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MEASURING AND INTERPRETING WORLD ECONOMIC PERFORMANCE 1500–2001

BY ANGUS MADDISON

University of Groningen, Netherlands

INTRODUCTION

Macro-measurement started in the seventeenth century, but did not emerge as a basic analytical tool for policy analysts and economic historians until the 1940s. In the past 60 years there has been an explosion in the sophistication of policy analysis and the interpretation of history. The explosion started in 1940 with two seminal works: Keynes' *How to Pay for the War* which demon-strated its usefulness as a tool of macroeconomic management, and Colin Clark's *Conditions of Economic Progress* which demonstrated its value in interpreting economic history. Dissemination and development of techniques of macromeasurement was a major objective of the founding fathers of the International Association for Research in Income and Wealth (IARIW). The initiative came from Simon Kuznets (1901–85), the pioneer of quantitative economic history. Milton Gilbert (1909–79) and Richard Stone (1913–91) were strategic partners with enormous international leverage in creating and diffusing standard procedures for construction of comparable national accounts by official statistical offices.

In the past half-century, I have followed the Kuznetsian approach, augmenting the historical accounts and broadening their geographic scope with my own research, using it to interpret economic performance with a similar analytical toolkit and the same emphasis on transparent description of source material, encouraging graduate students to follow the same path, and creating networks of scholars active in this brand of quantitative economic history. Now we have fairly comprehensive coverage for the whole of the capitalist epoch from 1820 onwards. There are of course gaps in the evidence and scope for improving its quality, but the new challenge, which I have taken up in recent years, is to push the quantitative record further back in time.

This article surveys the development and impact of macro-measurement in three epochs:

(a) Since the 1940s, its main purpose has been to illuminate policy options to improve growth performance at the national level, to analyze inter-

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country divergence in real income levels and to help devise policies for catch-up. We now have official estimates of growth and levels for the vast bulk of the world economy from 1950 onwards. Macro-measurement contributed to much more articulate and successful macro-management. In 1950–2001, world per capita GDP rose 2.1 percent a year, twice as fast as in 1900–50.

(b) For the Kuznetsian epoch of "modern economic growth" back to 1820, quantitative historians have made great progress in measuring growth performance and interpreting its causes. There is still a need to fill gaps and crosscheck existing estimates, but the broad contours of world development in this period are not under serious challenge.

(c) Until recently, serious quantitative investigation of the "merchant capitalist" epoch, 1500–1820, was neglected for three reasons: (i) growth was much slower than in the last two centuries; (ii) the evidence is weaker and there is greater reliance on clues and conjecture; and (iii) many (under the influence of Malthus) thought and think that it was a period of stagnation interrupted by catastrophe. Like Adam Smith, I take a much more positive view of what happened. I explain the derivation of my estimates of performance for 1500–1820 and my reasons for disagreeing with the pessimism of the real-wage pundits.

Finally I give my interpretation of the nature of the transition from merchant capitalism to modern economic growth. The roots of modernity were not a sudden "take-off", but a long apprenticeship, and the divergence in income levels between the West and the rest of the world started well before 1820.

1. Development of Macro-measurement as a Tool of Economic Policy, 1950–2001

(i) *Standardized Estimates of GDP Growth*

Standardized national accounts provide a coherent macroeconomic framework covering the whole economy, which can be crosschecked in three ways. From the income side, they are the total of wages, rents and profits. On the demand side, they are the sum of final expenditures by consumers, investors and government. From the production side, the sum of value added in different sectors (agriculture, industry and services) net of duplication. In all three dimensions these measures need to be adjusted to eliminate changes in the price level in the period they cover, so that they show changes in volume.

Milton Gilbert was responsible for the official U.S. accounts during the war and from 1950 to 1961 was head of statistics and national accounts in OEEC. The Marshall Plan required criteria for aid allocation, and NATO needed them for its burden-sharing exercises. Gilbert met these requirements by pushing official statistical offices of the 16 OEEC member countries to adopt the standardized system of national accounts (SNA) designed by Richard Stone.

Stone set up a program in Cambridge to train official European statisticians to implement the standardized system. A set of handbooks was prepared to explain the problems of adjusting national estimates to conform to the standard-

ized system. A first comparative set of accounts for the 16 OEEC member countries for 1938 and 1947–52 was published in 1954, with extensive notes explaining the adjustments which had been made to achieve comparability.

In 1953, Stone became chairman of a United Nations commission which established a standardized system of accounts for worldwide application. The U.N. could not exert as much leverage on its member countries to conform as was possible in OEEC. The communist countries used the Soviet MPS (material product system) which took a narrower view of the scope of economic activity than the SNA. MPS excluded many service activities which were considered "non-productive" (passenger transport, housing, health, education, entertainment, banking, insurance, personal services, government and party administration and the military). MPS involved double counting (measuring gross output without deducting inter-sector transfers of inputs) and exaggerated economic growth. The price system and tax-structures were different from those in capitalist countries, and measurement conventions gave incentives to exaggerate quality change when new products were introduced. Abram Bergson (1914–2003) pioneered procedures for re-estimation of Soviet GDP on a basis corresponding approximately to Western conceptions in coverage, inclusion of the ignored activities, elimination of double-counting, and repricing on an "adjusted factor cost" basis with imputation for capital costs which were not considered in Soviet-style accounting. These corrective procedures were applied to Soviet statistics by a team of CIA Sovietologists in Washington. In New York, Thad Alton and his colleagues did the same for Bulgaria, Czechoslovakia, East Germany, Poland, Romania and Yugoslavia. This work was financed for intelligence purposes, but was publicly available in annual reports to the U.S. Congress (see Maddison, 1998b).

In the 1990s most of the former communist countries adopted the standardized SNA system in principle, but implementation was complicated by the massive change in ownership, in the level and structure of prices, allocation of resources between consumption and investment, and statistical reporting procedures. It will take some years before these problems can be fully resolved. The IMF continues to use exaggerated measures of GDP growth for these countries (see Maddison, 2003a, p. 231). As a result, it shows a growth in world GDP averaging 3.9 percent a year for 1970–2001, compared with my estimate of 3.3 percent. For China it shows growth averaging 8.5 percent a year, whereas my adjusted measure shows a growth rate of 6.5 percent.

Another area of weakness is the national accounts for African countries, where there was and still is a great shortage of skills and money for such work. The gap in estimates of GDP growth was filled in substantial degree by the OECD Development Centre which compiled annual estimates of real GDP growth 1950–90 for 51 African countries. The Centre benefited from the expertise of Derek Blades, who had been chief statistician in Malawi for eight years, and by David Roberts who had similar experience in Gambia.

A third problem in the assessment of GDP growth performance in the higher income countries derives from recent changes in measurement conventions from 1995 onwards, involving adoption of hedonic indexes to adjust for assumed changes in quality of product, use of chain indices, and treatment of computer software as investment.

Hedonic indices are perfectly respectable in small doses, but one can be skeptical about the widespread assumption that quality changes have been so large and monotonically positive. In the U.S., where the switch to hedonics was most significant, their net impact was to raise the measured rate of growth to a somewhat greater degree than in western Europe and Japan. U.S. official estimates go back to 1929, and the changes in measurement technique had their biggest impact for 1929–50, raising the GDP growth rate for that period from 2.6 percent a year to 3.5 percent. There was no counterpart to this long retrospective readjustment in other countries, and I have continued to use the earlier U.S. official measure for 1929–50 (for reasons explained in Maddison, 2001, p. 138, and Maddison, 2003a, pp. 79–80). More than 40 years ago, Milton Gilbert warned that such adjustments could open Pandora's box: "In the end, they would make it impossible to construct measures of output and price changes that are useful to the study of economic growth" (Gilbert, 1961, p. 287). The danger which arises from an overdose of hedonics is discussed in Appendix 3.

Ed Denison (1915–92) opposed changes in national accounting which treat accretions of knowledge as investment. He considered this a "misclassification" which made "growth analysis chaotic" (see Denison, 1989, p. 10). A major justification for his complaint was that his growth accounts included "human capital", i.e. increments in the quality of the labor force due to increases in the level of education. In fact, the only form of knowledge which is now treated as investment is computer software. It is odd to treat this rapidly depreciating knowledge as investment, whilst ignoring the more durable influence of books and education.

(ii) *Purchasing Power Converters for Cross-country Comparison of GDP Levels*

Once standardized accounts of real GDP growth were available, the next step in inter-country comparison of economic performance and multi-country aggregation was the development of purchasing power parity converters (PPPs) to measure real GDP levels, rather than relying on exchange rate comparison. As noted above, measures of economic growth over time must be corrected to exclude the impact of inter-temporal price change. The purpose of PPP conversion is precisely analogous: The elimination of inter-country differences in price level, so that differences in the volume of economic activity can be compared across countries. By merging the time series for economic growth with the cross-country estimates of GDP levels now available we can make a coherent set of space-time comparisons.

