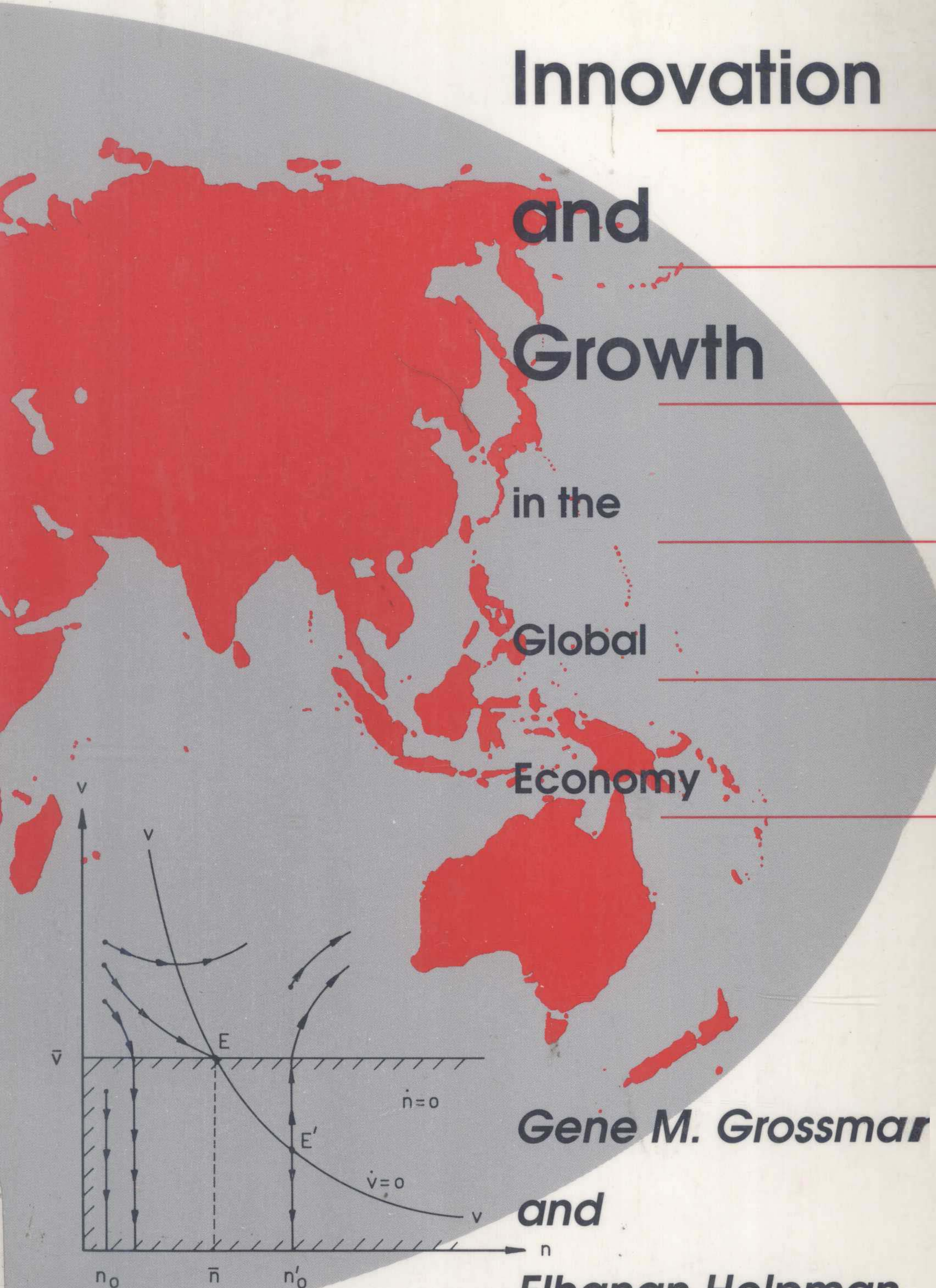
Innovation and Growth in the Global Economy



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Preface

Countries vary greatly in their growth performances. Standards of living in Japan, for example, have risen dramatically in the post-World War II period, while residents of many African nations continue to languish in poverty. A substantial body of evidence suggests moreover that these differences in experience are not simply the outcome of a random process. High growth rates correlate systematically with a number of variables that describe the economic and political environment. It is the job of the social scientist to uncover the mechanisms that link structural and policy conditions to realized growth performance.

