The Beginnings of Modern Growth in Europe: An Essay in Synthesis
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The Beginnings of Modern Growth in Europe: An Essay in Synthesis

I

THIS article is an essay in both historical synthesis and in the theory of growth. It seeks to explain the process at work in Europe which led up to the surge of British industrial expansion at the end of the eighteenth century as the result of three distinct, partially related, converging forces: public policies induced by the endemic international struggle for power; the expansion of international commerce and of the world trading area; and the complex impact of the scientific revolution. This historical view is then related to the concept of the preconditions for take-off and take-off, as well as to the case of increasing returns.

The elements in this analysis are, of course, familiar; but some obscurity still surrounds the manner in which the commercial revolution and the scientific revolution related to each other and to the industrial revolution. There is also some ambiguity about why Britain and not France was the first nation to move into take-off. The approach used here may, to a degree, help clarify these matters.

II

To begin, it is worth recalling that what we would now call political and economic modernization had often occurred in the ancient world and in later traditional empires under converging pressure from two of the three key variables examined here; that is, from their military requirements and the expansion of international trade. The dynamics of these systems evokes much familiar in the early modern history of Europe.[1]

In the preparation of this article I benefited greatly from exchanges with François Crouzet, David Kendrick, and M. M. Postan. The article reflects work going forward on a study of the world economy since the eighteenth century which has received support from the National Endowment for the Humanities.

[1] S. N. Eisenstadt has usefully summarized a great deal of historical data—mainly political, but some economic—in support of this proposition in his *The Political Systems of Empires* (New York: The Free Press, 1969, 1963, paperback edition with additional preface). I deal briefly with the economics of such systems in *Politics and the Stages of Growth* (Cambridge: Cambridge University Press, 1971), Chapter 2.

One can observe an endless struggle of the rulers to build and maintain unity, an ambivalent relation to the nobility, needed for fighting and tax collection but potential competitors for domestic power, the creation of large bureaucracies for the conduct of war, the building of roads, the maintenance of irrigation works (notably in China), and, above all, the mobilization of resources and men for military purposes. One can also observe periods of expansion in domestic and international commerce, accompanied by the growth of cities, the development of sophisticated banking and trading arrangements, an increase in handicraft manufactures not only to meet the luxury demands of the rich but to process the commodities drawn from abroad. And, as later, war and commerce were related. In some cases (for example, fifth century B.C. Athens) the rulers were governed by the equivalent of Josiah Child's dictum, which Charles Wilson has impressed on us all: "Profit and Power ought jointly to be considered."[2] In other cases (for example, classical China), the central bureaucracy's obsessive interest in revenue may have weighed excessively on commercial life,[3] although the conventional view of the merchant as "a despised profession" in Chinese (and Indian) society has, apparently, been overdone.[4]

The central fact about these traditional empires is that they were not capable of generating sustained growth. Their periods of expansion gave way to periods of decline.[5] The most typical proximate cause of decline was war. While the possibility of war and, sometimes, limited military engagement encouraged policies which tended to modernize the society, large and protracted wars led the rulers to grasp for more resources than the society could generate, and self-reinforcing processes of economic, social, and political decline ensued. The rapid decline of Athens in the fifth century B.C.

2 Quoted, Charles Wilson, *Profit and Power: A Study of England and the Dutch Wars* (London: Longmans, Green and Co., 1957), p. 1.

3 See, for example, Eisenstadt, *The Political Systems*, p. 43.

4 See, notably, Dwight H. Perkins, "Government as an Obstacle to Industrialization: The Case of Nineteenth Century China," JOURNAL OF ECONOMIC HISTORY, XXVII (Dec. 1967), 478-492. A similar conventional view of the limited power and influence of the Indian merchant has also been challenged. See, for example, Brij Narain, *Indian Economic Life* (Lahore: Uttar Chand Kapur & Sons, 1929), Chapters III and IV; also, M. N. Pearson, "Merchants and Rulers in Mughal India," and Howard Spodek, "Rulers, Merchants and Other Elites in the City-States of Saurashtra, India," papers delivered at the Association of Asian Studies 25th Annual Meeting, Chicago, Illinois, March 30-April 1, 1973 (mimeographed).

5 The inherently cyclical character of what I call pre-Newtonian societies is analyzed at some length in the author's *Politics and the Stages of Growth* Chapter 2.

and the slow grinding decline of the Roman Empire in the West are, of course, classic examples of this process. It can be seen also at work in the fall of some of the Chinese dynasties and elsewhere.

But protracted peace and prosperity could also put such societies under strain. As China's predecessor of Malthus, Hung Liang-chi concluded: ". . . during a long reign of peace Heaven and Earth could not but propagate the human race, yet their resources that can be used to the support of mankind are limited. During a long reign of peace the government could not prevent the people from multiplying themselves, yet its remedies are few."[6] Both Ch'ing China and Tokugawa Japan ultimately came under this kind of Malthusian pressure, as did, earlier, England in the Later Middle Ages.[7]

Declines induced by the excessive claims of war or by population pressure had the same root: the traditional societies did not generate inventions and innovations as a regular flow into the economy. Therefore, they ultimately strained and broke against a technological ceiling that set limits on the inputs of men and resources governments could generate for war or on the population that the land could support. Neither extensive wide-ranging commerce, highly sophisticated handicraft manufacture, virtuosity in civil engineering (roads, irrigation, and construction), a lively urban life, nor large and sometimes competent and dedicated bureaucracies could lift these economies into take-off. Rostovtzeff's ultimate questions about the Roman Empire could be asked of a good many others which experienced golden years of expansion and prosperity: "The problem remains. Why was the victorious advance of capitalism stopped? Why was machinery not invented? Why were the business systems not perfected? Why were the primal forces of primitive economy not overcome? They were gradually disappearing; why did they not disappear completely?"[8]

A rich body of scientific insights and observations were generated in the ancient Mediterranean world, India, and China. Important inventions were made (for example, the compass, gunpowder, and printing), and some of them found their way from time to time into the economy on an *ad hoc* basis. For the purposes of this essay it is

[6] Quoted, *ibid.*, p. 49.

[7] M. M. Postan, "Some Economic Evidence of Declining Population in the Later Middle Ages," *Economic History Review, II* (1950), 221-246.

[8] M. Rostovtzeff, *The Social and Economic History of the Roman Empire* (2nd ed., Oxford: Oxford University Press, 1957), Vol. I, p. 2.

not necessary to establish precisely what it was about these vital traditional societies that yielded this limited and sporadic result. It is sufficient to note that only during the eighteenth century did invention and innovation in the West begin to assume the character of a more or less regular flow and to try to establish how this came about.

It is still not certain that man can engineer in the future a reasonably stable relation between himself and his environment and avoid yet another grandiose cycle in his affairs. But it is clear that the technological breakthrough of the late eighteenth century was unique.

III

The breakthrough that occurred after 1783 arose, however, from a setting which in several respects was not unique. For more than two centuries European life had been marked by a new version of the old struggle of the empires to consolidate their unity and deal with their neighbors in an environment of endemic fear, ambition, and military hostilities. Struggles for territory and trade and over religion interwove in complex patterns. In the short run, wars were costly. The stimulus afforded by the increased demand for cannon and uniforms, ammunition and ships, was clearly outweighed by the depressing effect of war on foreign trade and construction, and on the king's revenues. Despite the rising trend in British foreign trade in the eighteenth century, the four major wars before 1783 cut the volume of total trade by about five percent as compared with prewar levels.[9] In the first five postwar years, the foreign trade level rose some thirteen percent above the prewar average. British timber imports, a fair reflection of construction, fell about twelve percent during the war years and rose about eight percent over prewar levels in the first five postwar years. With respect to industrial production as a whole, the apparent effect of war was deceleration rather than absolute decline. Hoffmann's overall index rises during the war years an average of four percent relative to prewar figures; the first five postwar years saw an average surge of nineteen percent over prewar levels. As compared with the more brutal struggles of the seventeenth century, touched by religious passions, those of the eighteenth century were more limited in objective and liability.

[9] For relevant data, see Appendix.

Nevertheless, Britain had more than 100,000 men under arms for thirty-nine years during the century. Armed forces of similar or larger size were mobilized for long periods and fought for the rulers of France, Prussia, Austria, Spain, and Russia. Whatever the cost of manpower diversion and loss at a time when the traditional view would regard the military as the dregs of the working force, the financial burden was heavy. In Britain, peak wartime expenditures ran about three times prewar normal levels, and apparently ranged somewhere between fifteen percent and twenty-five percent of GNP.[10] By 1782, Britain had accumulated a public debt larger than its GNP—£220 million versus an estimated GNP of, say, £150

[10] For purposes of rough calculation, I used the total net public expenditure figures provided by B. R. Mitchell with the collaboration of Phyllis Deane in *Abstract of British Historical Statistics* (Cambridge: Cambridge University Press, 1962), pp. 389-391, and extrapolations from the national income estimates of Gregory King (1688), Joseph Massie (1759-60), and Arthur Young (1770). The outcome, to be used for only the crudest purposes of approximation, is as follows:

	Peak Year	*Total Net Public Expenditure* (1) (*in £ millions*)	*Approximate GNP* (2)	*Col. 1 / Col. 2*
War of Spanish Succession	1711	15	60	25%
War of Austrian Succession	1749	12.5	84	15
Seven Years' War	1761	21	106	20
War of American Independence	1782	29	150	20

Jan Marczewski's data on French central government expenditure in relation to gross physical product (at current prices) fall in the same range. See "Some Aspects of the Economic Growth of France, 1660-1958" in *Economic Development and Cultural Change*, IX (April 1961), p. 372.