OEEC initiated official estimates of purchasing parity and inter-country differences in the level of GDP. The first study was co-authored by Milton Gilbert and Irving Kravis (1954) and a second, by Gilbert and Associates (1958). They estimated 1950 and 1955 PPPs in order to compare real expenditure levels in seven west European countries and the U.S. Irving Kravis, Alan Heston and Robert Summers (1975, 1978 and 1982) followed this up with more ambitious studies in their International Comparison Project (ICP) at the University of Pennsylvania from 1968 onwards. They involved collection of carefully specified price informa-

tion by statistical offices for more than two thousand representative items of consumption, investment and government services.[1]

The OEEC studies were binary comparisons of differences in price levels between pairs of countries. The three options were: (i) a Paasche PPP, with "own-country" quantity weights; (ii) a Laspeyres PPP with the quantity weights of the numeraire country—the United States; and (iii) a compromise geometric (Fisher) average of the first two measures. The corresponding measures of real expenditure were: (i) Laspeyres comparisons of GDP levels based on the prices (unit values) of the numeraire country; (ii) Paasche level comparisons based on "own-country" prices (unit values); and (iii) a Fisher geometric average of the two measures. Binary comparisons, e.g. Germany/U.S. and U.K./U.S., could then be linked with the U.S. as the star country. Such star comparisons could provide a proxy Germany/U.K. comparison, but it was not "transitive" (i.e. the result would not be identical to that derived from a direct Germany/U.K. comparison). This was not a great drawback for OEEC countries where the inter-country deviation in performance levels was not too wide. But Kravis, Heston and Summers were engaged in comparisons over a much wider range of countries. They therefore adopted the Geary-Khamis (G-K) method, invented by Roy Geary (1896–1983) and Salem Khamis, which multilateralized the results, provided transitivity and other desirable properties. They used it in conjunction with the commodity product dummy method (CPD), invented by Robert Summers, for filling holes in the basic dataset.

[1]OEEC experimented with an alternative technique, measuring comparative performance levels from the production side (see Paige and Bombach, 1959). This approach is particularly useful in comparisons of productivity. It has been neglected by international agencies, but I have made and promoted estimates of this kind for a large number of countries. Maddison (1970) was a comparative survey of growth experience in the six biggest OECD countries, the USSR and 22 developing countries for 1870–1968 representing about 75 percent of world GDP. The biggest statistical challenge was the absence of comparative measures of GDP levels at that time. I constructed benchmark estimates for 1965, with measurement of real value added by sector at U.S. prices. Output of farm, fishery, and forestry products was derived from detailed FAO data, with deduction of feed seed and non-farm inputs. For mining, manufacturing and utilities, I used Shinohara (1966). He had a sample of 70 commodities, weighted by value added derived from the U.S. Census of Manufactures. For services, direct measurement was not possible, so I used estimates of employment and a conjectured level of labor productivity, assumed to be related systematically to that in the commodity sector (i.e. agriculture plus industry). In Maddison (1998a), I used the industry-of-origin approach to make a much more elaborate comparison of the Chinese GDP level in 1990 compared with that of the U.S. Maddison (1983) was a confrontation of the Maddison (1970) results, by the product method, with the expenditure estimates of Kravis, Heston and Summers (1982). For the advanced countries, my results were on average about 4 percent lower. For developing countries the divergence was much bigger. The expenditure approach yielded per capita GDPs averaging 16.7 percent of the U.S., the product method 11.3 percent. The difference arose primarily from the treatment of comparison-resistant services. For teachers and civil servants, they assumed average labour productivity in developing countries to be about the same as in the U.S., whereas my average was one third of the U.S. level. When I returned to academic life, I set up the ICOP programme (International Comparisons of Output and Productivity) at the University of Groningen in 1983. It has since produced more than 80 research papers, a dozen Ph.D. theses, and established a world-wide network of researchers in this field. The overall results of the ICOP project are surveyed in Maddison and van Ark (2002). The only whole-economy results as yet available on an ICOP basis are for Brazil, Mexico, Korea, Japan and the United States for 1975. The average per capita GDP for these four countries relative to the U.S. was 34.8 percent for the ICOP measure against 36.9 percent for ICP, a much smaller discrepancy than I found in my 1983 confrontation. However, confrontation/reconciliation of the two methods needs to be done more rigorously and for a larger number of countries.

TABLE 1

NATURE OF PPP CONVERTERS FOR ESTIMATION OF GDP LEVELS IN 1990 (BILLION 1990 GEARY-KHAMIS DOLLARS AND NUMBER OF COUNTRIES)

	Europe and Western Offshoots	Latin America	Asia	Africa	World
ICP	15,273 (28)	2,131 (18)	8,017 (24)	0 (0)	25,421 (70)
PWT	59 (3)	71 (14)	524 (16)	891 (51)	1,516 (84)
Proxies	16 (10)	38 (15)	87 (17)	14 (6)	155 (48)
Total	15,349 (41)	2,240 (47)	8,628 (57)	905 (57)	27,122 (202)

Source: Maddison (2003a), p. 230.

Their masterpiece was their third study, the 1982 volume *World Product and Income*, which contained estimates for 34 countries (in Africa, the Americas, Asia and Europe) in 1975 prices and international Geary-Khamis dollars. These countries accounted for 64 percent of world GDP in 2001.

The U.N. Statistical Office extended the ICP work and had covered 84 countries by 1985. UNSO then dropped this endeavor, though some of the regional U.N. bodies continued with it. The OECD recommenced its comparisons on a regular basis in 1982. Its latest work covered the 28 OECD countries (see OECD 2002) and 20 others in Eastern Europe, the 15 successor states of the USSR, and Mongolia (see OECD, 2000).

Since 1978, Alan Heston and Robert Summers have produced short-cut estimates of PPPs and real income levels for countries for which full-scale ICP type measures are not available. The latest version of their Penn World Tables (PWT 6.1 October, 2002) can be found on their website.[2] As a result, we now have reasonably acceptable PPP adjusted measures available for over 99 percent of world GDP.

There were three Eurostat estimates (for 1980, 1985 and 1993) of PPPs for 22 African countries, but the results were erratic, and I preferred to use the more comprehensive and plausible results of the Penn World Tables. Table 1 summarizes the nature of the PPP estimates I used to create my 1990 benchmark estimates of world GDP.

Table 2 shows the difference between PPP and exchange rate conversion for the world's 10 largest economies (which represented 65 percent of world GDP in 2001). The exchange rate conversions on the right hand side show much lower levels for the poorer countries (China, India, Russia and Brazil) and somewhat higher levels for the west European countries and Japan relative to the U.S. than the PPP converters. In the case of China the deviation was very large. Purchasing power was more than five times higher than the exchange rate. In India the ratio was more than three times higher, in Russia twice as high and in Brazil more than 50 percent higher. In Japan and the west European countries, the exchange rate overvalued purchasing power relative to the U.S. dollar. In fact the big differential for poorer countries is a fairly systematic outcome in such comparisons (see footnote 1). For the west European countries and Japan the differential is smaller and has varied above and below parity in the past two decades. The implausibility of exchange

[2]See http://www.pwt.econ.upenn.edu/.

TABLE 2

World's 10 Largest Countries: Comparative Ranking, 1950 and 2001, at constant 1990 prices, using 1990 Geary-Khamis PPP converters and 1990 exchange rates

	1950	2001	1950	2001
GDP	$billion, with 1990 PPP conversion		$billion, with 1990 rate exchange	
U.S.	1,456	7,966	1,456	7,966
China	240	4,570	47	886
Japan	161	2,625	206	3,358
India	222	2,003	62	558
Germany	265	1,537	337	1,951
France	221	1,258	261	1,491
U.K.	348	1,202	363	1,253
Italy	165	1,101	191	1,272
Brazil	89	990	58	638
Russia	315	791	154	388
GDP per head	$, with 1990 PPP conversion		$, with 1990 exchange rate	
U.S.	9,561	27,948	9,561	27,948
China	439	3,583	85	695
Japan	1,921	20,683	2,458	26,466
India	619	1,957	172	545
Germany	3,881	18,677	4,928	23,717
France	5,271	21,092	6,244	24,985
U.K.	6,939	20,127	7,266	20,985
Italy	3,502	19,040	4,046	21,996
Brazil	1,672	5,570	1,077	3,588
Russia	3,086	5,435	1,515	2,669

Source: Maddison (2003a).

rate conversion is clear when we look at the results for 1950 where exchange rate conversion implies a per capita GDP of $85 in China and $172 in India (both in 1990 prices). These levels are much too far below subsistence to be credible.

There has been reluctance on the part of many poorer countries to accept PPP conversion, because they felt it might weaken their case for foreign aid or favorable loan programs of the IDA type (the cheap loan window of the World Bank). In fact, the World Bank has provided substantial financial support for the ICP programme, but generally avoids explicit use of PPP converters in its analytical work and loan decisions.

In spite of the creeping acceptance of PPP adjusted estimates, there continues to be significant error in comparative economic analysis because of ignorance of the pitfalls of exchange rate conversion. This is true in journalism, in political discourse, and also amongst some economists. Newspapers frequently refer to Japan as the world's second largest economy, though its GDP is less than 60 percent of the Chinese, and some British politicians continue to believe that their economy is bigger than China's.[3] In this situation, it is highly desirable that

[3]Christopher Patten, the last British governor of Hong Kong, stated in an article in the *Economist* newspaper of January 4, 1997 that "Britain's GDP today is almost twice the size of China's." If he had been briefed on PPP converters, he might have said that Britain's GDP was one third the size of the Chinese.

statistical offices be more vigorous in explaining the merits of PPP adjustment and in pushing for reinvigoration of this work on a worldwide basis.

(iii) *Reasons for Worldwide Adoption of Macro-measurement Since 1950*

The main reason for the massive increase in coverage and quality of official national accounts from 1950 onwards was the realization of their usefulness as a tool of macroeconomic policy. Denison, Gilbert, Kaldor, Kuznets, Ruggles, Stone, and others in the U.K. and U.S., knew from personal experience that such accounts were also an extremely important tool for resource mobilization in wartime.[4]

In the 1950s, Keynesian analysis had a powerful influence on economic policy in many Western countries and its fundamental concern was with macroeconomic magnitudes (Keynes was the godfather of the first British accounts created by his pupils, Meade and Stone). Harold Macmillan discovered national accounts in 1956, when he became Chancellor of the Exchequer. He compared them to a railway timetable, without which you wouldn't know when the trains were running.