A casual reading of recent economic history suggests two important trends in the world economy. First, technological innovations are becoming an ever more important contributor to economic well-being. Second, the nations in the world economy are becoming increasingly open and increasingly interdependent. The two are not unrelated. Rapid communication and close contacts among innovators in different countries facilitate the process of invention and the spread of new ideas. And rapid changes in technology intensify the motives for trade and the consequences of integration into the world trading system. It is not surprising therefore to find that increasing attention is being paid to issues of productivity and technology, on the one hand, and to international competitiveness and the world trading system, on the other, as commentators seek to understand recent growth experiences and to develop scenarios for the future.

This book attempts to integrate the theory of international trade with the theory of economic growth. As growth theory, it focuses on the economic determinants of technological progress. As trade theory, it deals with the dynamic evolution of comparative advantage and the consequences of international trade in a world of global technological competition. Our premise in writing this book is that new technologies stem from the intentional actions of economic agents responding to market incentives. In an open world economy these incentives invariably reflect aspects of the international trade environment. Thus we concentrate on mechanisms that link the growth performance and the trade performance of nations in the world economy.

Our work has antecedents in both the literatures on international trade and economic growth. On the trade side, we draw heavily on recent analyses of international trade with imperfect competition. Paul Krugman, Kelvin Lancaster, Avinash Dixit, Victor Norman, and Wilfred Ethier, among others, have shown how approaches developed in the field of industrial organization can be incorporated into a general-equilibrium framework to provide a static theory of trade in differentiated products. These static models provide the building blocks for our treatment of imperfectly competitive world markets for innovative products. On the growth side, Paul Romer, Phillipe Aghion, and Peter Howitt have applied similar tools from the theory of industrial organization, and their extensions in trade theory to general-equilibrium settings, to develop aggregate models of ongoing investments in new technologies. Their insights have been useful to us in extending the static trade models to a dynamic setting.

In the light of the dual focus of our book and the dual nature of its intellectual origins, we believe that it will be of interest both to macroeconomists concerned with the mechanisms of aggregate growth and to international economists concerned with the evolution of trading patterns and with the dynamic effects of trade policies. We regard the book as too circumscribed in its focus to serve as a primary text in a regular graduate course. However, we hope that it will find use as a supplementary text in both macroeconomics and international trade classes, with some chapters being adopted by courses on industrial organization as well. Industrial organization economists may benefit from our general-equilibrium treatment of technological competition in chapters 3 and 4. For a macro course the first five chapters offer a self-contained discussion of the mechanisms of growth in a closed economy. These chapters provide evidence on the role of technology in growth, a discussion of the relationship between the traditional growth theory based on factor accumulation and our own approach based on industrial innovation, and a thorough analysis of two distinct but related models of endogenous technological progress. Students of macroeconomics may also wish to refer to chapter 9, which addresses the interdependencies in the growth processes in different countries and which can be read immediately following chapter 5 without loss of comprehension. Students of international trade will want to read (at least) chapters 3 and 4 for background, and then could skip to chapter 6 which begins our treatment of open economy issues. Chapters 7 through 10 form the corps of our discussion of technological competition between advanced industrial countries. The first two of these chapters concern the determination of patterns of specialization and trade in a dynamic setting of endogenous comparative advantage, while the last two treat the link between the trade environment (including the policy environment) and growth. Finally, chapters 11 and 12 study North–South trade in a setting in which firms in the South imitate technological developments in the North.