	Central Government Expenditure (1)	*Gross Physical Product* (2)	*Col. 1 / Col. 2*
1701-10	200	1485	13%
1758	237	(2350)	(10%)
1774	400	(3300)	(12%)
1777-9	613	(3500)	(17%)

( ) indicates interpolated estimates.
(Annual Averages in Millions of Francs at Current Prices)

French GNP per capita, in a less urbanized society, was probably 20 percent below that of Britain down to the 1780's, when the gap widened. On the other hand, French GNP was absolutely much larger, given the difference in population between the two countries of about three to one, for most of the eighteenth century. The absolute levels of French expenditures were, therefore, much larger than those for Britain, despite the lower proportion they bear to national product.

million—while the French debt figure was of the same order (£215 million).[11] In Britain this kind of burden was mitigated by a banking and credit system (including foreign borrowing) which permitted annual interest charges as low as three percent. In France, the interest burden, about twice as high, finally helped detonate a revolution. In Russia, where the burden of the state's military and other efforts came directly to bear on the bodies and diet of the serfs, as well as on any source of taxation that ingenious men could perceive, a generation of fighting and striving under Peter the Great left the people, in Kliuchevskii's phrase, "leaner and leaner."[12]

But Kliuchevskii also noted, "the State grew fatter and fatter."[13] The enlarged states of the mercantilist era set in motion policies which, on balance, helped create the setting from which modern industrial growth emerged.

Mercantilist policies and imperatives directly encouraged the two processes examined later in this essay; that is, the expansion of international trade and the enlargement of efforts in science and invention. Putting aside for a moment these two areas, the headings of mercantilist policy emerge as a package rather typical of modernizing activities in a pre-industrial society: improvements in internal communications, tending to unify and lower costs within domestic markets; the direct and indirect encouragement and protection of handicraft industry and mining; special efforts to achieve an autonomous economic base for the armed forces (guns, explosives, uniforms, ships, and so on); measures to assure an adequate supply of food, including assurance of the agrarian labor supply; measures to expand the supply of public revenues, including, in the English and Swedish cases, the emergence of an effective central bank; and measures to improve the quality of public administration.

[11] J. F. Bosher, *French Finances, 1770-1795* (Cambridge: Cambridge University Press, 1970), pp. 23-24.

[12] Quoted, Alexander Gerschenkron, *Europe in the Russian Mirror* (Cambridge: Cambridge University Press, 1970), p. 85. Kliuchevskii's phrase refers to Russia in the seventeenth century, under pressure from Peter's predecessors. Gerschenkron notes it as a peculiarly apt evocation of the impact of Peter's reign. For an explanation of the emergence of substantial nation states in response to the changing technology and economic exigencies of war, see Richard Bean, "War and the Birth of the Nation State," JOURNAL OF ECONOMIC HISTORY, XXXIII (March 1973), 203-221, and subsequent discussion.

[13] The long run calculus for policies conditioned by war and the possibility of war is, of course, quite different from the short run. For an analysis, based on this distinction examining the impact of Britain's wars from the thirteenth to the twentieth centuries, see the author's "War and Economic Change: The British Experience," Chapter VII in *The Process of Economic Growth* (2nd ed., Oxford: Clarendon Press, 1960), pp. 154 ff.

To set out these bare headings immediately raises the need for a host of qualifications. For example, the degree to which domestic markets were actually unified varied greatly among the states of Europe, as did the nature and efficiency of policies of control over industry and mining, tax policies, and the size and competence of central bureaucracies. Excepting the colonization of new areas, notably in parts of Germany and Russia, the encouragement of agriculture by public policy was generally feeble, although new crops from America had their impact in Europe as in China and there was a good deal of private innovation in Western European agriculture. Moreover, mercantilist policies not only varied among the European states but changed with the passage of time. Finally, as we are all brought up to believe, some mercantilist policies, however understandable their initial rationale, obstructed the process of economic development viewed over a substantial period of time.

But the fact remains that an important array of initiatives was undertaken by the states of Europe, primarily to expand the revenues in the monarchs' hands and otherwise to assure their military capacity, which contributed also to the long run modernization of their economies. As Gerschenkron has pointed out, the extent and vigor of the state's role in the mercantilist period, as opposed to changes brought about by the pursuit of private advantage, increases as one moves to the East: from Holland and Britain through France, Prussia and Austria, to the Russia shaped by Peter the Great.[14] Gerschenkron relates the relative weight of the state's hand to the "degree of backwardness" of the economy and the society as a whole. One does, indeed, emerge from a reading of early modern European history with a sense that the exertions of the monarchs in pressing forward measures to strengthen their war potential was inverse to the state of their economic development and, especially, the size of the classes able to carry forward for private advantage what were then modern economic activities.

IV

The relative economic development of the European states and regions was, in turn, roughly related to the level, character, and dynamism of their foreign trade, to whose nurture and protection a great deal of mercantilist policy was directed.

14 Alexander Gerschenkron, *Europe in the Russian Mirror,* especially pp. 86-8.

Foreign trade data for the seventeenth and eighteenth centuries are generally poor, excepting perhaps the British and (to a lesser extent) the French figures for the latter period. Nevertheless, we have available the following somewhat enigmatic table developed by that remarkable statistician, Michael Mulhall.[15] It must, evidently, be used with caution; however his approximations do not grossly violate what we know from other evidence on the changing scale of international trade over these eighty years.

The key characteristics of Mulhall's data appear to be these:

(1) The increase in British trade is typical rather than extraordinary until the take-off in the last twenty years of the century when cotton textile and iron exports (as well as raw cotton imports) radically expanded. The British (and German) trade data are also exaggerated for 1800 by Britain's quasi-monopoly in re-exports from the Western Hemisphere and Hamburg's role as the continent's entrepôt at this stage of the Napoleonic Wars.

(2) The data for northern and central Europe down to 1780 exhibit the economic (as well as military and political) emergence on the scene of Prussia and Russia, and a sharing in the general expansion by Austria, Scandinavia, Holland, Belgium, and Switzerland. The 1800 figures reflect the differential impact on this region of the Napoleonic Wars in their first phase.

(3) Southern Europe was somewhat less dynamic. Italy maintains its modest relative trading position, but Spain, despite its eighteenth-century surge in modernization, loses ground relatively. And, we know, Portugal also loses momentum after 1760.[16]

(4) Spanish America, with its large outflow of bullion, holds a

[15] In the case of Great Britain, Mulhall evidently added imports, British exports, and re-exports (but not specie exports) to derive his figures. Presumably, he followed a similar procedure in the other cases, although precious metals evidently do enter into his calculations for the Spanish colonies, Spain, and Portugal. Where his data can be checked, they are accurate approximations of the best sources available in the late nineteenth century. But they must, of course, be regarded as approximations. The British and French data, for example, accord with the official series, although it may be that the French figure for 1720 is too low; the French value figures must be deflated by about sixty percent over the eighteenth century to match roughly the British official value (volume) data. Moreover, 1780 is an awkward year, involving as it does the damping and distortion of trade caused by the American War of Independence and related conflicts. The British and American figures for 1780 are, in particular, abnormally low.

[16] See, especially, H. E. S. Fisher, "Anglo-Portuguese Trade, 1700-1770," *Economic History Review*, 2nd series, XVI (1963), republished in W. E. Minchinton (ed.), *The Growth of English Overseas Trade* (London: Methuen & Co. Ltd., 1969), especially pp. 158-63.

TABLE 1
APPROXIMATE WORLD TRADE: 1720, 1750, 1780, 1800
(in millions £ sterling)

Country	*1720*	*% World*	*1750*	*% World*	*Increase from 1720*	*1780*	*% World*	*Increase from 1750*	*1800*	*% World*	*Increase from 1780*
Great Britain[a]	13	15	21	15	62%	23	12	10%	67	22	291%
France	7	8	13	9	86	22	12	69	31	10	41
Germany	8	9	15	11	88	20	11	33	36	12	80
Russia	8	9	14	10	75	17	9	21	30	10	76
Austria	2	2	4	3	100	6	3	50	8	3	33
Italy	3	3	5	4	67	7	4	40	10	3	43
Spain	10	11	14	10	40	18	10	29	12	4	−33
Portugal	2	2	3	2	50	4	2	33	4	1	0
Scandinavia	2	2	3	2	50	5	3	67	5	2	0
Holland and Belgium	4	5	6	4	50	8	4	33	15	5	88
Switzerland	1	1	2	1	100	3	2	50	5	2	67
Turkey, etc.	2	2	3	2	50	4	2	33	5	2	25
Total: Europe	62		103		66	137			228		66
Europe as Percent of Total World	70		74			74			75		
United States						3	2		17	6	567
Spanish America	10	11	15	11	50	20	11	33	25	8	25
British Colonies	2	2	3	2	50	1	.5	−67	2	1	100
India	9	10	9	6	0	10	5	11	10	3	0
Various	5	6	10	7	100	15	8	50	20	7	33
Total: Outside Europe	26		37		42	49		32	74		51
Total: World	88		140		59	186		33	302		62

[a] Due to rounding, percentage figures do not always add up to 100.

Source: *The Dictionary of Statistics* (London: George Routledge and Sons, Limited, 1892), p. 128.

substantial place in world trade, down to the last twenty years of the century, continuing to lubricate not only northern European commerce with Spain but also European trade with India and even China.

(5) Although Mulhall only isolates the trade of the United States after 1780, the eighteenth-century expansion of commerce in the colonies was almost as astonishing as their twenty-one-fold population increase. Exports to Great Britain increased 6.6 times from the first to the seventh decade of the century.[17] British trade was about sixty percent of the total for the colonies before the War of Independence.

