which dominated the export market for long periods, were anything more than small craftsmen, working alone or with a handful of staff. The linen weavers, complains Dio Chrysostom (34.21–23), were respectable men, yet they were too poor to afford the 500-drachma fee required by Tarsus for the exercise of the rights of citizenship.

We are too often victims of that great curse of archaeology, the indestructibility of pots. As R. M. Cook has observed, it is only 'because pottery survives

[1] The references are Pliny, *N.H.* 36.195; Petronius, *Satyricon* 51; Dio Cassius 57.21.7.

that its industrial importance has appeared great'. In the fifth century B.C. Athens supplied much of the fine pottery for the whole Greek world and for the Etruscans, and the total production at any one time was the work of about 125 painters working with a still smaller number of shapers and assistants. Furthermore, the evidence is that 'a regular connection between a potter and a merchant or market was unusual'.[1] In the following century this trade died because demand disappeared, but the Athenian economy was not visibly affected, nor was its prosperity any more than Corinth's had been in the earlier age when Athens replaced it in the world market. A few craftsmen were displaced, quality dropped sharply – that is all.

The first century of the Roman Empire offers another kind of example. The fine pottery of this period was the *terra sigillata*, rather simple, well-made red ware, with moulded decorations if any. It is often called Arretine ware because at the beginning of the period the north Italian town of Arezzo monopolized production. But not for long: the Augustan peace and the consequent expansion of population and urbanization in the western provinces saw the diffusion of the manufacture of *terra sigillata* to various centres in Gaul and along the Rhine. Arezzo was knocked out of the market and quality declined. Out of this and one or two similar developments, in the manufacture of terra cotta lamps, for example, Rostovtzeff and others following him have constructed a great theory about economic decentralization, the ruin of the bourgeoisie, the end of emergent capitalism, and the seeds of the decline of the Roman Empire.[2] I mean no offence, but this theory is an anachronistic burlesque of the affluent society. All that had happened was that a few minor trades over-reached the market, some hundreds of craftsmen in the western Empire in a few cities were displaced by some hundreds in a few other cities, and nothing else. They were no bourgeoisie to begin with, and imperial society was both oblivious to, and unharmed by, the displacements. Not that all this is insignificant as an indicator. It reveals, first, that the minimum technology and small amounts of capital required, the wide diffusion of craft skills, and the excessive costs of transport by land, all combined to promote diffusion of manufacture when population spread away from the Mediterranean coasts; and second, that production for the domestic market and inelasticity of demand were as predominant as Xenophon believed. On the larger issue David Hume saw the picture exactly, when he wrote: 'I do not remember a passage in any ancient author, where the growth of a city is ascribed to the establishment of a manufacture. The commerce, which is said to flourish, is chiefly the exchange of those commodities, for which different soils and climates were suited'.[3]

And now I have another story, about another Roman emperor and another unnamed inventor. This man came to Vespasian with a device for transporting

[1] R. M. Cook, *Greek Painted Pottery* (1960), pp. 275, 273, respectively; cf. his 'Die Bedeutung der bemahlten Keramik für den griechischen Handel', *Jahrbuch d. deutschen archäologischen Instituts*, LXXIV (1959), 114–23.

[2] M. Rostovtzeff, *The Social and Economic History of the Roman Empire*, 2nd ed. rev. by P. M. Fraser (Oxford, 1957), I, pp. 172–91; cf. F. W. Walbank, *The Decline of the Roman Empire in the West* (1946), pp. 28–33.

[3] 'Of the Populousness of Ancient Nations', *Essays* (World's Classics ed. 1903), p. 415.

heavy columns to the Capitol at small cost. The emperor rewarded him well but refused to use the invention, saying, 'How will it be possible for me to feed the populace?' [1] I have never been able to understand this story; the emperors fed the populace at Rome with bread and circuses, not with jobs. But the oft-quoted gnomic remark stands in sharp contrast to Arthur Young's 'Every one but an idiot knows that the lower classes must be kept poor, or they will never be industrious',[2] and that distinction is not hard to understand. There was never the slightest danger in antiquity that the lower classes would be anything but poor, and it did not much matter if some of them, notably the citizens of the capital cities, were industrious or not. They provided neither the products nor the profits. Those came from peasants and from dependent labour, and their industriousness was secured by ways which had nothing to do with wages or technology.

One constant factor throughout ancient history was the presence of a sufficiently abundant supply of dependent labour. In the central periods, both Greek and Roman, they were chattel slaves; at other times, they were clients, helots, debt-bondsmen, *coloni*. This is obviously a key fact, but its implications are complex and often elusive. It is not often that one can point to slaves and say, simply and with confidence, 'There lies the explanation for a static technology and a static economy'. An occasional one-for-one relationship seems likely, as in the hauling of ores or draining of water from the mines. Mechanical devices were sometimes used for these purposes, but normally ore continued to be brought from the mines in leather bags on the backs of slaves and water to be removed by hand-bailing, also by slaves. On the other hand, it was in the Spanish mines (where the exploitation shocked even contemporary writers [3]) that the Archimedean screw was employed, and it was on the Roman latifundia, with their notorious *ergastula*, that most progress was made with farm machinery. Whatever the effect of slave labour, in this respect it was not the effect observed in the American South where slaves impeded progress by the destruction of fine tools and other forms of sabotage. Columella (*De re rustica*) 1.7.6–7) raises this question – alone of ancient writers so far as I know – and, curiously, he does so in the context of corn-growing, while he urges the employment of slaves for the most skilled jobs, such as vine-dressing. Skilled slave labour in antiquity was as good as any: that is obvious from fine pottery, metal-work, or monumental buildings.