This new macroeconomic perspective was very different from that of Hayek and Schumpeter. The latter considered "total output a figment which, unlike the price level, would not as such exist at all, were there no statisticians to create it. We seem indeed to be faced by a meaningless heap—for most purposes, a highly inconvenient composite" (Schumpeter, 1939, pp. 484, 561).

The operational significance of national accounts became obvious in OEEC, when Milton Gilbert became responsible for economic policy analysis from 1955 to 1961, and greatly improved its quality. National accounts became the bedrock on which analysis of comparative growth performance was based. It provided a yardstick for assessing the success of policy which had never existed before. We served as the secretariat for a new Group of Economic Experts which included Otmar Emminger from the Bundesbank, Etienne Hirsch, head of the French Plan, Jan Tinbergen from the Netherlands, Arthur Burns, chairman of the U.S. Council of Economic Advisors, and Robert Hall, chief advisor to the U.K. Treasury. In 1955, Hall described the significance of their work as follows: "These meetings are really something quite exceptional for economists and I should think are quite new

[4]Kaldor (1946) concluded that "Germany made no serious attempt to exploit her own war potential fully, except for a brief period in August and September 1944, when it was too late to be of any consequence." Galbraith (1971) made the same point. Kaldor's analysis was drawn from material gathered as a staff member of the U.S. Strategic Bombing Survey (1945), and interrogation of Karl Otto Saur, Albert Speer's deputy in the Armaments Ministry. The survey team was directed by Galbraith, and included Paul Baran, Ed Denison, Burton Klein, and Tibor Scitovsky (under the nom-de-guerre "Thomas Dennis"). Kaldor and Scitovsky interrogated Saur in Austria, the day the war ended (see Scitovsky, 1999). He indicated where they could find the wartime production records, and they whisked them away just before the Russians arrived. Denison and Haraldson made a detailed estimate of German GNP, 1936–44, to put military mobilization in perspective. Richard Ruggles served with the U.S. Office of Strategic Services in London, inferred German production of tanks, trucks, and planes by decoding information on serial numbers of captured equipment (see Tobin, 2001). Stone worked with British intelligence and predicted the date of Italian entry in the war, by tracking movement of ships in the Mediterranean. Kuznets used national accounting to help organize the massive expansion of U.S. military output in the Planning Committee of the War Production Board (see Kapuria-Foreman and Perlman 1995), with help from Moe Abramovitz. The moral of this digression is that the initial stage in construction of national and historical accounts is not a boring bureaucratic business. It requires detective work and imagination, and can be as exciting as the adventures of Sherlock Holmes.

in the history of the world, in the sense that economic experts, if they existed at all as Government advisers, were not generally very important people until Keynes's ideas had been commonly accepted in the West. So that there were not the people to meet as we do: now we have 7 or 8 or 9 people who are by and large the chief professional advisers of the main Western Governments—all have more or less the same professional training in that they understand how to maintain the level of activity and what forces operate on it" (Cairncross, 1991, p. 35).

2. Quantifying and Interpreting World Economic Growth in the Capitalist Epoch

Simon Kuznets (1901–85) did more than anyone else to push back the quantitative time horizon beyond 1950 by promoting the development of historical evidence on "modern" economic growth and interpreting its driving forces. He revolutionized the analytical scope of economic history by giving it a quantitative underpinning.

In the 1930s and 1940s, he made a massive scholarly contribution to the macroeconomic history of the U.S. (growth and structure of GDP, capital stock, employment, immigration, distribution of income and foreign trade), and made the first official U.S. national accounts. In the 1950s and 1960s he played a major role in encouraging construction of similar accounts for other countries. He did this in IARIW sessions, was a driving force in creating the Yale Growth Center, whose graduate students produced growth studies on Argentina, Egypt, Korea, Sri Lanka, Taiwan and the USSR, and he chaired a Social Science Research Council Committee which provided financial support for construction of basic historical accounts for China, France, Germany and Italy, and a subsequent project on factors influencing economic growth in France, Germany, Italy, Sweden and the USSR. He synthesized the international evidence on economic growth in four volumes containing 43 interpretive essays published between 1953 and 1989.

Kuznets spent more than four decades as a university teacher. He convinced many of his distinguished students, and an international network of scholars, that comparative research in quantitative economic history was feasible, exciting and important. His persuasive power and influence stemmed mainly from his professional integrity and depth of scholarship. He was free from partisanship, avoided polemical confrontations, open to new ideas and willing to comment sympathetically in detail on the work of others. His influence was reinforced by his style of analysis—use of ideas and concepts that could be clearly expressed in literary form, implementable with relatively simple statistical techniques.

His technique of exposition virtually never made use of algebra or regressions. The approach was basically inductive. He was a cautious "interpreter" of economic growth, very sensitive to the quality of the quantitative evidence, and the multilayered complexity of causality. He did not try to "explain" economic growth with the exactitude to which econometricians and growth accountants often aspire. He stuck to respectable macroeconomic measures whose scope and significance were clear and well defined. His estimating procedures were fully and transparently described. He had no time for proxy measures, metaphors, stylized facts, leading sector analysis, or real wage indicators and was sometimes overly

TABLE 3

COVERAGE OF MADDISON (2003a) GDP SAMPLE OF REGIONAL AND WORLD GDP

	1500	1700	1820	1870	1913	1950
Western Europe	61.6	74.2	84.5	98.7	99.6	99.9
Western offshoots	0.0	84.9	94.2	99.2	99.0	100.0
Eastern Europe and former USSR	0.0	0.0	10.4	76.2	79.2	99.8
Latin America	49.2	49.4	54.5	63.6	85.0	99.9
Asia	80.6	85.5	92.9	91.8	94.8	98.5
Africa	0.0	0.0	0.0	0.0	37.9	99.5
World	64.8	70.2	78.6	88.5	93.1	99.6

Source: Maddison (2003a), p. 226.

fastidious. However, he was not averse to what Paul David (1967) called controlled conjectures.

Thanks to the work of Kuznets and his successors, we now have fairly comprehensive coverage for the whole of the capitalist epoch from 1820 onwards (see Table 3). There are of course gaps in the evidence and scope for improving its quality, but the evidence available on world economic performance in the capitalist epoch is incomparably richer than it was 60 years ago.[5]

(i) *Characteristics of the Kuznetsian Epoch Back to 1820: What Have We Learned?*

(a) Kuznets' evidence was fairly Eurocentric. He was not able to measure world performance. We now have a much broader range of evidence on growth and levels. Table 4 shows the long-term divergence in income levels between the advanced capitalist group (the "West") and the Rest. Average per capita income of the West rose 20-fold between 1820 and 2001, and less than nine-fold in the Rest. The spread between the two groups rose from 2:1 to nearly 7:1 and the inter-regional gap increased much more from 3:1 to 18:1. Nevertheless, it is clear from Table 5 that the Western share of world GDP has peaked and will in all probability fall considerably more if the two Asian tigers, India and China maintain a high growth momentum.

(b) The evidence now available suggests that the transition to accelerated growth started around 1820, not 1760 as Kuznets thought. The work of Crafts and others (1983 and 1992) on British performance in the eighteenth century helped demolish the old notion of a sudden take-off in the second half of that century. The important point about Britain's exceptionalism is not an industrial revolution, but a much longer process of ascension, with per capita growth much faster from 1500 than anywhere else in Europe, except the Netherlands (see Table 8a).

[5]Colin Clark (1940) had estimates (some of them very rough) of GDP growth for 16 countries, with an average coverage of 19 years for the period since 1820. We now have historical accounts for a much wider range of countries and for these 16 countries we have better quality accounts for an average of 151 years. At that time there were only ten countries with some kind of official national accounts. In 2001 there were 179 countries producing official estimates, using standardized SNA guidelines.

TABLE 4

LEVELS OF PER CAPITA GDP: WORLD AND MAJOR REGIONS, 1500–2001 (1990 INTERNATIONAL DOLLARS)

	1500	1820	1870	1913	1950	1973	2001
Western Europe	771	1,204	1,960	3,458	4,579	11,416	19,256
Western offshoots	400	1,202	2,419	5,233	9,268	16,179	26,943
Japan	500	669	737	1,387	1,921	11,434	20,683
West	**702**	**1,109**	**1,882**	**3,672**	**5,649**	**13,082**	**22,509**
Asia (excluding Japan)	572	577	550	658	634	1,226	3,256
Latin America	416	692	681	1,481	2,506	4,504	5,811
Eastern Europe and former USSR	498	686	941	1,558	2,602	5,731	5,038
Africa	414	420	500	637	894	1,410	1,489
Rest	**538**	**578**	**606**	**860**	**1,091**	**2,072**	**3,377**
World	**566**	**667**	**875**	**1,525**	**2,111**	**4,091**	**6,049**
Interregional spread	1.9:1	2.9:1	4.8:1	8.2:1	14.6:1	13.2:1	18.1:1
West/rest spread	1.3:1	1.9:1	3.1:1	4.3:1	5.2:1	6.3:1	6.7:1

Source: Maddison (2003a), p. 259. Western offshoots are Canada, U.S., Australia and New Zealand.