The economic meaning of foreign trade as it bore on the wider process of modernization going forward in the eighteenth century depended, of course, not merely on its scale but on its content. It was one thing to export, say, slaves or bullion; it was quite another matter to export tobacco or sugar, which required the development of plantations at one end, processing at the other; and it was still another matter to export iron, textiles, or manufactured metal products, involving as they did a substantial industrial sector. And so, also, with imports, which might merely enrich the fare or dress of a comfortable nobility or gentry, or supply a critical raw material for industry, or open up, as did Indian textiles, the possibility of a mass market.

In short, one cannot regard the commercial revolution of the seventeenth and eighteenth centuries as an undifferentiated Smithian expansion of the market. One must try to specify its impact. It had two major direct consequences and, converging with other influences at work, contributed to a third.

First, a whole range of activities connected with trade increased: commerce itself, and banking, as well as the size of coastal towns and the intensity of internal trade, notably to distribute the enlarged flow of American and Asian commodities.

Second, enlarged trade brought with it certain kinds of increased manufacturing or processing activity. Crouzet summarizes well this kind of linkage in eighteenth-century France:

> . . . the eighteenth-century European economy was organized around a number of big seaports, the most prosperous being those with the largest share

[17] Emory R. Johnson, *et al., History of Domestic and Foreign Commerce of the United States* (published by the Carnegie Institution of Washington, D.C., 1915), Vol. I, p. 89, Table 3.

in the growing colonial trade, such as Bordeaux or Nantes; each of these had, not only its own industries, but also its industrial hinterland in the river basin of which it was the outlet. For instance, Bordeaux had shipbuilding yards, sugar refineries, distilleries, tobacco factories, and glassworks, while along the Garonne and its tributaries were to be found industries such as sail and rope making, foundries making guns for West Indiamen and boilers for sugar mills, manufactures of linens for slaves and woolens for planters, as well as cornmills producing fine flour for export to the West Indies. The seaboard provinces of France were undoubtedly the most industrialized in the eighteenth century, but the influence of the great seaports penetrated far into the interior; for instance, Pierre Léon has shown how much the industries of a landlocked province such as Dauphine were also interested in the West India trade.[18]

Similar processes of trade-related industrial expansion can be traced in Holland, Spain, and some of the North German ports, as well as in Britain.

The multiplier effects of the expansion of foreign trade are, of course, hard to measure. In Britain it clearly contributed to the relative expansion of the population living in concentrations of 5,000 and over from a maximum of thirteen percent at the beginning of the eighteenth century to, say, sixteen percent at mid-century, and twenty-five percent by 1801.[19] The continental figures were clearly lower, but there was almost certainly a relative as well as absolute rise in their urban populations since (with the exception of Spain during the Napoleonic Wars) foreign trade per capita increased, as roughly measured in Table 2.[20]

As noted earlier, there was nothing historically unique about this kind of expansion in trade, increase in urbanization, stimulus to commerce-related institutions, and growth in handicraft processing

[18] François Crouzet, "Wars, Blockade, and Economic Change in Europe, 1792-1815," JOURNAL OF ECONOMIC HISTORY, XXIV (Dec. 1964), 568-9.

[19] Phyllis Deane and W. A. Cole, *British Economic Growth, 1688-1959* (Cambridge: Cambridge University Press, 1969), p. 7. The basis for these calculations is not clear from the text, but they appear to derive from estimates of population increase in the major cities and towns.

[20] J. -C. Toutain, for example, has re-examined the rather unsatisfactory French data on rural-urban population in the eighteenth century ("La population de la France de 1700 à 1959," *Cahiers de L'Institut de Science Économique Appliquée*, Suppl. No. 133, January 1963, pp. 48-57). He accepts the traditional measurement for urban population as those living in concentrations of 2,000 or over. His figures (Table 15, pp. 54-5) show a rise in the following ranges for the urban population during the eighteenth century: 1700, 2.9-3.3 million or 15-17 percent; 1801, 4.5-6.4 million or 16-23 percent. I have arbitrarily taken the higher figure in both cases. If the English and Welsh figure for urban population were calculated also on the basis of communities larger than 2,000, it would approximate 40 percent for 1801, according to the data of R. Price Williams, "On the Increase of Population in England and Wales," *Journal of Statistical Society*, XLIII (1880), 466-467.

TABLE 2
FOREIGN TRADE PER CAPITA, 1720, 1750, 1800
(in £ sterling)

	1720	*1750*	*1800*
Great Britain	1.9	2.8	6.2
United States	—	2.4 (1769)	3.2
Holland and Belgium	1.3	1.7	3.2
Germany	.7	1.1	2.0
Portugal	1.0	1.1	1.2
Spain	1.3	1.6	1.1
France	.3	.5	1.1
Russia	.6	.7	1.0
Italy	.3	.4	.6

Sources: The trade figures are from Michael Mulhall (*Dictionary*) (see Table 1, above); the European population figures are drawn from H. J. Habakkuk, "Population, Commerce and Economic Ideas," Chapter II in Vol. VIII of *The New Cambridge Modern History: The American and French Revolutions, 1763-93* (Cambridge: Cambridge University Press, 1965), pp. 714-5; and K. F. W. Dieterici, "Uber die Vermehrung der Bevolkerung in Europa seit dem Ende oder der Mitte des siebenzehnten Jahrhunderts," published in *Abhandlungen der k. Akademie der Wissenschaften,* Berlin, 1850, pp. 73-115. The 1720 population figure for Russia is taken at 14 million (1722) from Alexander Baykov, "The Economic Development of Russia," *The Economic History Review,* 2nd series, VIII (1954), p. 137, reprinted in Barry E. Supple (ed.), *The Experience of Economic Growth* (New York: Random House, 1963), pp. 413 ff. The U.S. figure for 1769 (when trade data are available) is extrapolated from the data in Evarts B. Greene and Virginia D. Harrington, *American Population Before the Federal Census of 1790* (New York: Columbia University Press, 1932), pp. 4 and 5.

and manufactures. The widening of the market carried with it many of what we now call modernizing institutions, activities, and attitudes, but it did not set in motion a self-reinforcing process of industrial invention and innovation. Production was generally by long-familiar methods. There was, roughly speaking, constant returns to scale rather than increasing returns. There was capital widening but not significant capital deepening.[21]

What this lateral expansion did accomplish was an increase in the absolute numbers of people—in Europe and in the North American colonies—pulled out of the agricultural sector into urban life, thus expanding, as considered below, the pool of those likely to respond

[21] The argument here is that Adam Smith's famous perception about the relation between the widening of the market and the division of labor is not a sufficient explanation for technological change. The issue remains important, because Allyn Young perpetuated Smith's incomplete view of technological change in his famous article, "Increasing Returns and Economic Progress," *Economic Journal,* XXXVIII (1928), 527-542, and Nicholas Kaldor has reinforced it forty-four years later ("The Irrelevance of Equilibrium Economics," *Economic Journal,* LXXXII (1972), 1237-1255). For further discussion, see below, pp. 574-578.

to the incentives offered by rising yields from invention and innovation, in the context created by the scientific revolution.

A third aspect of the expansion of foreign trade concerns its more direct linkage to the critical inventions and innovations which arose in Britain from problems in three sectors: how to produce good pig iron cheaply with coke as the fuel; how to make a reasonably efficient steam engine; and how to spin cotton with machinery. The incentives to solve these problems were connected with British foreign trade, but not in the loose sense that the commercial revolution is sometimes linked to the industrial revolution.

British dependence on iron imports (from Sweden, then also Russia and the American colonies) was an embarrassment in a war-like mercantilist age, and iron manufacture faced not merely an expanding domestic demand but an extremely rapid expansion in the demand for hardware from the relatively rich and rapidly expanding population in the North American colonies.

The first major use of the steam engine was to make deeper coal seams accessible by pumping out the water, at a time when increased demand for coke in iron-making contributed something to a domestic coal requirement already expanding in response to rising population and increased urbanization.

Above all, the introduction to the British market during the seventeenth century of Indian calicoes by the East India Company revealed a latent demand that would not be denied. The import-inhibiting legislation of 1700 and 1720 turned out to have the effect of a high protective tariff behind which British inventors and innovators ultimately solved the problem of matching with machinery the deftness of Indian hands in using cotton as warp.[22] By the time that problem was solved, there already existed a substantial industry skilled in dyeing Indian white calicoes and in manufacturing fustians of cotton weft and linen warp. On this foundation, the cot-

[22] See, especially, P. J. Thomas, *Mercantilism and the East India Trade* (London: Frank Cass & Co. Ltd., 1963 edition), for an account of the economic and political debates which marked the struggle to inhibit Indian imports and the loopholes which permitted the cotton textile industry to find its feet in Britain. The famous pamphlet of 1701, *Considerations upon the East India Trade* (probably written by Henry Martyn), had predicted that the East India trade, in products produced by cheap labor, would "be the cause of the inventions of Arts, and Mills, and Engines, to save the Labour of Hands in other Manufactures," even under the free trade conditions he advocated. But the inhibitions imposed on Indian cotton manufactures heightened still further the incentive to learn to produce their equivalent by machine methods.

ton textile industry could move rapidly forward to supply overseas as well as British markets, when the technical breakthroughs were achieved.

Foreign trade played its role in the story of these sectors, but, in each case, it is a quite narrow and specific role. More than the commercial revolution is required to explain the industrial revolution. The great innovative breakthroughs were linked also to the scientific revolution. We turn, therefore, to the knotty question of how science, invention, and innovation were related.

V

The scientific revolution affected both the supply of inventions and the effective demand for them.[23] It had this consequence because it operated in a variety of ways.

1. *The Philosophic Impact*

By embracing a wide range of observed phenomena in a few axiomatic propositions, man was put in a position to understand, to predict, and to manipulate nature. It was no trivial thing for Edmund Halley to proclaim in his prefatory ode to the *Principia*:

> Here ponder too the Laws which God,
> Framing the universe, set not aside
> But made the fixed foundations of His work.