The crucial test came in the Roman Empire. Internal peace and the inclusion within the Empire of many former centres of slave-supply reduced the flow of slaves onto the market (compensated, though to an extent which we cannot calculate, by more slave-breeding). In the later Empire, furthermore, a persistent increase in the parasitical classes – the army, the bureaucracy, and the church – created something of a manpower shortage. When we read, therefore, in Pliny's *Natural History* (18.300) in the sentence immediately following the description of the Gallic reaper, that 'the diversity of methods

[1] Suetonius, *Vesp.* 18: 'sineret se plebiculam pascere'.
[2] *Eastern Tour* (1771), IV, p. 361, quoted from Tawney, *op. cit.*, p. 224.
[3] Diodorus 5.36–38.

employed depends upon the quantity of the crops and the scarcity of labour', the implication, the consequence, ought to be self-evident. Unfortunately, the facts belie the logic. Adoption of the water-mill *does* look like another response to shortages of labour (and animals), but we have seen how slow and incomplete the response was in both instances. And otherwise there was nothing.

It is unnecessary to examine the economic history of the later Roman Empire in detail to make the point, with which no one disagrees, that neither technique nor productivity nor economic rationalism made an advance in those final centuries of antiquity. It is, necessary, however, to ask once more why, when circumstances seemed to demand progress on those lines, the only solutions to the problems of labour and production were bureaucratic pressures, greater tax exploitation, and a general debasement of the status (and perhaps the standards) of the free elements in the productive population. The answers, I suggest, are those I pointed to earlier. Servile and other forms of dependent labour were very profitable. Such changes as occurred in the Roman Empire in the position of the wealthy were political, not economic, and therefore *they* had no significant incentive to alter the productive arrangements. In the end, it was the military and political breakdown of the Empire which drove the western aristocracy back onto their estates and to the beginnings of a manorial system.

The interests of the state were another matter; from the second century on, the emperors were faced with continuing difficulties and crises in supplies and revenues. *They* had good reason to think of more production. That, instead, they thought of more regimentation, of a bigger bite out of the old pie, seems to me explicable largely in terms of attitudes, of thought-processes. Not even that extraordinary but anonymous man, who in the fourth century wrote a short work, *De rebus bellicis*, begging the emperor (probably Valentinian I) to adopt a number of military inventions which would save both money and manpower, had any idea that inventions might also be applied to civilian purposes. He poured out his indignation at the misery and poverty of the people, at excessive taxes, at the idleness and hoarded wealth of the aristocracy. He praised the inventiveness of the barbarians. But he had none himself outside the traditional field of military technology.[1]

The pejorative judgments of ancient writers about labour, and specifically about the labour of the artisan, and of anyone who works *for* another, are too continuous, numerous, and unanimous, too wrapped up in discussions of every aspect of ancient life, to be dismissed as empty rhetoric. In other slave-owning societies for whom there is fuller documentation, these implications and their practical effects are unmistakable. Writing about the Great Trek, for example, Sir Keith Hancock said: 'The Boers very soon convinced themselves that artisans' work and slaves' work were the same thing – a conviction which struck such deep roots in their minds that their descendants in the nineteenth century left to British immigrants almost all the opportunities of skilled industrial employment in the expanding towns'.[2] Or Tocqueville, whose 1831 notebooks

[1] See generally the edition of this work, with commentary, by Thompson, *op. cit.*

[2] 'Trek', *Economic History Review*, 2nd ser., X (1958), 331–39, at p. 332.

are filled with the theme that 'slavery is even more prejudicial to the masters than to the slaves', because, as a leading Louisville merchant said to him, 'it deprives us of the energy and spirit of enterprise that characterises the States that have no slaves'.[1] Greek and Roman slavery functioned in a different context, to be sure, both internally and externally, and comparisons must be made with caution and reserve. But this particular one seems to me to be valid and necessary.

Nothing that I have said should be taken to suggest that there was no technical or economic progress whatever in antiquity. Obviously the range and quality of products were enhanced and standards of life rose, at least for the rich. The spread of urbanization suggests, and the quality of urban living confirms, that a larger share of the total income was available for non-productive expenditures. And there was a more or less continuous rise in population, probably through the first century after Christ. This last point is tricky. It requires qualification, and it reveals, more decisively than anything else perhaps, the low upper limit to economic expansion. Population rose in the sense that there were more Greeks in the fifth century B.C. than in the eighth, more Romans in the first century B.C. than in the fifth. In the same time-spans, however, Greeks and Romans, respectively, occupied far more territory. That is the only way a rising population could be absorbed, and to appreciate the significance of this point, we must remember that for most of the period under discussion, the terms 'Greeks' and 'Romans' are abstractions, not the labels on actual political and economic units. The so-called Greek colonization period from about 750 to about 550 B.C., for example, during which new and independent Greek states were established as far east as Trebizond on the Black Sea and as far west as Marseilles, represented no real gain to the original Greek settlements in the Aegean. They were merely the consequence of population outstripping the available means (even after allowance is made for inequitable distribution of goods).

The ancient world had only two solutions to the disequilibrium brought about by a serious increase in population. One was to reduce the population by sending it out. The other was to bring in additional means, in the form of booty and tribute from conquests. Both are stop-gaps, not solutions, and therefore proof of an incapacity to raise productivity sufficiently, or, indeed, significantly. For a relatively brief time Rome offered the illusion of an escape from this dilemma. Having acquired large, sparsely occupied areas, she proceeded to a rapid internal colonization (in Spain and Gaul, for example). The illusion came to an end in the first century. Some historians think that there followed a stable equilibrium, Gibbon's golden age of the Antonines, but it is unnecessary to debate the question. Barbarian pressures now began to place new demands on the empire. That challenge the economy and the political organization could not meet in the west.

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[1] *Journey to America*, transl. by G. Lawrence, ed. by J. P. Mayer (1959), p. 99.