TABLE 5

LEVELS OF GDP: WORLD AND MAJOR REGIONS, 1500–2001 (BILLION 1990 INTERNATIONAL DOLLARS)

	1500	1820	1870	1913	1950	1973	2001
Western Europe	44.2	160.1	367.6	902.3	1,396	4,096	7,550
Western offshoots	1.1	13.5	111.5	582.9	1,635	4,058	9,156
Japan	7.7	20.7	25.4	71.7	161	1,243	2,625
West	**53.0**	**194.4**	**504.5**	**1,556.9**	**3,193**	**9,398**	**19,331**
Asia (excluding Japan)	153.6	392.2	401.6	608.7	823	2,623	11,481
Latin America	7.3	15.0	27.5	119.9	416	1,398	3,087
Eastern Europe and former USSR	15.2	62.6	133.8	367.1	695	2,064	2,072
Africa	19.3	31.2	45.2	79.5	203	550	1,222
Rest	**195.3**	**501.0**	**608.2**	**1,175.2**	**2,137**	**6,626**	**17,862**
World	**248.3**	**695.3**	**1,112.7**	**2,732.1**	**5,330**	**16,024**	**37,194**
% West/world	21.3	28.0	45.3	57.0	59.9	58.6	52.0

Source: Maddison (2003a), p. 262. Western offshoots are Canada, U.S., Australia and New Zealand.

(c) The acceleration in Western Europe was synchronous, not staggered as Gerschenkron and Rostow believed. Hansen's (1974–76) work on Denmark showed evidence of substantial advance in the early nineteenth century; Tilly (1978) found the same for Prussia; Levy-Leboyer and Bourguignon (1985) and Toutain (1987) for France; Hjerppe and Associates (1987) for Finland; Krantz (1988) for Sweden; Hodne and Grytten (1994) for Norway; Smits, Horlings and van Zanden (2000) for the Netherlands. Their research strongly suggests that the acceleration of economic growth was quite general in Western Europe after the Napoleonic wars. It was slower in 1820–70 than it became in 1870–1913. Nevertheless the pace of advance in Western Europe in 1820–70 was clearly much faster than in the eighteenth century and earlier.

(d) Kuznets (1930) demolished the Kondratieff notion of long cycles and Kuznets (1940) found Schumpeter's cyclical schema unacceptable: "The

TABLE 6

PER CAPITA GDP GROWTH: WORLD AND MAJOR REGIONS, 1500–2001 (ANNUAL AVERAGE COMPOUND GROWTH RATES)

	1500–1820	1820–70	1870–1913	1913–50	1950–73	1973–2001
Western Europe	0.14	0.98	1.33	0.76	4.05	1.88
Western offshoots	0.34	1.41	1.81	1.56	2.45	1.84
Japan	0.09	0.19	1.48	0.88	8.06	2.14
West	**0.14**	**1.06**	**1.57**	**1.17**	**3.72**	**1.95**
Asia (ex Japan)	0.00	–0.10	0.42	–0.10	2.91	3.55
Latin America	0.16	–0.03	1.82	1.43	2.58	0.91
Eastern Europe and USSR	0.10	0.63	1.18	1.40	3.49	–0.05
Africa	0.00	0.35	0.57	0.92	2.00	0.19
Rest	**0.02**	**0.06**	**0.82**	**0.65**	**2.83**	**1.75**
World	**0.05**	**0.54**	**1.30**	**0.88**	**2.92**	**1.41**

Source: Maddison (2003a), p. 263.

failure to follow articulate methods of time series analysis reduces the statistical methods to a mere recording of impressions of charts, impressions with which it is often difficult to agree" (p. 269). Technical progress did not come in big Schumpeterian waves, but was a smoother more diffused process: "flowing in a continuous stream, a stream magnified in a constant proportion by the efforts of imitators" (p. 263). This way of thinking he transmitted to his students, Fogel (1964) and Schmookler (1966), who gave it fuller articulation.

(e) Kuznets concentrated on performance in the capitalist epoch as a whole, but we now have enough evidence to discern five phases from 1820 to 2001 in which the momentum of growth and fashions in economic policy differed substantially (see Table 6). The years 1950–73 were a golden age of unparalleled prosperity. World GDP rose at an annual rate of 5 percent, per capita GDP near 3 percent and world trade almost 8 percent a year. There was a significant degree of convergence in per capita income, with most regions growing faster than the U.S. (the lead economy). After 1973, there was a marked slowdown in world growth, with substantial divergence between different regions, and performance in many of them below potential. Nevertheless, on a world basis, this latest phase was the second-best since 1820. It is clear that "modern economic growth," in all its phases, has been much faster than in the preceding centuries. From the year 1500 to 1820, world per capita income rose 0.05 percent a year. From 1820 to 2001, it averaged 1.23 percent, nearly 25 times as fast.

(f) It is important to distinguish between lead and follower countries to understand the dynamics of technological diffusion, and analyze processes of catch-up and falling behind. "Lead" countries are those whose economies operate nearest to the technical frontier; "follower" countries have a lower level of labor productivity (or GDP per capita). Since 1500 there have been four lead countries, Northern Italy in the sixteenth century, the Netherlands from the sixteenth century until the Napoleonic wars, when the U.K. took over. The British lead lasted until around 1890, and the U.S. has been the lead country since then.

(ii) *Quantifying the Causes of Growth*

As quantitative evidence on comparative GDP growth has accumulated, it has became feasible to sharpen analysis by quantifying the reasons for intertemporal and interspatial variance in performance.

The first step in growth accounting was to measure labor input and productivity. Labor input has grown unevenly over time and between countries. It has been very different from the movement of population. Since 1820, labor input has increased less than population; and labor productivity a good deal faster than GDP per capita.

Early post-war analysts laid great stress on the role of capital in economic growth, though for lack of accurate information, some assumed that the capital-output ratio was stable, some used incremental investment-output ratios, wealth surveys, insurance valuations, company book-values or stock exchange values as a proxy. A major breakthrough came when Goldsmith (1951) pioneered the "perpetual inventory" method in which stock estimates were derived by cumulating historical series on past investment at constant prices, and deducting assets scrapped, written off or destroyed by war. In the course of the 1970s and 1980s, several OECD countries developed official stock estimates of this type, when they had accumulated a long enough run of investment data to permit their construction. These official estimates are similar conceptually but need adjustment because of different assumptions about asset lives. Academic researchers such as Feinstein and Pollard (1988) and Gallmann (1986 and 1987) pushed these capital stock estimates much further back in time.

I made standardized estimates of fixed non-residential capital for France, Germany, Japan, the Netherlands, U.K. and U.S. in Maddison (1995c) broken down into structures, and machinery. This is a very pertinent distinction, as the rate of growth of the latter component has been much faster than the former, and technical progress is probably more rapidly embodied in machinery investment than in structures.

Schultz (1961) suggested that inputs of "human capital" should also be regarded as a factor of production. The main component he had in mind was the increase in formal education, but improvements in skill through working with sophisticated equipment, and improvements in health are also relevant. The idea proved attractive and measures of joint factor productivity were soon constructed in which education was treated as part of factor input. In growth accounts, the normal procedure is to treat increases in education as an improvement in labor quality, rather than as an independent factor of production analogous with physical capital.[6]

[6]Estimation of the stock of human capital is analogous to the procedure for physical capital. A useful starting point is scrutiny of successive population censuses where respondents report the age at which their formal education ended (see estimates for 19 countries by sex and age-cohort in OECD, 1975, vol. 1, pp. 31–108). These can be updated by annual cumulation of increments to the stock (see annual school enrolment in OECD, *Education at a Glance* and its predecessor volumes), and deduction for people who retire from the labor force. The value of the stock can be derived from estimates of earnings of people with primary, secondary and higher education (see Psacharopoulos, 1975). This is the procedure I used in growth accounts for advanced OECD countries (see Maddison, 1987) and for 22 developing counties (Maddison, 1970, pp. 45–50).

TABLE 7a

DETERMINANTS OF GROWTH: U.K., U.S. AND JAPAN, 1820–1998

	U.K.	U.S.	Japan	U.K.	U.S.	Japan
	Gross Stock of Machinery and Equipment Per Capita (1990 $)			Gross Stock of Non-Residential Structures Per Capita (1990 $)		
1820	92	87	n.a.	1,074	1,094	n.a.
1870	334	489	94a	2,509	3,686	593
1913	878	2,749	329	3,215	14,696	852
1950	2,122	6,110	1,381	3,412	17,211	1,929
1973	6,203	10,762	6,431	9,585	24,366	12,778
1998	11,953	25,153	29,987	21,066	35,810	49,042
	Primary Energy Consumption Per Capita (tons of oil equiv.)			Average Years of Education Per Person Employed*		
1820	0.61	2.45b	0.20	2.00	1.75	1.50
1870	2.21	2.45	0.20	4.44	3.92	1.50
1913	3.24	4.47	0.42	8.82	7.86	5.36
1950	3.14	5.68	0.54	10.60	11.27	9.11
1973	3.93	8.19	2.98	11.66	14.58	12.09
1998	3.89	8.15	4.04	15.10	19.46	16.03
	Land Area Per Capita (hectares)			Exports Per Capita (1990 $)		
1820	1.48	48.1	1.23	53	25	0
1870	1.00	23.4	1.11	390	62	2
1913	0.69	9.6	0.74	862	197	33
1950	0.48	6.2	0.44	781	283	42
1973	0.43	4.4	0.35	1,684	824	875
1998	0.41	3.5	0.30	4,680	2,755	2,736
	Hours Worked Per Head of Population			GDP Per Man-hour (1990 $)		
1820	1,153	968	1,598	1.49	1.30	0.42
1870	1,251	1,084	1,598	2.55	2.25	0.46
1913	1,181	1,036	1,290	4.31	5.12	1.08
1950	904	756	925	7.93	12.65	2.08
1973	750	704	988	15.97	23.72	11.57
1998	657	791	905	27.45	34.55	22.54

Notes: (a) 1890; (b) 1850; *equivalent years of primary education.
Source: Appendix K of Maddison (1995, pp. 252–5), amended and updated.