The scientific revolution thus gave man a new sense of confidence that an order of nature was there to be found, and that such knowledge was the key to solving problems and, therefore, shaping, to a degree, his own destiny. This new sense of power—the Faustian outlook, to use David Landes' designation—suffused the literate Western world. Few read Newton's *Principia,* but its triumphant message, popularized by many hands, had the kind of impact that Marx and Freud, Einstein and Keynes were later to enjoy. By changing the way man looked at the world around him, the Newtonian perception increased, in ways impossible to measure, the supply of scientists, the supply of inventors, and the willingness of entrepreneurs to introduce innovations.

[23] A demand-supply approach to fundamental science, invention, and innovation is elaborated in the author's *The Process of Economic Growth,* Chapters II and IV.

2. *Scientists and Tool-Makers*

More narrowly, the experimental method, built into the scientific revolution, directly increased the supply of inventions, through the two-way linkage of scientists and tool-makers. The scientists needed pumps and telescopes, the microscope, the thermometer, the barometer, and accurate clocks. Inventors and others could also use them. As Lilley concludes: ". . . scientists like Gilbert, Guernicke, and Boyle became willing to learn what they could from the craftsmen's apparatus to make scientific instruments."[24] The medieval separation of the man of learning from the craftsman began to disappear. We would have to take this linkage seriously even if we had only the case of the gifted instrument-maker at Glasgow University, but there is more to it than the story of James Watt.

3. *Scientists, Inventors, and Innovators*

Quite aside from the Faustian outlook, the pursuit of principles of maximum generality by the experimental method was understood, from an early stage, to open the way to practical and profitable inventions and innovations. This was, of course, a central theme of Francis Bacon before Newton emerged on the scene; and from Galileo's interest in shipbuilding, mine pumps, and artillery to Newton's fruitless alchemy, some of the scientists interested themselves directly in practical matters. The Baconian linkage of science to material progress was more or less explicit in the founding of the Royal Society (1645-61) and the almost concurrent forming of the French Academy of Sciences. Mercantilist governments came to regard science and invention as a tool capable of increasing the power of the state. And as Ashton and others have demonstrated, there was a web of osmotic ties among scientists, inventors, and innovators, stemming not only from the Royal Society but from the lively provincial societies, in Birmingham and elsewhere.[25] These linkages were probably stronger in eighteenth-century Britain than elsewhere, but they existed to a degree in France and other parts of

[24] Samuel Lilley, "The Development of Scientific Instruments in the Seventeenth Century," Chapter VI in *The History of Science: Origins and Results of the Scientific Revolution: A Symposium* (Glencoe, Illinois: The Free Press, 1951), pp. 74-5. See also Lilley's *Men, Machines and History* (New York: International Publishers, 1966).

[25] See, notably, A. E. Musson and Eric Robinson, *Science and Technology in the Industrial Revolution* (Manchester: Manchester University Press, 1969).

the West, formalized in France by the role of the Academy in sponsoring, approving, or rejecting inventions. The meaning of these osmotic ties is underlined by Postan's observation about science and invention in medieval Europe: "Mediaeval technology and mediaeval science each kept to their carefully circumscribed spheres."[26]

The task of analysis would be simplified if we could demonstrate clear, direct links between new propositions derived from basic science and inventions. But the more we learn of science and invention in the eighteenth century, the less easy it becomes to make that linkage. Evidently, men of different tastes and talents were increasingly drawn to specific fields of science, invention, or, occasionally, to both. Those fields had a life of their own. The stock of knowledge and technology within them built up cumulatively. There is no doubt that contact with science and scientists stimulated the inventors. There is also some evidence that the inventors and inventions stimulated the scientists. But the nearer we come to understanding a particular moment of inventive creativeness, the more elusive the link to scientific propositions becomes. As Charles Gillispie demonstrates, the processes for manufacturing soda in late eighteenth-century France evolved under the supervision of scientists of the French Academy; but:

> Leblanc seems to have found his process, not through some flashing theoretical insight, but by means of a fallacious analogy with the smelting of iron ore. Not only so, but after he worked it out, neither he nor any of the other artisans interested in alkali production made any attempt to investigate or explain the nature of the reactions involved."[27]

Gillispie goes on to develop his general thesis: science and invention are distinct but related activities, the contribution of science being not merely to educate the inventor and entrepreneur about the properties of the physical world but also to introduce them to modes of thought and perception they might not otherwise command. In the eighteenth century at least, Gillispie's insight appears generally valid. The scientific revolution operated obliquely to help generate inventions and stimulate entrepreneurs to adopt them.

The lack of simple, demonstrable linkages between emerging

[26] "Why Was Science Backward in the Middle Ages?" Chapter II in ***The History of Science,*** p. 31.

[27] Charles E. Gillispie, "The Natural History of Industry," *Isis,* XLVIII (1957), 398-407, republished in A. E. Musson (ed.), *Science, Technology and Economic Growth in the Eighteenth Century* (London: Methuen & Co. Ltd., 1972), p. 126.

propositions of science and particular inventions in the eighteenth century by no means reduces, however, the importance of the scientific revolution in the equation that finally yielded the industrial revolution. Taken together as distinct but related activities, science and invention constituted an additional factor of production which, when exploited by innovating entrepreneurs, successfully fended off diminishing returns to other factors of production and the Malthusian spectre for about two centuries. We can regard, then, the pursuit of science and invention as forms of investment by societies or, as knowledge moved more freely across international boundaries, an international society.

Like other forms of investment, they appear to have been subject to certain general patterns which decreed in the modern era phases of increasing and then diminishing returns in particular sectors and relative overall stability in the profit rate, when the quantum of resources applied reached a certain point.[28] There were heroes in this process—breakthroughs associated with individual men of creative genius—but that is also true of sectoral innovation in the economy itself. The business historian has his heroes to place alongside Newton and Watt. But generally, progress in both science and technology was by modest increments, reflecting the work of many hands. In part, therefore, progress was a function of the numbers engaged in these pursuits.

What determined the numbers engaged in invention? The volume of talent and resources devoted by a given society to invention, the sectors on which inventors concentrated, and the expected yields to be derived from invention were not solely a function of what was going on in fundamental science. Forces beyond the scientific revolution itself were also at work in various societies affecting the supply of inventors and innovating entrepreneurs.

Here we confront the problem of the interdependence of demand and supply in the Marshallian long period. A high and increasing demand for invention may not only decree an intersection point further to the right than a low demand, assuming some short-run elasticity of supply[29]; it may also induce in time a shift to the right

[28] For the author's view of the sectoral pattern of investment in modern growing economies, see *The Process of Economic Growth*, especially pp. 96-103, as well as *The Stages of Economic Growth* (2nd ed., Cambridge: Cambridge University Press, 1971), especially pp. ix-xiv; 12-16; 174-6; 184-6.

[29] The sensitivity of the British patent series for the eighteenth century to both wars and cyclical fluctuations tends to confirm that the supply curve of invention

of the supply curve as a whole. In human terms, this interdependence is dramatized by the close connection between key entrepreneurs, anxious to solve production problems, and inventors. The Boulton-Watt relationship is perhaps the most famous team of this type, but it is not unique. Given this interdependence, is there anything meaningful to be said about the supply of inventors more or less independent of the demand for inventions, as decreed by the economic forces at work and the innovating propensity of entrepreneurs in different societies and particular sectors of their economies?

The answer is: something, but only with caution. Inventors (like scientists and creative businessmen) are a distinctive breed. They are, no doubt, moved by monetary rewards and those of prestige. But their creative contriving and tinkering capacity—like other inborn gifts—seeks expression; and inventors evidently derive satisfaction from solving practical problems in new ways, quite aside from the rewards that might await them.[30] As nearly as we know, such talent is distributed at random. The question is: What kind of circumstance (aside from increasing reward for inventions) is likely

was elastic in the short period with respect to the level of demand in the private sector, although there may be some ambiguity as between the act of invention and the filing of patents. See, for example, T. S. Ashton, "Some Statistics of the Industrial Revolution in Britain," *The Manchester School,* XVI (1948), pp. 214-34, partially reprinted (including the patent series) as Chapter 3 in A. E. Musson (ed.), *Science, Technology and Economic Growth in the Eighteenth Century.*

[30] In one of the few efforts explicitly to assess the motives of inventors, of which I am aware, Shelby T. McCloy has this to say about French inventors of the eighteenth century (*French Inventions of the Eighteenth Century* (Lexington, Kentucky: University of Kentucky Press, 1952) p. 189): "The question of the motives or incentives of the inventors is much more difficult to solve. In our own century, due in no small degree to the writings of Karl Marx, a reader might easily jump to the conclusion that the economic motive was paramount. With not a few of the inventors it must have been. It is probable, in fact, that most of them hoped to realize some financial benefit from their inventions. This is far from saying that the hope of economic gain was the paramount motive, or, indeed, that it was the original driving force. Few inventors benefited appreciably from their inventions; a much greater number squandered their inheritance and savings on their inventive activity. The largest return to most of them was a government pension, usually modest. Some received no reward whatever. As a matter of fact, some inventors were so indifferent to monetary returns that they renounced claim to economic exploitation of their inventions. In this category were Berthollet, Berthelot, Camus, and Saint-Sauveur. With difficulty the friends of Conté persuaded him not to do likewise, and only the consideration of the other members of his family moved him. Vaucanson bequeathed his collection of machines, on which he had spent much of his earnings, to the king for public display. With these men patriotism and humanitarianism burned brightly. Even more brightly burned the desire for achievement and fame; this was the dominant motive of the French inventors. Economic returns were of secondary consideration, and humanitarianism and patriotism were seldom absent."

to expand the effective supply of inventive talent and bring it into the marketplace?

A supply curve purports to represent how men act. Action is a choice among the alternatives men perceive to be open to them. A society increasingly suffused with the Newtonian (or Faustian) perception, offering increasing educational opportunities to its citizens, permitting increased movement from rural village to town and city (thereby widening the options open to individuals of talent), is likely to produce more inventors (out of a given population) than, say, a society structured like medieval Europe or the ancient empires.[31]

In different ways most of Western Europe was changing in these directions as the cities expanded, absolutely and relatively, in the latter part of the seventeenth century and during the eighteenth century. But a supply of inventors without demanding innovators prepared to absorb their creations into the capital stock is sterile. We turn directly, therefore, to the demand side of the equation.

At least one Marxist analyst has interpreted Newton and the scientific revolution itself as the supply response of talented bourgeoisie to the practical profit-making and power requirements of other members of their class.[32] The *Principia* is seen as an attempt to solve a set of physical problems whose solution was required to make transport, mining, and war-making more efficient. G. N. Clark has challenged this simplistic view without denying (and, to some extent, strengthening) the judgment that Newton and his predecessors were interested in and partially stimulated by the possibility of helping to solve problems in the active world.[33]

This utilitarian strand in the story would not deny the reality of Copernicus' desire to produce a view of the universe of a simplicity and elegance more appropriate to the Deity than the received view

[31] Shelby T. McCloy (*ibid.*, pp. 186-8) notes that the largest group of French inventors of the eighteenth century were men and women trained through apprenticeship, who had received some instruction in the sciences, were drawn to the large cities from towns, villages and rural districts, and were from the French middle class.

[32] B. Hessen, "The Social and Economic Roots of Newton's 'Principia,'" in *Science at the Crossroads*, papers presented to the International Congress on the History of Science and Technology, held in London, June 29-July 3, 1931, by the Delegates of the U.S.S.R., especially pp. 167, 176, 182-3, and 191.

[33] G. N. Clark, *Science and Social Welfare in the Age of Newton* (Oxford: Clarendon Press, 1937), especially Chapter III, pp. 60-91. Clark (p. 86) distinguishes five groups of influences which "worked upon science from the outside: those from economic life, from war, from medicine, from the arts, and from religion."

of his time, when observations had accumulated to a point where the Ptolemaic system had to be elaborated to more than eighty spheres, in order "to save appearances." As Giorgio de Santillana said:[34] ". . . man very much wants the universe to make sense . . ."; and this impulse requires no cash nexus to make itself felt. In a society where some men believe their observations and reflections can make sense of the universe and where such men can find ways to subsist, the supply curve of scientists can be highly inelastic with respect to economic yields.

Nevertheless, the voyages of discovery, the early phase of the commercial revolution, and the power (as well as profit) imperatives of mercantilism, certainly played a role in setting the stage for the scientific revolution of the seventeenth century.

Once in motion the scientific revolution, in the increasingly lively urban settings stimulated by the commercial revolution, had the diffuse and complex effects suggested above, including its effect on state and private demand for inventions.

The argument can be illuminated by comparing the outcome in France and Britain. Before looking at French and British data on inventions, it is useful to recall the basic economic data set out in Table 3. The story told by this Table is essentially that so well elucidated by François Crouzet. Despite Britain's civil war of the seventeenth century, it gained on larger France, which suffered a severe economic setback, starting in the 1690's. From the 1720's down to 1783, France, from a depressed base, gained relatively on Britain. Both moved forward in the 1780's, Britain with greater momentum, but the period of revolution and war relatively set France back severely.

Against this background it is worth focusing on Table 4 which exhibits British patents granted and French inventions approved by the Academy of Sciences.[35]

[34] Giorgio de Santillana (ed.), *Galileo Galilei: Dialogue on the Great World Systems* (Abridged text edition, Chicago: The University of Chicago Press, 1955), p. xv.

[35] The British patent series down to 1755 is from Walther Hoffmann, *British Industry, 1700-1950*, translated by W. H. Chaloner and W. O. Henderson (Oxford: Basil Blackwell, 1955), Table 54, Part A, column 64, opposite p. 330, converted back to absolute numbers from his index, with 1913 = 100; from 1756 Ashton's figures are used (A. E. Musson, ed., *Science, Technology and Economic Growth*, p. 119). Ashton comments on the patent series as follows (p. 118): "It may also be objected that many patents were taken out by men whose hopes outran their ingenuity or practical sense, and that the high figures of the booms represent not

These data justify only the most obvious and large conclusions; for they reflect rather than measure exactly the forces at work in the two countries. In particular, they can only symbolize the cumulative improvement by many hands, outside the patent systems, which gradually refined industrial technology.

The average annual rate of patents granted and inventions approved rises in both cases in the second half of the eighteenth century, but the French increase is more modest than the British. The average annual rate for France increases from about 6 to 22 between the first decade and the years 1788-92; the equivalent British increase in annual rate is from 3 to 63. Even before the British take-off begins after 1783, there is a ten-fold increase between the first decade of the century and the 1770's. Put another way, Britain, starting the century with an invention rate half that of France, emerges in the latter part of the century with a rate about three times higher.

The question then arises: Were the potential yields from invention and innovation as high elsewhere as in Britain? The answer must be, by and large, affirmative. The scientific revolution, with its multiple consequences for invention and innovation, was widely, if

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solid progress but the mere blowing of bubbles. A glance at the names of the patentees in each of the years of high activity suggests, however, that there is something more in it than that. The list includes, for 1769, Arkwright, Watt, and Wedgwood; for 1783, Cort, Onions and Bramah; for 1792, Wilkinson, Cartwright, and Curr; for 1801-2, the Early of Dundonald, Trevithick, and Symington; for 1813, Horrocks; for 1818, Brunel and Mushet; and for 1824-5, Maudslay, Roberts, and Biddle. One could write a fairly complete history of technology for this period without mention of any other names than these."

Witt Bowden (*Industrial Society in England Towards the End of the Eighteenth Century*, New York: The Macmillan Company, 1925, p. 12) sets out decadal figures for patents back to 1660. The annual averages suggest the first decade of the eighteenth century was abnormally depressed, perhaps by the impact of the war of Spanish Succession: 1660's, 3; 1670's, 5; 1680's, 5; 1690's, 10.

The French data are from Shelby T. McCloy, *French Inventions*, pp. 192-3. McCloy drew his figures (unfortunately incomplete for the second half of the century) from the account of inventions approved by the Academy of Sciences, down to 1754, edited by Gallon; down to 1773, *The Mémoires* of the Academy of Sciences are used; and the records of the Institute of France, after its organization in 1794. He notes that there are discrepancies between Gallon's figures and the later *Mémoires*, but the discrepancies are not great. The figures for 1796-8 are obviously damped by the effects of war and political instability. Those for 1789-92 better represent the lift in French inventiveness (and industrial activity) in the prewar years, and they represent inventions from Paris alone (*ibid.*, p. 193 n). McCloy concludes (p. 104): "Not only did the second half of the century see a larger number of inventions than the first half, but in this latter period there were many more inventions of real significance." McCloy demonstrates well the effect of wars in the first half of the eighteenth century in damping the number of inventions approved.

TABLE 3
FRANCE AND GREAT BRITAIN IN THE EIGHTEENTH CENTURY

	France			Britain		
	1700	*1780*	*1800*	*1700*	*1780*	*1800*
Population[a] (in millions)	19.25	25.6	27.4	6.9	9.0	10.8
Urban Population[b] (in millions)	3.3	5.7	6.4	1.2	2.2	3.2
Foreign Trade[c] (in £ millions)	9	22	31	13	23	67
Iron Production[d] (in 000 tons)	22	135	—	15	60	190
Cotton Consumption[e] (in million lbs),	.5	11	—	1.1	7.4	42.9
Agriculture Production[f] (1700 = 100)	100	155	177	100	126	143
Industrial Production[f] (1700 = 100)	100	454	700	100	197	387
Total Production[f] (1700 = 100)	100	169	202	100	167	251
Income Per Capita[f] (1700 = 100)	100	127	142	100	129	160

[a] French population figures are from J. -C. Toutain, "La population de la France de 1700 à 1959," p. 16. The 1780 figure is the estimate for 1776; the 1800 figure, for 1801. The British figures, covering England, Wales, and Scotland, are from Phyllis Deane and W. A. Cole, *British Economic Growth, 1688-1959*, p. 6, for the years 1701, 1781, and 1801, respectively, the figure for Scotland's population in 1781, by extrapolation, taken as 1.44 million.

[b] French urban population (in concentrations over 2,000) is from J. -C. Toutain, "La population," p. 54, with the 1780 figure roughly extrapolated backward from the rate of increase between 1791 and 1796. The British data, as in footnote 20, above, are from percentages for population in concentrations over 5,000, estimated by Phyllis Deane and W. A. Cole, *British Economic Growth*, p. 7, but corrected to include those in concentrations between 2,000 and 5,000. The problem of correction, however, is not easy. The Deane and Cole estimate of, say, 25 percent in concentrations above 5,000 in Great Britain in 1801 compares with Williams' estimate of 40 percent in concentrations above 2,000 for England and Wales in that year. If the figures for Scotland were comparable in structure to those for England and Wales, this suggests 15 percent of the population of Great Britain living in units between 2,000 and 5,000. On the other hand, Williams estimates 15 percent living in units between 2,000 and 20,000 in 1801. This seems more nearly correct. French data (from Le Duc de Boulainvilliers, *État de France*, London, 1752, quoted in W. Bowden *et al.*, *An Economic History of Europe Since 1750*, New York: American Book Company, 1937, p. 6) suggest that, in the late seventeenth century, the figure over the range of 2-5,000 was about 5 percent, and it did not change much during the eighteenth century. Therefore, I have added 5 percent (rather than 15 percent) to the Deane and Cole proportions, to arrive at the total urban population figures in Table 3.