Denison (1962) created expanded growth accounts to explain twentieth-century American economic performance. In 1967 he applied the technique to explain differences in growth rates and levels of achievement in eight West European countries and the U.S. for 1950–64. Denison and Chung (1976) incorporated Japan into the sample.

Tables 7a and 7b present accounts for the two successive lead countries, the U.K. and U.S., back to 1820, and Japan, the most successful catch-up country, for the whole period of its "modern economic growth." The accounts show:

(a) A huge increase in the stock of physical capital, significant for non-residential structures, but sensational for machinery and equipment. The

TABLE 7b

CAPITAL/OUTPUT RATIOS, GROWTH OF LABOR AND TOTAL FACTOR PRODUCTIVITY: U.K., U.S. AND JAPAN, 1820–1998

	U.K.	U.S.	Japan	U.K.	U.S.	Japan
	Capital-Output Ratio Machinery and Equipment/GDP			Capital-Output Ratio Non-Residential Structures/GDP		
1820	0.05	0.07	n.a.	0.63	0.87	n.a.
1870	0.11	0.20	0.10a	0.79	1.51	0.59a
1913	0.18	0.52	0.24	0.65	2.77	0.61
1950	0.31	0.64	0.72	0.49	1.80	1.00
1973	0.52	0.64	0.93	0.80	1.46	1.12
1998	0.64	0.92	1.47	1.13	1.31	2.40
	Labor Productivity (annual average compound growth rates)			Total Factor Productivity (annual average compound growth rates)		
1820–1870	1.10	1.10	0.18	0.15	–0.15	n.a.
1870–1913	1.22	1.93	2.00	0.31	0.36	–0.05b
1913–1950	1.66	2.47	1.79	0.81	1.62	0.20
1950–1973	3.09	2.77	7.75	1.48	1.75	5.12
1973–1998	2.19	1.52	2.70	0.83	0.60	0.58

Notes: (a) 1890; (b) 1890–1913.
Source: see Table 7a.

ratio of the latter to GDP rose 13-fold in the U.K. and U.S. between 1820 and 1998, and nearly 14-fold in Japan from 1890 onwards. This increase was linked to the acceleration of technical progress, much of which had to be embodied in machinery.

(b) The education level rose nearly eightfold in the U.K., 11-fold in the U.S. and Japan. This increase in human capital, measured by years of formal educational experience of those in employment (weighted by the earnings differential associated with years of primary, secondary and tertiary) was also linked to technical progress. The increasing complexity of production processes required better educated people to make it operational, and the involvement of educated people in R&D helped institutionalize the process of innovation.

(c) Labor input per head of population dropped by 40 percent in the U.K. and Japan, 20 percent in the U.S.

(d) International specialization: the ratio of foreign trade to GDP rose from 3 to 25 percent in the U.K., from 0.2 to 13 percent in Japan and from 2 to 10 percent in the U.S.

(e) Natural resource scarcities were not a constraint; land area per capita fell 14-fold in the U.S., about fourfold in Japan and the U.K.

(f) The increase in energy inputs was relatively modest—a threefold increase per capita in the U.S., sixfold in the U.K. and eightfold in Japan. However, the composition of energy inputs changed drastically. In 1820, 94 percent came from organic matter. By 2001, this had dropped to 11 percent.

3. Economic Performance in the Merchant Capitalist Epoch: 1500–1820

Quantitative investigation for this earlier period has been relatively neglected for three reasons: (a) it is clear that growth was much slower than it has been in the last two centuries; (b) quantitative evidence is harder to find; and (c) many thought the results would be uninteresting—a long litany of stagnation interrupted by catastrophe.

(i) *Divergent Interpretations of Merchant Capitalist Epoch 1500–1820*

There were already two very different views on growth performance at the end of the eighteenth century. Adam Smith (1776) took a mildly euphoric position and Malthus (1798) was deeply pessimistic.

Positive: Adam Smith (1776), argued that the discovery of the Americas and southern route to Asia opened up new and significant opportunities for economies of scale and specialization through international trade. Though these possibilities were not fully exploited because of mutually hostile trade restrictions, Smith was mildly euphoric about progress achieved. He did not quantify growth performance explicitly, but arrayed countries in descending level of achievement: Netherlands, England, France, North American colonies, Spanish America, China, Bengal and Africa. For him, policy and institutions were a major reason for this inter-country variance.

Negative: Robert Malthus' (1798) growth schema had only two factors of production—natural resources and labor—with no allowance for technical progress, capital formation or gains from international specialization. He portrayed the general situation of humanity as one where population pressure put such strains on the ability of natural resources to produce subsistence that equilibrium was attained only by various catastrophes—wars, famine, and disease—which brought premature death on a large scale and which he described as "positive" checks. The only policy measures he envisaged to check catastrophe were "preventive" checks to lower the birth rate. His influence has been strong and persistent, largely because his forceful rhetoric and primitive argument appeal to simple minds.

The dichotomy between positive and negative views persists. Kuznets (1965), Landes (1969), Cipolla (1976), Jones (1981), Jan de Vries (1993, 1994) and Maddison (2001) take a view similar to Smith's, but there has been a raft of latter-day pessimists.

LeRoy Ladurie, a French Malthusian (1966, 1978), thought the French economy was stagnant from 1300 to 1720. "Real wage" pundits are more pessimistic. Phelps Brown and Hopkins (1956) suggested that English living standards in 1820 were 44 percent lower than in 1500. Wilhelm Abel (1978) suggested that such a drop was characteristic for the whole of Western Europe. These judgements were endorsed by Bairoch, Braudel, Wrigley and Schofield, but later they switched sides. A new wave of real wage pessimism has been launched by Robert Allen (2001) and Jan Luiten van Zanden (1999, 2002). Allen finds negative per capita growth for 1500–1820, van Zanden less than half the growth I find (see Appendix 1).

Most of the pessimist literature is Eurocentric, but Susan Hanley (1997) and Kenneth Pomeranz (2000) claim, respectively, that Japan and China had living

standards equal to those in the U.K. early in the 19th century They imply or suggest that there was no significant European ascension in 1500–1820.[7]

(ii) *The Nature of the Quantitative Evidence on Economic Performance 1500–1820*

In 1965, Kuznets advanced an influential conjecture about the rate of population and per capita GDP growth in Western Europe from the end of the fifteenth to the second half of the eighteenth century. Judging from the demographic evidence then available (Carr-Saunders, 1936; Urlanis, 1941), the work of Deane and Cole (1962) on British per capita income growth in the eighteenth century, and adjusting for the likelihood of better-than average performance in the U.K., which had also had faster demographic advance, he "set the possible (and perhaps maximum) long-term growth in per capita product for 1500–1750 in developed countries of Western Europe at about 0.2 percent per year" (Kuznets, 1973, p. 139). He felt that a higher rate was unlikely as the 1750 level was low, and that a lower growth rate was plausible. Kuznets did not advance a conjecture about growth rates in the rest of the world, but he clearly thought that they were lower than in western Europe, and that their 1750 level was lower than that in Europe.

Maddison (2001) involved a major effort to test the Kuznets' conjecture and muster quantitative evidence on world economic performance before 1820, as summarized below:

(a) For *western Europe*: I encouraged other researchers to extend their time horizon backward by interactive networking of the type which proved so fruitful in building up evidence for 1820 onwards. Between 1985 and 1994, I organized six workshops on quantitative economic history (two at the University of Groningen, two at IARIW conferences, and two at sessions of the International Economic History Association).

Most of the papers involved exploration of pre-modern growth in Western Europe and the evidence was mainly from production and expenditure side. As can be seen in Table 8a, the estimates show per capita growth averaging 0.14 percent a year between 1500–1820, significantly slower than Kuznets' (1965) hypothesis. Details of the estimation procedure and the conjectures used to fill gaps in the GDP database are shown in Maddison (2001), Appendix B.

Thanks to the work of modern demographic historians, the quality and coverage of estimates of population levels and movement have been greatly improved, and also yield useful corroborative evidence on changes in urbanization and life expectation—where European exceptionalism is clear.

Jan de Vries (1984, 1993, 1994) made a major contribution to analysis of this period in three dimensions: the comparative study of European urbanization; the changing structure of European expenditure patterns; and the demonstration that

[7]Kenneth Pomeranz (2000) asserted that China was ahead of Europe until 1800. He suggests that Western Europe was "a non-too-unusual economy: it became a fortunate freak only when unexpected and significant discontinuities in the late eighteenth and especially nineteenth centuries enabled it to break through the fundamental constraints of energy and resource availability that had previously limited everyone's horizons." I explained my disagreement at length in Maddison (2003, pp. 248–51). Hanley had a similar view about Japan, see my comment in Maddison (1999).