[c] The French figure for 1700 is Arnould's average for 1716-20, from E. Levasseur, *Histoire du Commerce de la France, Première Partie: Avant 1789* (Paris: Librairie Nouvelle de Droit et de Jurisprudence, 1911) p. 512, converted at 25 livres tournois per English pound. It is somewhat higher than Mulhall's estimate for 1720 (£7 million). Mulhall's figures are used for 1780 and 1800. British data are from Elizabeth B. Schumpeter, *English Overseas Trade Statistics, 1697-1808* (Oxford: The Clarendon Press, 1960), pp. 15-16, which are consistent with Mulhall's figures.

[d] The British figure for 1700 is extrapolated backward from the 1720 estimate of 17,350 tons (Phyllis Deane and W. A. Cole, *British Economic Growth*, p. 22, including note 3), although there are estimates as high as 25,000 tons for 1720. Mulhall's figure for British iron production in 1700 is as low as 12,000 tons (*Dictionary*

of Statistics, p. 332). The French figure for 1700 and the British figure for 1800 are from Mulhall, the latter being roughly consistent with the reasonably firm estimate for 1806 of 250,000 tons, given the extraordinarily high rate of expansion in the iron industry at this time. The French and British iron production figures for 1780 are the estimates for the 1780's ("on the eve of the Revolution") of F. Crouzet. See "England and France in the Eighteenth Century: A Comparative Analysis of Two Economic Growths," Chapter 7 in R. M. Hartwell, editor, *The Causes of the Industrial Revolution in England* (London: Methuen & Co. Ltd., 1967), pp. 151-2. Pierre Léon gives a somewhat different impression of French iron production in "L'industrialisation en France en tant que facteur de croissance économique, du début du XVIII[e] siècle à nos jours," in *Congrès et Colloques I,* contributions to the First International Conference of Economic History, Stockholm, August 1960 (Paris and the Hague, 1960), pp. 177-8 and 198. His estimates suggest a figure of about 60,000 tons in 1789, rising sharply over 100,000 tons by 1800, under the impact of wartime requirements. Mulhall's figure for 1800 (60,000 tons) is much lower than Léon's and, by implication, Crouzet's. Mulhall's figure for Britain in 1790 (68,000 tons) is comparable to Crouzet's.

[e] The British figures for retained cotton imports are averages for the years 1700-09, 1775-84, and 1795-1804, from Phyllis Deane and W. A. Cole, *British Economic Growth,* p. 51. The French figure for 1780 is for the year 1786, from F. Crouzet, "England and France," p. 151. The British figure for that year is 19.1 million pounds, the cotton industry being already in a rapid stage of acceleration not shared by France. The French estimate for 1700 is Mulhall's figure for 1688 (*Dictionary,* p. 160), assuming no expansion in this troubled period in French economic history.

[f] For France, Jan Marczewski's calculations, in "Some Aspects of the Economic Growth of France, 1660-1958," *Economic Development and Cultural Change,* IX (April 1961), 375-76, are converted to index numbers, with 1700 = 100, so as to be roughly comparable with the calculations of Phyllis Deane and W. A. Cole (*British Economic Growth,* p. 78). Marczewski (p. 376) uses two methods for calculating gross physical product: one assumes the 1905-13 price relation of agricultural and industrial goods; the other assumes a moving relationship weighted by the average values added at current prices of the two sectors for each pair of decades. The former data are used in Table 3. The latter method yields higher growth rates as follows: for total production, 100, 260, 341; for per capita production, 100, 196, 239. I would not attempt to arbitrate this large discrepancy except to note that the severe depression around the turn of the century in the French economy makes the increase down to the 1780's more credible than may at first appear; but my overall impression is that Marczewski's first method somewhat damps, his second method somewhat exaggerates overall French growth in the eighteenth century. French growth is, however, slightly exaggerated in any case, since 1780 is the index number for 1781-90 and 1800 is the index number for 1803-12.

TABLE 4
ANNUAL AVERAGE PATENTS GRANTED AND INVENTIONS APPROVED: GREAT BRITAIN AND FRANCE IN THE EIGHTEENTH CENTURY

	Great Britain		*France*	*Great Britain for Comparable Years*
1702-11	3		6	—
1712-21	5		7	—
1722-31	8		10	—
1732-41	5		6	—
1742-51	9		4	—
1752-61	10		—	—
1762-71	23	(1760-69	7	21)
1772-81	31	(1770-71	10	25)
1782-91	54	(1789-92	22	63)
1792-1801	72	(1796-98	8	69)

Sources: See footnote 35.

not uniformly, spread. The achievements of eighteenth-century French science match or outstrip those in Britain. The general stimulus of expanded foreign trade was, again, endemic if not uniform. The governments in Prussia, Russia, Spain, as well as in France, pursued policies designed to encourage inventions and innovations in the Colbertian tradition. And it was not merely in Britain that the taste for Indian calicoes was acquired. The level of income per capita in France may have been a little below that of Britain at the close of the seventeenth century, and the gap may have widened somewhat during the subsequent century, notably in the post-1783 period.[36] But the French market, with its absolutely larger urban population, was not so poor as to rule out an ample domestic as well as foreign market for cheap cotton textiles, if French industry had produced them first.[37] It is true that the British timber shortage was more acute and an old well-developed coal industry was available as a potential alternative source of fuel for the iron industry. But interest in a steam engine extended beyond the demand for pumps in coal mines. And that interest was not confined to Britain, as the significant role of Denis Papin dramatizes: A French Huguenot, who worked with both Christian Huygens and Robert Boyle, taught at Marburg, and was a member of the Royal Society of London. And Papin was by no means the only Frenchman who worked on steam engines and their refinement.

Indeed, it is only in the last two decades of the eighteenth century that British industrial technology emerges as unique. In Spain, the initial sponsoring of rather inefficient royal textile factories[38] gave way in the course of the eighteenth century to more efficient private entrepreneurs: notably, in the Catalonian cotton textile industry and the Basque iron industry. In its post-1783 surge, the former ranked second only to England in production of cotton cloth, with

[36] Gregory King estimated average annual income in 1688 as £8 1s. 4d. for Holland; £7 18s. for England; £6 3s. for France. For discussion of relative income per capita levels in eighteenth-century Europe, see *The Cambridge Economic History of Europe*, Vol. VI, H. J. Habakkuk and M. Postan, editors (Cambridge: Cambridge University Press, 1966), Chapter I, "The Growth of National Incomes," by W. A. Cole and Phyllis Deane, especially pp. 3-6.

[37] Shelby T. McCloy traces out the extensive efforts of the French government to acquire British (and other) advanced manufacturing technology, as well as to generate French textile inventions, in *French Inventions*, pp. 90-102 and 178-85. On the very considerable expansion of French cotton production during the eighteenth century, see Pierre Léon, *Congrès et Colloques*, p. 178.

[38] See, notably, J. Clayburn La Force, "Royal Textile Factories in Spain, 1700-1800," JOURNAL OF ECONOMIC HISTORY, XXIV (Sept. 1964), 337-363.

eighty factories, 2500 looms, and 80,000 workers.[39] Frederick the Great, having annexed Silesia in 1741, successfully encouraged the development of a sophisticated iron industry there, as he sponsored similar developments in other significant directions, including textiles. And despite the heavy burden of its wars and the passing of a great modernizing leader, industry continued to expand in post-Petrine Russia. In France, the Colbertian tradition was maintained. Despite the many famous frailties of the *ancien regime,* production expanded on a wide front.[40] Habakkuk can conclude:

> There were a number of industrial areas in Europe which, around the middle of the eighteenth century, did not differ very widely in the state of their techniques or in the nature of their organization: Saxony, Silesia, the mining areas of Germany, the metallurgical and metal-processing centres of the Urals, the silk industry at Lyons, textile production in Barcelona.[41]

What distinguished Britain from the rest as the eighteenth century wore on was the scale of the inventive effort that went into the breaking of crucial technical bottlenecks, and the scale of the entrepreneurial corps which introduced them as the century moved towards its close. This difference in scale appears greater than can be accounted for by differences in income per capita, the size of urban populations, or the quality of scientific or inventive achievement, in which the French were certainly not inferior.[42]

[39] J. Lynch, "The Iberian States and the Italian States, 1763-93," in Vol. VIII of *The New Cambridge Modern History: The American and French Revolutions* (Cambridge: Cambridge University Press, 1965), p. 370. See, also, Jaime Vicens Vives, *An Economic History of Spain* (Princeton: Princeton University Press, 1969), especially pp. 524-39, on Spanish industrial growth in the eighteenth century. Vicens Vives (p. 538) states that at the end of the century the Catalonian cotton cloth industry totalled more than 3,000 establishments and some 100,000 workers.

[40] See, notably, F. Crouzet, "England and France in the Eighteenth Century: A Comparative Analysis of Two Economic Growths," Chapter 7 in R. M. Hartwell (ed.), *The Causes of the Industrial Revolution in England.*

[41] H. J. Habakkuk, "Population, Commerce and Economic Ideas," p. 42.

[42] The quality of French inventiveness is incontestable, as is the weakness of innovation, relative to Britain. Thus, Peter Mathias ("Who Unbound Prometheus? Science and Technological Change, 1600-1800," Chapter 1 in A. E. Musson (ed.), *Science, Technology and Economic Growth,* p. 81) says: "The French record of scientific growth and invention in the eighteenth century was a formidable one. Berthollet first revealed to the world the bleaching possibilities of chlorine, first isolated as a gas in 1774 by a Swedish chemist Scheele, which was followed by energetic efforts to promote its manufacture in France. A similar sequence followed with Leblanc making soda from salt and sulphuric acid. Very sophisticated work was done in the production of dyestuffs in France; with varnishes, enamels, and many other techniques and materials. Yet the difference in the rate of industrial growth based on these advances in chemistry between France and Britain in the period 1780 to 1850 was remarkable. Almost all the theoretical work on structures, stresses, and the mechanics of design

VI

The problem of scale brings us to an element in the equation beyond mercantilism, the commercial, and scientific revolution: the disproportionate role of the British nonconformists as inventors and innovators. Behind their emergence is the whole tale of Europe's offshore island making its way to self-conscious nationhood in the face of the successive challenges of Rome and Spain, Netherlands and France, undergoing its critical and bloody domestic confrontation—and reconciliation—by 1688, a process affecting the fundamentals of political, social, and religious life.[43] And, as we are all brought up to know, embedded within the emergent British social structure were the nonconformists, denied access to Church and State, but permitted to live and learn, practice their religions, educate their young, develop their talents, and to make money. It is in the late seventeenth century that one can observe on both sides of the Atlantic the Puritan ardor shifting from theology to the marketplace. Clearly, the nonconformists generated a disproportionate supply of both inventors and entrepreneurs.

There is a considerable literature which sought to find in the somewhat paradoxical theology of the Protestant Reformation the clue to the nonconformists' ardent pursuit of economic ends. But William Petty early perceived what subsequent economic history would confirm about the role of creative minorities in traditional societies. Blocked in routes to the top, but not denied access to education and money, they found modernizing activities congenial. In a passage entitled "The Trade of any Country is chiefly managed by the Heterodox party," he said this:

> It is to be observed . . . that Trade is most vigorously carried on, in every State and Government, by the Heterodox part of the same, and such as profess Opinions different from what are publickly established: (that is to say) in

in civil engineering was French. This did not appear to have much relationship to the speed of development, or even innovations in these fields, as far as economic progress was concerned. The same was true of power engineering and hydrodynamics." For a systematic survey, see Shelby T. McCloy, *French Inventions*, which covers the full range of French inventiveness in the eighteenth century as well as (Chapter XII) government encouragement of inventions before and after the first French patent law of 1791.

[43] So far as the economy is concerned and the pool of those from which inventors and innovators might be drawn, it is the absolute size of urban populations that matters most. So far as politics is concerned, the proportion of the urban-rural breakdown can matter significantly. It may be that Britain's precocious urbanization helped tip the balance in the civil war of the seventeenth century just as France's disproportionate rural population shaped French politics down through the first half of the twentieth century, at least.

India where the *Mahometan* Religion is Authorized, there the *Banians* are the most considerable Merchants. In the *Turkish* Empire the *Jews,* and Christians. At *Venice, Naples, Legorn, Genoua,* and *Lisbone, Jews,* and Non-Papist Merchant-Strangers . . . even in *France* it self, the *Hugonots* are proportionably far the greatest Traders; Nor is it to be denied but that in *Ireland,* where the said *Roman* Religion is not Authorized, there the Professors thereof have a great part of the Trade. From whence it follows that Trade is not fixt to any Species of Religion as such; but rather as before hath been said to the Hetrodox part of the whole, the truth whereof appears also in all the particular Towns of Greatest Trade in *England.*[44]

Thus the problem of religion in early modern history and all that lay behind Britain's Revolution of 1688 (and the French revocation of the Edict of Nantes in 1685) become directly relevant to the locus of the first industrial revolution.[45]

VII

But in the matter of invention and innovation, and in all the other dimensions of economic modernization, we are dealing with questions of degree. In terms of growth theory, what we observe in the century or so before 1783 is an endemic process, from St. Petersburg to the American colonies, of what I would call the preconditions for take-off. Agricultural output was expanding; domestic markets were being linked with new roads and canals; international commerce was increasing, with all it carried in its train; handicraft manufactures were rising; the cities were growing disproportionately; and the scientific revolution had set many men in many places to contriving mechanical solutions to economic and technical problems.

[44] Charles Henry Hull (ed.), *The Economic Writings of Sir William Petty,* Vol. I (Cambridge: The University Press, 1899), pp. 263-4.

[45] We are left with two interesting puzzles. Neither Holland nor the American colonies suffered the political and social inhibitions of France vis-à-vis Britain. For most of the eighteenth century, income per capita was probably higher in Holland than Britain, while the American colonies expanded their population at an astonishing rate, with high and probably rising per capita incomes, quite possibly above the British level. Why did the industrial breakthrough not occur in one or the other area? The answer may lie in the fact that entrepreneurship in Holland was concentrated on holding its ground in international commerce, in all its aspects, shifting, in fact, towards finance rather than industry when the rise of Britain and France constrained its commercial possibilities; while the yields from agriculture and international commerce in the North American colonies were so attractive as to prevent a buildup of industrial inventiveness and entrepreneurship. British colonial regulations, of course, were designed to deter manufacturing development in North America in most sectors; however, as American economic history from 1783 to 1806 suggests, it was probably a marginal factor. In the vocabulary of *The Process of Economic Growth,* the yields related to industrial inventiveness and entrepreneurship were deficient in Holland and North America rather than the underlying propensities.

What varies among the states of the West (and Russia) is the degree and extent of movement in these directions.[46] Without indulging in counter-factual history, it is not unreasonable to assume that sooner or later the forces at work would have yielded a take-off elsewhere in Europe (or in the United States), if Britain had not led the way. It probably would not have been long delayed, and cotton textiles would have been the leading sector, as it was in Britain.

After the British made their demonstration in the last two decades of the eighteenth century, the job of industrialization, to a degree, changed its character. As Gillispie notes: "In textile manufacturing —and even in metallurgy—French entrepreneurs were shown the way, not by scientific research, but by Englishmen and Scotsmen."[47] And not only French entrepreneurs.

But more was required for take-off than itinerant British engineers and managers. It was the widespread, diffuse modernization of the Continent in the seventeenth and eighteenth centuries (as well as the revolutionary changes wrought during the long period of war) that made the rapid absorption of the British example feasible after 1815. In fact, the sequence of the nineteenth-century take-offs on the European Continent relates not rigidly but quite closely to the extent to which preconditioning had proceeded by the close of the eighteenth century, for example, in France, Belgium, Germany, Spain, Sweden, Italy, and Russia.

VIII

There is another way to look at a critical part of the growth process—the leading sector—in partial equilibrium terms: that is, the case of increasing returns.

[46] This view, of an endemic process of modernization throughout Europe and the Atlantic, should be contrasted with that presented by Phyllis Deane and W. A. Cole, *British Economic Growth, 1688-1959*, especially pp. 82-97. Briefly put, their hypothesis is that relatively high agricultural prices at home and unfavorable British terms of trade, expanding the money value of British imports, supplied the expanding market for the domestic and foreign sale of British manufactures. I believe this is too narrow and parochial a view of the process at work throughout the world trading area. Moreover, the postwar behavior of British imports and exports, set out in the Appendix, does not conform to the Deane and Cole hypothesis when examined on a year-to-year basis; that is, British exports move promptly to higher than prewar levels and do not await a prior rise in British imports. The data suggest that endogenous processes of expansion were at work in the major British markets, a judgment confirmed by direct historical evidence on their eighteenth-century experience.

[47] Charles C. Gillispie, "The Natural History of Industry," in A. E. Musson (ed.), *Science, Technology and Economic Growth*, p. 125.

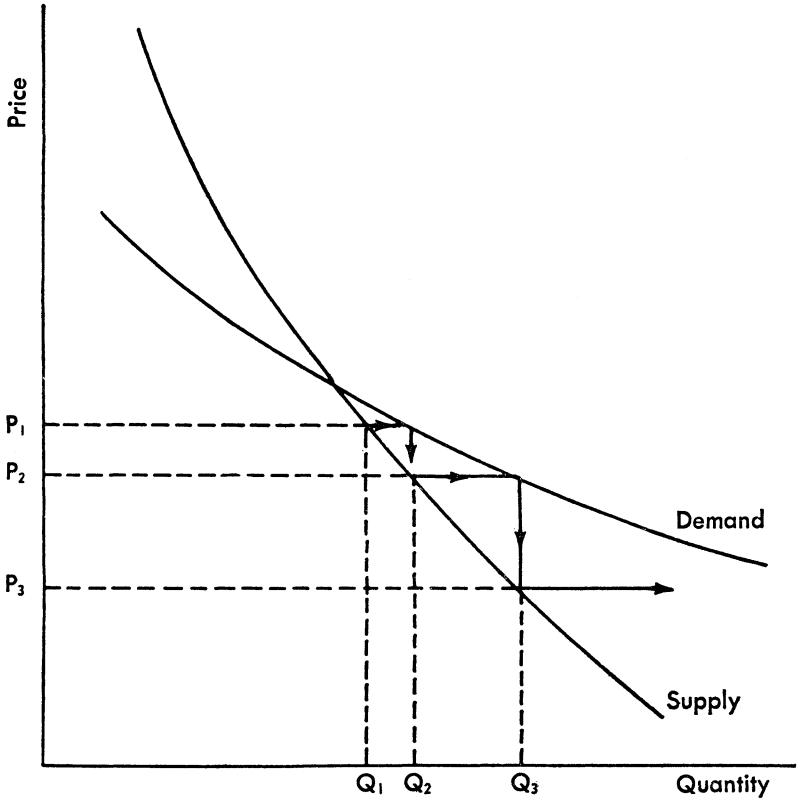

FIGURE 1
Source: I. D. Burnet, "An Interpretation of Take-off," *The Economic Record* (Sept. 1972).