TABLE 8a

PER CAPITA GDP LEVELS, 1500 AND 1820 (IN 1990 G-K $)

	Dynamic Countries and Regions		
	1500	1820	Growth rate
Belgium	875	1,319	0.13
France	727	1,135	0.14
Germany	688	1,077	0.14
Italy	1,100	1,117	0.00
Netherlands	761	1,838	0.28
Portugal	606	923	0.13
Spain	661	1,008	0.13
Ireland	526	880	0.16
Britain (excl. Ireland)	762	2,121	0.32
Other western Europe	650	1,051	0.15
All western Europe	**771**	**1,204**	**0.14**
Brazil	400	646	0.15
Mexico	425	759	0.18
Caribbean	400	636	0.15
Other Latin America	412	683	0.16
U.S. and Canada	400	1,231	0.35
All Americas	**415**	**1,148**	**0.32**
	Less Dynamic Countries and Regions		
	1500	1820	Growth rate
China	600	600	0.00
India	550	533	–0.01
Japan	500	669	0.09
Other Asia	565	584	0.01
All Asia	**568**	**581**	**0.01**
Russian Empire	**499**	**688**	**0.10**
Eastern Europe	**496**	**683**	**0.10**
Egypt	475	475	0.00
Other north Africa	430	430	0.00
Black Africa	405	415	0.01
All Africa	**414**	**420**	**0.00**
Australia and NZ	**400**	**490**	**0.06**
World	**566**	**667**	**0.05**

Source: Maddison (2001), Appendix B, and Maddison (2003a), pp. 242–63.

in this period per capita labor inputs rose, and productivity grew more slowly than per capita income. He called this latter phenomenon an "industrious" revolution, in contrast to the long-term trend to reduced working hours in the course of the nineteenth and twentieth centuries.

(b) For the *U.S. and Canada; Australia and New Zealand; Brazil and Mexico*, I adopted what Noel Butlin (1986) called a "multicultural" estimate, making separate estimates for the indigenous population, slaves, and white settlers. For the first two groups I used a stylized per capita income for 1500 of $400 intended to represent an income at near-subsistence level.

(c) for the *Caribbean*, with its highly specialized export economies, I based the estimates on commodity production and exports. For the Americas as a whole, per capita GDP growth was faster than in western Europe.

TABLE 8b

GDP Levels, 1500 and 1820 (billion 1990 G-K $)

	Dynamic Countries and Regions		
	1500	1820	Growth rate
Belgium	1.23	4.53	0.41
France	10.91	35.47	0.37
Germany	8.26	26.82	0.37
Italy	11.55	22.54	0.21
Netherlands	0.72	4.29	0.56
Portugal	0.61	3.04	0.51
Spain	4.50	12.30	0.32
Ireland	0.42	6.23	0.85
Britain (excl. Ireland)	2.39	30.00	0.79
Other western Europe	3.69	14.93	0.44
All western Europe	**44.16**	**160.15**	**0.40**
Brazil	0.40	2.91	0.62
Mexico	3.19	5.00	0.14
Caribbean	0.20	1.86	0.70
Other Latin America	3.50	5.26	0.13
U.S. and Canada	0.90	13.29	0.84
All Americas	**8.19**	**28.31**	**0.39**
	Less Dynamic Countries & Regions		
	1500	1820	Growth rate
China	61.80	228.60	0.41
India	60.50	111.42	0.19
Japan	7.70	20.74	0.31
Other Asia	31.30	52.18	0.16
All Asia	**161.30**	**412.96**	**0.29**
Russian Empire	**8.46**	**37.68**	**0.47**
Eastern Europe	**6.70**	**24.91**	**0.41**
Egypt	1.90	1.99	0.01
Other North Africa	1.85	2.92	0.14
Black Africa	15.53	26.25	0.16
All Africa	**19.28**	**31.16**	**0.15**
Australia and NZ	**0.22**	**0.21**	**–0.01**
World	**248.31**	**695.35**	**0.32**

Source: see Table 8a.

(d) for Africa, there was a sharp division north and south of the Sahara. Egypt's production potential was favored because of the Nile provided a regular and abundant water supply and an easily navigable transport route. The Maghreb had a higher degree of urbanization and literacy, more sophisticated economic and political institutions, and a greater participation in international trade than black Africa. In spite of losses due to the slave trade, demographic expansion was faster in black Africa, because agriculturalists were replacing hunter-gatherers, and had new crops—maize and manioc from the Americas.

(e) For *China, India and Japan*, the estimates are based on production, expenditure patterns, and demographic evidence. Japanese per capita performance was better than Chinese or Indian, but for Asia as a whole, income levels were stagnant. It is clear however, that China had "extensive" growth in this period. It

sustained a large increase in population, without a fall in living standards, and its GDP growth rate was the same as that of western Europe.

China: China had a strong physiocratic bureaucracy which kept printed records on population and agricultural performance back to the ninth century. There is also a great deal of scholarly work which I used in Maddison (1998). This includes Needham (1954–97, 1970) on the development of Chinese technology, Ho (1959) on Chinese demography, the interpretative analysis of Balazs (1931–33), Elvin (1973) on the economic history of the Tang and Sung dynasties, and Perkins (1969) on agricultural development from 1368. Grain output rose about fivefold from 1400 to 1820—in line with population. The cultivated area rose threefold and yields about 80 percent. Ester Boserup (1965) demonstrated that this was achieved by increased labor inputs per capita, and more intensive use of land by double-cropping, improved seeds, fastidious collection and application of manure and the introduction of new crops from the Americas. Rozman's (1973) analysis of the demographic records shows no significant change in the relative size of the urban population over this period. Earlier, it is clear that that China did experience a growth in per capita agricultural output and GDP in the Sung dynasty (960–1280).

India: Maddison (1971) contained an analysis of the social structure and institutions of the Moghul empire and the British raj. For the Moghul period, I relied heavily on the economic survey made by Abul Fazl for the emperor Akbar in the sixteenth century (see Jarrett and Sarkar, 1949). Between 1600 and the 1860s, the quantitative evidence is not so good, but the two leading historians of Moghul India, Irfan Habib and Shireen Moosvi (at Aligarh Muslim University), adduce evidence which led them to conclude, I think rightly, that there was some decline in per capita income after the collapse of the Moghul Empire and the takeover by the East India Company.

Japan modeled its economy, society, literature and institutions on China from the seventh century. The official commitment to catch up with the West started in 1867, but the Chinese model was abandoned in the eighteenth century, at about the time Japan had caught up with China. In 1720 the shogun lifted the ban on European books, and translations of Dutch learning (*rangaku*) had a significant impact in transmitting knowledge of European science and technology (see Maddison, 2001, pp. 204–6, 252–60).

(iii) *The Proximate Causes of Growth in the Merchant Capitalist Epoch*

In analyzing the causes of growth in the merchant capitalist period, it is not possible to present the same kind of growth accounts as in Tables 7a and 7b. However, Boserup (1965) and de Vries (1994) have shown that labor input per head of population increased in this period, instead of declining, as it did later. We also know that there was a big increase in capital formation in shipping, an improvement in human capital and knowledge. It is clear that the process of globalization was very important.

(a) International Trade

Dramatic progress in western shipping and navigation permitted a 20-fold increase in world trade between 1500 and 1820. It brought gains from specializa-

TABLE 9

COMPARATIVE GROWTH IN VOLUME OF WORLD TRADE AND GDP
(ANNUAL AVERAGE COMPOUND GROWTH RATES)

	World Trade	World GDP	Col.1/2
1500–1820	0.96	0.32	3.0
1820–1870	4.18	0.93	4.5
1870–1913	3.40	2.11	1.6
1913–1950	0.90	1.82	0.5
1950–1973	7.88	4.90	1.6
1973–2001	5.22	3.05	1.7
1820–2001	3.93	2.22	1.8

Source: Maddison (2004b), p. 45.

tion of the type stressed by Adam Smith. It provided European consumers with new products—tea, coffee, cacao, sugar, potatoes, tobacco, porcelain, silk and cotton textiles. In relative terms this globalization process was a more important component of growth in these centuries than in the twentieth. European countries were also able to extract a colonial surplus: the Spanish and Portuguese from the Americas in the sixteenth century, the Dutch in Asia from 1600, the British and French in the eighteenth century. Spanish plunder was mainly in the form of precious metals. These were very important in financing European trade with Asians, who were not interested in buying European products. Most of the European trading nations profited from the enslavement of Africans.

(b) Ecological, Technical and Demographic Transformation of the Americas

Agricultural potential in the Americas was increased by introduction of wheat, rice, sugar, coffee, vines, olives, onions, cabbages, lettuce, oranges, bananas, yams, cattle, pigs, chickens, sheep, goats. Traction and transport was improved by the introduction of horses, oxen, asses and mules. Production potential was increased by the introduction of iron weapons, tools and ploughs, wheeled vehicles, ships and shipbuilding, printing, literacy, education, political and economic institutions; European mining technology led to production and export of 1,700 tons of gold and 73,000 tons of silver in 1500–1820 which financed European trade with Asia.

The introduction of European diseases had a major adverse effect. It killed off two-thirds of the indigenous inhabitants. The continent was repopulated by African slaves and European migrants attracted to a continent with much greater land resources per capita. In 1820, 37 percent of the population of the Americas were indigenous or mestizo; 41 percent were white, and 22 percent black or mulatto.

(c) Ecological Gains Emanating from the Americas

The transfer of American crops—maize, manioc, potatoes, sweet potatoes, beans, peanuts, tomatoes, pineapples and cacao—enhanced production potential in Europe, Africa and Asia. The availability of these new crops was a major factor in helping sustain accelerated population growth in all three areas, and their impact was particularly large in China and Africa.

(iv) *Intellectual and Institutional Changes underlying Western Ascension*

Looking beyond the proximate and measurable elements of causality, we can discern four intellectual and institutional changes which were important in Western economic ascension and which had no counterpart elsewhere.

(a) Development of Secular Knowledge and Science

From about 1500 there is evidence of a new awareness of human capacity to transform the forces of nature through rational investigation and experiment. The first European university was created in Bologna in 1080. By 1500 there were 70 such centers of secular learning in Western Europe (see Goodman and Russell, 1991, p. 25). Until the mid-fifteenth century, most of the instruction was oral, and the learning process was similar to that in ancient Greece. Things changed after Gutenberg printed his first book in Mainz in 1455. By 1500, 220 printing presses were in operation throughout Western Europe and had produced eight million books (see Eisenstein, 1993, pp. 13–17). The productivity of universities and their openness to new ideas was greatly enlarged.

Venetian publishers regularly had a print-run of 1,000 copies or more. By the middle of the sixteenth century, they had produced some 20,000 titles, including music scores, maps, books on medical matters, and a flood of new secular learning. Before printing, books were cherished for their artistic or iconic value, and their content mainly reflected the wisdom and dogma of the past. Printing made books much cheaper. Publishers were much more willing to risk dissemination of new ideas and to provide an outlet for new authors. The proportion of the population with access to books was greatly increased, and there was a much greater incentive to acquire literacy. With the exception of China, the European printing revolution had no counterpart in most other parts of the world until the beginning of the nineteenth century. The major difference between Europe and China was the competitive character of European publishing, and the international trade in books.

Fundamental changes in intellectual horizons occurred between the sixteenth and seventeenth centuries, when medieval notions of an earth-centered universe were abandoned. Thanks to the Renaissance, the seventeenth century scientific revolution and the eighteenth century enlightenment, Western elites gradually abandoned superstition, magic, and submission to religious authority. The scientific approach gradually impregnated the educational system. Circumscribed horizons were abandoned. A Promethean quest for progress was unleashed. The impact of science was reinforced by the creation of scientific academies and observatories which inaugurated empirical research and experiment. Systematic recording of experimental results and their diffusion in written form were a key element in their success.

(b) Emergence of an Urban Bourgeoisie and Protection of Property Rights

In the eleventh and twelfth centuries, important urban trading centers emerged in Flanders and Northern Italy with autonomous property rights. This fostered entrepreneurship and abrogated feudal constraints on the purchase and sale of property. Development of accountancy helped make contracts enforceable.

New financial institutions and instruments provided access to credit and insurance, facilitated risk assessment and large scale business organization.

(c) Changes in the Nature of the Family, Marriage and Inheritance

Adoption of Christianity as a state religion in 380 AD led to basic changes in nature of European marriage, inheritance and kinship. The Papacy imposed a pattern which was dramatically different from that prevailing earlier in Greece, Rome and Egypt and later in the Islamic world. Marriage was to be strictly monogamous, with a ban on concubinage, adoption, divorce, remarriage of widows or widowers, consanguineous marriage with siblings, ascendants, descendants, including first, second, and third cousins, or relatives of siblings by marriage. A Papal decision in AD 385 imposed priestly celibacy. The primary intention of the new regime was to channel assets to the church which became a property owner on a huge scale, but it had much wider ramifications. Inheritance limited to close family members and widespread adoption of primogeniture broke down loyalties to clan, tribe or caste, promoted individualism and accumulation, and reinforced the sense of belonging to a nation state (see Goody, 1983; Lal, 2001).

(d) Emergence of a System of Nation States

A fourth distinctive feature was the emergence of a system of nation states in close propinquity, with significant trading relations and relatively easy intellectual interchange in spite of linguistic differences. This benign fragmentation stimulated competition and innovation. Migration to or refuge in a different culture and environment were options open to adventurous and innovative minds. Mercantilist commercial policies of the leading European countries were mutually discriminatory and restrictive, and often led to wars. However, the balance of advantage lay with Europe, if one compares their regime with that of the Ottoman, Moghul or Chinese empires.

4. The Roots of Modernity, "Takeoff" or Long Apprenticeship?

Having considered the quantitative evidence on macroeconomic performance in the epochs of modern economic growth and merchant capitalism, and the differences in the driving forces which determined their growth momentum, it is useful to consider the nature of the transition between merchant capitalism and modern economic growth. There is in fact a sharp divergence of views on the "roots of modernity," which echoes the divergence already noted between the Smithian and Malthusian interpretations of what happened in the merchant capitalist epoch.

(a) *Sudden "Takeoff" . . .*

There is a school of thought which attributes modern economic growth to an "industrial revolution" in Manchester, preceded by centuries of Malthusian stagnation. The metaphor was first popularized by Arnold Toynbee in 1884, and has continuing resonance, e.g. in Rostow's (1960) "take-off," and Mokyr's (2002) history of technology: "most techniques before 1800 emerged as a result of chance

discoveries . . . Before the industrial revolution the economy was subject to negative feed back . . . the best known of these negative feedback mechanisms are Malthusian traps" (pp. 31–2). Nordhaus (1997) and DeLong (1998) overdosing on hedonics, have constructed fairytale scenarios which greatly exaggerate progress since 1800, before which they seem to believe that people lived like cavemen (see Appendix 3). These views are fundamentally wrong.

(b) *. . . or Long Apprenticeship?*

In 1500, Western Europe already had 70 universities. Education and diffusion of knowledge were revolutionized by printing. Venetian publishers regularly had a print-run of 1,000 copies or more. By the mid-16th century, they had produced 20,000 titles, with a flood of new secular learning. Forty years earlier, a scribe would have taken a year to produce one volume.

By the end of the eighteenth century, great progress had been made in the design of ships and rigging, in gunnery, in meteorological and astronomical knowledge and in the precision of navigational instruments. Mariners acquired logarithmic tables, sextants, naval almanacs and accurate watches. Maps were enormously improved and supplemented by detailed coastal surveys, knowledge of winds and currents. Sailing had become safer, the duration of voyages more predictable, the incidence of shipwreck had fallen, disease mortality was greatly reduced on long voyages.

These changes were the result of scientific endeavor. In 1543 Copernicus rejected the notion that the earth was the centre of the universe. Kepler and Galileo made detailed observation of celestial bodies, the nature and mutability of their orbits. Newton in 1687 showed that the whole universe was subject to the laws of motion and gravitation. Progress in astronomy and physics was accompanied by major advances in mathematics and design of telescopes, microscopes, micrometers, thermometers, barometers, air pumps, clocks and watches and the steam engine.

These developments in Europe were an essential prelude to the much faster economic development that occurred in the 19th and 20th centuries. They had no counterpart elsewhere.

Appendix 1: Real Wage Revivalists—Robert Allen and Jan Luiten van Zanden

In an extensive review of Maddison (2001), Giovanni Federico (2002) suggested that I may have exaggerated West European performance in the merchant capitalist epoch, citing alternative estimates of Robert Allen which imply that aggregate West European income per capita actually fell in this period, and those of Jan Luiten van Zanden which imply a growth rate of only 0.06 percent a year. I do not regard their gloomier conclusions as an effective challenge to my estimates for the reasons explained below.

Allen (2001) presents real wage estimates for Europe, 1500–1913. He shows nominal wages (in grams of silver per day) for building craftsmen and laborers in 18 European towns, and consumer price indices based on 12 items, two-thirds of

which were bread, beer and meat. The results are presented for fifty-year time segments. His basic data are for daily wages, which he converts to an annual basis by assuming a working year of 250 days (this multiplier was apparently applied uniformly to his inter-temporal and cross-country data). For the 14 towns where he has results for craftsmen for both 1500–49 and 1750–99, the average real wage in the latter period was 66 percent of that in 1500–49, London was the only case where the real wage was higher, with a rise of less than 1 percent. In the 12 towns for which he had results for building laborers for the two periods, there was a rise of about 3 percent in Amsterdam and a fall everywhere else. The average real wage for laborers was 76 percent of the 1500–49 level in the end period (p. 428). This is less gloomy than Phelps Brown, but the clear implication is that living standards in western Europe declined substantially from 1500 to 1800. Allen (2000) was "an exercise in historical reconstruction based on simple economic theory" which presented estimates of the movement in agricultural output per capita for nine countries for 1500–1800. He shows a fall in all nine countries between these two points of time, and in most cases they are very substantial. For England, he shows a 32 percent drop (see p. 19). This is very different from Wrigley's estimate that English agricultural output per capita doubled in the shorter period 1600 to 1800. It also differs substantially from the estimates presented by van Zanden and Horlings (1999, p. 28). Allen does not measure agricultural output directly. He derives it econometrically from his estimates of occupational structure and the assumption that his real wage measures are a valid proxy for total output per capita.

Van Zanden (2002) presents estimates of real GDP for five countries which imply that, from 1500 to 1820, average West European per capita income grew less than half as fast as I estimated in Maddison (2003a). Table A1 compares his estimates with mine.

For the U.K., he shows slightly slower growth, because he uses a different source for agriculture. We both agree that growth was most rapid in the U.K., and

TABLE A1

CONFRONTATION OF MADDISON AND VAN ZANDEN PER CAPITA GDP ESTIMATES FOR FIVE EUROPEAN COUNTRIES, 1500–1820

	Maddison		Van Zanden	
	1500	1820	1500	1820
Belgium	875	1,319	989	1,319
Italy	1,100	1,117	1,353	1,117
Netherlands	761	1,838	1,252	1,838
U.K.	714	1,706	792	1,706
Spain	661	1,008	946	1,008
Average	882	1,345	1,116	1,345

Source: Cols. 1, 2 and 4 from Maddison (2003a), p. 262. Col. 3 derived from growth rates implicit in the index numbers of Van Zanden (2002), p. 76. Van Zanden presented his estimates as ratios to the U.K. per capita GDP level in 1820 as estimated by Maddison. For Spain I assumed van Zanden's 1580–1820 growth rate also applied for 1500–1820. The bottom row is a weighted average for the five countries. For 1500–1820, my average grew by 0.132 percent per annum, van Zanden's by 0.058 percent.