In a recent article, I. D. Burnet has explicitly interpreted the take-off as a case of increasing returns, along the lines of Allyn Young's famous article.[48] He draws his diagram as indicated in Figure 1 and comments:

Contrary to one's first impression, Figure 1 is representative of an explosion rather than an equilibrium. Starting, for example, from P_1Q_1 in period T_1, industry decides to expand production in period T_2 to Q_2, which reduces costs to P_2, which inspires industry to expand production to Q_3 . . . and so on. The only constraints to the explosion are the time lags involved in accumulating capital, refining technology, acquiring tastes, training the work force and so on.

After citing some famous cases of explosive growth in particular sectors (from Model T Ford to ball point pens), he asserts: "The

[48] I. D. Burnet, "An Interpretation of Take-Off," *The Economic Record* (September 1972), pp. 424-8; A. A. Young, "Increasing Returns and Economic Progress," *The Economic Journal*, XXXVIII (1928), 534 ff.

entrepreneur lucky enough to discover a virgin field of consumer demand can look forward to a golden age of self-generating growth." And he links this process to the concept of leading sectors in growth analysis.

Burnet's formulation is a quite useful point around which to sum up the argument presented here on the first take-off leading sector, if we extend his supply curve for a particular sector until constant or diminishing returns take hold; because trees do not grow to the sky, deceleration is inevitable, and a succession of leading sectors is required for sustained growth.[49] The successive price and quantity points of intersection in Burnet's diagram describe the typical path of a leading sector incorporating new technology, as elaborated, for example, by Simon Kuznets in his *Secular Movements in Production and Prices* (New York: Augustus M. Kelley, 1930); that is, a phase of accelerating, then decelerating growth in output, of rapid, then slower decline in price.

In these terms, the transition of Europe between the fifteenth and late eighteenth centuries can be summarized as follows:

(1) On the side of demand, the gradual expansion of domestic and international commerce, the expansion of urban life, the increase in European populations, the expansion of acreage and technological improvement in agriculture required to feed them, the movement from serfdom towards an independent land-owning peasantry, the slow increase in income per capita, the movement away from the harshly polarized income distribution of medieval (and other traditional) societies, and the contact with Indian calicoes yielded a price-and-income elastic demand curve for cotton textiles in large portions of Europe during the eighteenth century. And the generalized slow expansion of the European economy (plus the rapid expansion of the North American colonial economy) kept the curve shifting to the right. As later experience in nineteenth-century India, China, and Japan indicates, an elastic demand existed even in quasi-traditional, low income economies for cheap manufactured cotton textiles, as opposed to handicraft manufactures, but the eighteenth-century European (and North American) economies offered an even more promising market environment.

[49] I owe the suggestion of extending Burnet's downward sloping supply curve into a phase of constant or diminishing returns to my colleague, Professor David Kendrick. For a discussion of factors leading to deceleration of output (and price decline) in a leading sector, see *The Process of Economic Growth,* pp. 96-103.

(2) On the side of supply, increasing returns implies the effective absorption and market exploitation of a new technology. It means inventors have cumulatively created the potentiality of a supply curve incorporating increasing returns and that a sufficient corps of creative entrepreneurs has emerged which will, in fact, exploit its potentialities when confronted by a price elastic demand curve. Western Europe was moving in this direction during the eighteenth century. But those conditions were first fully and effectively established in Britain. Behind the explosive expansion of British raw cotton consumption in the late eighteenth century lay all the elements considered in this article: British mercantilist policy, notably towards India as well as its own woolen industry; the commercial revolution; the scientific revolution; the religious dispensation which emerged in post-1688 Britain; and, one must add, the rare case of a one-man inventive breakthrough in Eli Whitney's cotton gin.

(3) Although cotton textile manufacture for the domestic market and export was clearly the leading sector in the British take-off, technology and innovation in other less dramatically expanding sectors (for example, transport, metal-working, and the steam engine) were critical to the take-off; for without them the spreading effects from cotton textiles would not have occurred on the scale that they did and modern industrialization would not have emerged as an on-going diffusing process.

It is worth underlining the full implications and range of variables relevant to the case of increasing returns for a particular contemporary reason. The world of economic theory is now caught up in a salutary re-examination of the constructs which have dominated the field over the last generation and more. In one of many current essays in re-evaluation, Nicholas Kaldor has re-discovered Allyn Young's 1928 article on increasing returns.[50] He accepts its explosive meaning for static equilibrium economics and explores tentatively some of the implications of that acceptance, as he sees them. But, in the tradition of Adam Smith and Allyn Young, he views technological progress solely as a diffuse incremental process, related simply to a widening of the market, and scale of industrial investment. This heroic over-simplification permits Kaldor to concentrate on the problems of macro-demand which primarily interest him. Kaldor is here repeating the kind of procedure which has rendered Harrod-

[50] Nicholas Kaldor, "The Irrelevance of Equilibrium."

Domar growth models so sterile; that is, freezing or rendering exogenous, excessively abstract, or over-aggregative the critical factors on which growth, in fact, depends. In Kaldor's case, the deficiency is that increasing returns (and the direction of investment) cannot be properly understood without introducing the concept of leading sectors which, after a possible phase of acceleration, yield the decelerating increases in output and decelerating price declines which are the substance of the case.

Historians will welcome the entrance of Mr. Kaldor and others into the world of increasing returns, in particular, and the Marshallian long period, in general. But economists should enter this revolutionary world without illusion; this is a terrain where greater disaggregation is required than they have been used to, where, as in the present essay, not only do supply and demand interact but one cannot evade the full range of forces, including those generated from the side of politics and the social structure, which determine the course of technical change, its absorption into the economy, and the pattern of investment. These are factors which must be taken into account if we are to generate a dynamic theory of "moving equilibrium" (in Allyn Young's phrase[51]) to supplant static Walrasian theory. The short-cuts to a full dynamic analysis of output and prices, whatever their formal elegance, turn out to be illusory.

IX

To return to the origins of modern growth, as noted earlier, the problem changed significantly once the British take-off had occurred and the initial set of technologies in textiles, iron, and the steam engine was available for copying. Despite some inhibitions on the export of technology and despite the closeness with which particular firms tried to guard special tricks in the production process, it was possible for followers to learn from leaders. Invention, as well as fundamental science, became an international enterprise, enlarging the potentialities for all capable of absorbing them.

But the availability of technology was not enough. The problems for latecomers seeking to enter into modern growth after 1815 have continued down to the present day to bear a family relation to those that were confronted under the converging impulses of mercantilism, the expansion of commerce, and the scientific revolution: to

[51] A. A. Young, "Increasing Returns," p. 535.

bring about the changes in transport, agriculture, and foreign trade necessary to build a national market, feed growing urban populations, and acquire a preliminary experience in simple forms of industry; and then to find viable leading sectors for the take-off, which, as two centuries ago, tend still to be light manufactured consumers goods produced in substitution for imports. And, above all, the generation of an adequate corps of innovating entrepreneurs (in public as well as private sectors) remains crucial for increasing returns to take hold in the leading sectors and for the potential spreading effects to be exploited over a wide front; for without them, the great international pool of unapplied modern technology remains sterile. In this sense, there is continuity between the story of eighteenth-century Europe, including the reasons for the British bursting first through the barrier, and the struggle of contemporary developing nations to move into take-off and beyond.

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WAR AND THE BRITISH ECONOMY: THE EIGHTEENTH CENTURY

War of Spanish Succession, 1701-14

	Exports	*Re-Exports (in £ millions)*	*Imports*	*Timber Imports (in £ thousands)*	*Industrial Production (Hoffmann total index, 1913 = 100)*
Prewar peak	4.6 (1701)	2.2 (1701)	6.0 (1700)	68 (1700)	1.59 (1700)
Wartime average (1702-13)	4.5	1.6	4.6	58	1.61
Postwar average (1713-18)	5.1	2.2	5.9	60	1.86

War of Austrian Succession, 1740-48 (Jenkins' Ear, 1739)

	Exports	*Re-Exports (in £ millions)*	*Imports*	*Timber Imports (in £ thousands)*	*Industrial Production (Hoffmann total index, 1913 = 100)*
Prewar average (1734-38)	6.2	3.3	7.4	70	2.08
Wartime average (1739-48)	6.2	3.5	7.3	55	2.21
Postwar average (1748-52)	8.6	3.5	7.9	60	2.42

Seven Years' War, 1756-63

	Exports	*Re-Exports (in £ millions)*	*Imports*	*Timber Imports (in £ thousands)*	*Industrial Production (Hoffmann total index, 1913 = 100)*
Prewar average (1751-55)	8.4	3.5	8.3	68	2.48
Wartime average (1756-63)	9.6	4.0	9.3	63	2.51
Postwar average (1763-67)	10.1	4.6	11.2	80	2.67

American War of Independence, 1775-1783

	Exports	*Re-Exports (in £ millions)*	*Imports*	*Timber Imports (in £ thousands)*	*Industrial Production (Hoffmann total index, 1913 = 100)*
Prewar average (1770-74)	10.0	5.6	12.6	114	2.96
Wartime average (1775-82)	8.3	4.4	11.3	106	3.23
Postwar average (1783-87)	10.7	4.2	14.4	145	3.97

Sources: Foreign trade data as compiled by Elizabeth Schumpeter, and reproduced by T. S. Ashton in *Economic Fluctuations in England, 1700-1800* (Oxford: Clarendon Press, 1959), pp. 183, 184, and 188. Industrial Production index is from Walther G. Hoffmann, *British Industry, 1700-1950*, translated by W. H. Chaloner and W. O. Henderson (Oxford: Basil Blackwell, 1955), opposite p. 330.