I see no reason to modify my estimate. For the Netherlands, our estimates are quite similar for 1570 onwards. the main difference is that he assumes Dutch per capita income to have been stagnant from 1500 to 1570, whereas I assume a substantial increase. Between 1470 and 1570 the Dutch merchant fleet increased nearly fourfold—a growth rate of 1.4 percent a year (see Maddison, 2001, p. 77), and urbanization was increasing substantially.

Van Zanden agrees with me that Dutch per capita income in 1500 was lower than in what is now Belgium. Nevertheless his estimates show the opposite situation in 1500. To mitigate this he adjusted the Blomme–van der Wee (1994) growth rate for Belgium downward, whereas I accepted it. Van Zanden and I agree that Italy was the highest income country in 1500, but he assumes an 18 percent fall in per capita GDP from 1500 to 1820, whereas I assumed stagnation. He quotes Malanima's (1994) estimate for northern Italy as his source. In fact, Malanima (1994 and 1995) suggested a fall of 7 percent, but van Zanden's estimate is near that of Malanima (2003), and shows a fall of about a fifth. The evidence for Italy as a whole is not very good and there are two schools of thought on performance in this period. Malanima's judgment resembles that of Cipolla (1976), whereas Rapp (1976) and Sella (1979) argued that per capita income was stagnant from 1500 to 1820. I lean towards their judgment, but as the urbanization rate was slightly higher in 1800 than in 1500, I assumed a very slight rise. For Spain, van Zanden shows a growth rate of 0.02 percent a year for 1570–1820, which he derives by modifying the estimate of Yun (1994) for Castile, 1580–1800. In fact, Yun's estimate (p. 105) shows growth twice as fast as this. In Maddison (2001, p. 249), I explained my reasons for modifying Yun's estimate, which omits the years 1500–80 when Spain's economy received a major boost from the conquest of the Americas.

Van Zanden (1999) presented real wage estimates for unskilled building laborers in 14 European cities/regions, using cereal prices (rye or wheat) as a deflator. He shows a fall in all the 10 cases where he had estimates for 1500–20 and 1780–1800, the average for the latter period was 60 percent of that in 1500–20, an annual average change of –0.17 percent a year. This is more pessimistic than the Allen (2001) results for laborers, but is similar to the findings of Phelps Brown and Hopkins (1956, pp. 29–30) for English building craftsmen for the same period. Van Zanden feels that real wage estimates are "an important source of information on living standards" (p. 178), even though they are in sharp conflict with a large body of other evidence. He suggests that a reconciliation may be possible. His estimates are for daily wages, and he suggests that there may have been a substantial increase in average annual working time of laborers over the period covered and that their family income may have been supplemented by increased labor force activity of women and children. It seems likely that there were changes in this direction as indicated in de Vries (1993), but van Zanden does not attempt to quantify them, and it is highly doubtful that their effect would be big enough to achieve a reconciliation. Van Zanden's desire for reconciliation may have introduced a downward bias in his (2002) estimates of real per capita GDP for 1500–1820.

The founder of real wage analysis, Thorold Rogers (1823–90), was professor of economics in Oxford and a liberal member of parliament who argued that the condition of English wage earners could be improved by extending the franchise and encouraging trade union activity. For him, low wages were the result of

exploitation of the laborer by the ruling elite. He made a sharp distinction between wage income and national income, as is clear from his citation of Gregory King's estimates of inequality in 1688 (Rogers, 1884, pp. 463–5). He summarized his position, saying (p. 355): "society may make noticeable progress in wealth, and wages remain low . . . relatively speaking, the working man of today is not so well off as he was in the fifteenth century."

Some of the real wage revivalists have forgotten this and use real wages for a small group of workers as a proxy for GDP per head, without considering their representativity in macroeconomic analysis. Lindert and Williamson (1982, p. 393) show that only 5.3 percent of families derived their livelihood from the building trades in 1688. In the Phelps Brown–Hopkins study, whose sources were meticulously documented, there were about three wage quotations a year for building laborers, and for 1500 to 1800 there were 82 years without an estimate. The real wage enthusiasts do not discuss changes in the nature of building work. Over such a long period there were big changes for those whose wages are recorded, with a shift from decorative ecclesiastical stonework to bricklaying.

Appendix 2: Joel Mokyr and the "Industrial Revolution"

The most recent and sophisticated devotee of the "industrial revolution" metaphor is Joel Mokyr (2002) who considers that modern economic growth derived from a sudden leap in industrial technology. He provides a detailed, erudite, illuminating but complex history of the interaction of "propositional" and "prescriptive" (useful) knowledge since the mid-eighteenth century, with a more cursory acknowledgement of what happened earlier. He suggests (pp. 31–2) that "most techniques before 1800 emerged as a result of chance discoveries, trial and error." He makes a grudging acknowledgement of the importance of printing (p. 8), and only a fleeting reference to advances in shipping and navigation technology but is dismissive about their impact: "those earlier mini-industrial revolutions had always petered out before their effects could launch the economies into sustainable growth. Before the Industrial Revolution, the economy was subject to negative feedback; each episode of growth ran into some obstruction or resistance that put an end to it . . . The best known of these negative feedback mechanisms are Malthusian traps, in which rising income creates population growth and pressure on fixed natural resources" (p. 31). He is very insistent on the narrowness of the "epistemic base" before 1800, and argues that positive feedbacks between the two types of knowledge have increased hugely in the course of three "industrial revolutions" since the eighteenth century. There has been a cascading interaction (p. 100) and we have now arrived at a point where modern information technology has produced "an immensely powerful positive feedback effect from prescriptive to propositional knowledge" (p. 115). His analysis of the economic impact of this new knowledge is based on assertions rather than quantitative evidence. They are presented with characteristic fervor, e.g. his assessment of the impact of his second "industrial revolution": "The pivotal breakthrough in the propositional knowledge set was the identification of the structure of the benzene molecule by the German chemist August von Kekulé in 1865 . . . the discovery of the chemical structure is a paradigmatic example of a broadening of the epistemic base of

an existing technique" (p. 85). My problem with Mokyr's analysis is with his judgment on the impact of science and not with his model which can be useful in explaining why the scientific revolution of the 17th century had a delayed payoff, and why the innovative impact of science and technology accelerated in the past two centuries. The problem is that he assumes no net improvement in living standards before 1800, and a constantly accelerating cornucopia since then. This contradicts the quantitative findings of historical national accounts in the Kuznetsian tradition for the period before and after 1800. Mokyr is of course aware of this. In his defense (pp. 116–17) he suggests that "aggregate output figures and their analysis in terms of productivity growth may be of limited use in understanding economic growth over long periods. The full economic impact of some of the most significant inventions over the past two centuries would be entirely missed in that way." Instead he opts for the Silicon Valley serendipity of DeLong (see Appendix 3).

Appendix 3: Hallucigenic History (Nordhaus and DeLong)

Nordhaus (1997) was an ambitious attempt to measure long-term changes in the price of light using the hedonic approach. He estimated that the "true," i.e. hedonic price of artificial light *fell* by 4.2 percent a year (about 3,450-fold) between 1800 and 1992 in the U.S., whereas the annual *rise*, using the conventional consumer price approach, was 1.2 percent a year. He neglects the fact that the supply of daylight did not change between 1800 and 1992. If had assessed the degree to which natural light had been augmented, the impact of artificial light would seem a good deal more modest. At the beginning of his analysis, he says that "unobstructed daylight provides about 10,000 lux, while the level of illuminance of an ordinary home is about one hundred lux. In the candle age, a room lit by two candles would enjoy about 5 lux" (p. 31). Thus there was a 20-fold increase in artificial light per house, but daylight had been augmented only 1 percent since 1800! The augmentation of moonlight and the invention of spectacles were obviously more significant but are not described.

He illustrates the implications of his approach in measuring real wages. The conventional measure showed a 13-fold increase between 1800 and 1992. The "true" rise, he suggests, was between 40- and 190-fold. He derived this result by converting conventional price indices into hedonics for three economic sectors. For "run-of-the-mill" activities, where the characteristics of goods and services have changed relatively little, he adjusted conventional price indices downward to eliminate "bias"—assumed to be 0.5 percent a year. For "seismic" sectors where the goods and services of 1800 have changed, but are still recognizable, conventional price indices received a downward adjustment equal to half of his measure of bias for light. For "tectonic" sectors, where the nature of the good or service has changed drastically, or did not exist in 1800, he applied his bias adjustment for light. He assumed that 75 percent of goods and services were in the first category in 1800, and that this proportion fell to 28 percent in 1992, when 36 percent were seismic and 37 percent tectonic. I estimate that U.S. per capita GDP rose 21-fold from $1,087 in 1800 to $23,169 in 1992. An increase of 190-fold would mean an 1800 level of $122 which would be well below subsistence.

Taking his cue from Nordhaus, DeLong (1998) rather cavalierly suggested that my estimate of the rise in world GDP per capita involved massive understatement because of uncaptured quality improvements (which he does not specify). To correct the alleged mismeasurement he assigned "somewhat arbitrarily . . . an additional fourfold multiplication to output per capita since 1800." He shows a 35-fold increase in world GDP per capita from 1800 to 2000, against my 9-fold increase.

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