Some of the chapters in this book build on material that we have published in professional journals and conference volumes. The interested reader may wish to refer to some of the following articles: (1) "Growth, Technological Progress, and Trade" (*Empirica–Austrian Economic Papers* 15, March 1988, pp. 5–25); (2) "Product Development and International Trade" (*Journal of Political Economy* 97, December 1989, pp. 1261–1282); (3) "Trade, Innovation, and Growth" (*American Economic Review* 80, Papers and Proceedings, May 1990, pp. 86–91); (4) "Explaining Japan's Innovation and Trade" (*Bank of Japan Monetary and Economic Studies* 8, September 1990, pp. 75–100); (5) "Comparative Advantage and Long-Run Growth," (*American Economic Review* 80, September 1990, pp. 796–815); (6) "Quality Ladders in the Theory of Growth" (*Review of Economic Studies* 58, January 1991, pp. 43–61); (7) "Growth and Welfare in a Small Open Economy" (in E. Helpman and A. Razin, eds., *International Trade and Trade Policy*, MIT Press, 1991); (8) "Quality Ladders and Product Cycles" (*Quarterly Journal of Economics* 106, May 1991, pp. 557–586); (9) "Trade, Knowledge Spillovers, and Growth" (*European Economic Review* 35, Papers and Proceedings, 1991, forthcoming); and (10) "Endogenous Product Cycles" (*The Economic Journal* 101, September, 1991, forthcoming).

During the course of our collaboration on the subject of this book, we have received financial support from the National Science Foundation, the Institute for Advanced Studies at the Hebrew University in Jerusalem, the Bank of Sweden Tercentenary Foundation, the International Monetary Fund, the World Bank, the Bank of Japan Institute for Monetary and Economic Studies, the MITI Research Institute, the Haas School of Business of the University of California at Berkeley (where Grossman was visiting professor in the B. T. Rocca Chair in International Trade), and the Board of Governors of the Federal Reserve System. Support for the writing of this book has been generously provided by the National Science Foundation in the form of a grant to the National Bureau of Economic Research, by the Pew Charitable Trusts in the form of a grant to the Center for International Studies at Princeton University, and by the U.S.–Israel Binational Science

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Contents

1 Growth and Technology

1.1 Facts about Growth

Two facts about the economic growth experience of the world economy beg for an explanation. First, growth in per capita income has been sustained at positive and apparently nondeclining rates in many countries for prolonged periods of time. Second, dynamic performance has varied greatly across different countries in a given time period, and across different historical periods in a given country. Moreover realized growth rates seem not to be the outcome of a random process but rather relate systematically to observable features of the economies, including their government policies.

Kaldor (1961) observed as one of his celebrated "stylized facts" about growth that output per worker rises continually and productivity growth rates show no tendency to decline. More recent evidence is provided by Romer (1986, 1989a) and Scott (1989). In his 1986 paper Romer (following Maddison 1979) reported that in four successive periods of several decades or longer since 1700, the rate of growth of output per person-hour in the world's highest productivity country has increased relative to the growth rate of the technological leader in the preceding period. He also calculated using data from Maddison (1979) that, in a sample of decade-long growth rates of per capita GDP for eleven industrialized countries, the proportion of observations in which a country's growth rate was higher than that in the previous decade varied between 0.58 (for Sweden) and 0.81 (for Norway). Romer's 1989a paper addresses the perception that growth has been slowing in the United States in recent years, and concludes that the last few annual observations on labor productivity growth seemingly represent an aberration in a generally upward trend. Scott (1989) provides evidence that growth rates of nonresidential business output have been roughly constant in the United States, the United Kingdom, and Japan within ten to thirty year periods since the late nineteenth century. He also corroborates the view that productivity growth rates in these countries have shown no tendency to decline.

Concerning the cross-country variation in growth performances (which was another of Kaldor's "stylized facts"), the data from the Summers and Heston (1988) international comparison project can be used to compute growth rates of real per capita income in 114 countries for the period from 1960 to 1985. Figure 1.1 plots these growth rates, which ranged from a low of −2.8 percent per annum in Chad to a high of 7.5 percent per annum in Singapore (with a mean annual growth rate of 2.2 percent), against the level of per capita income in 1960.[1] The figure reveals the great dispersion in realized growth rates in the sample and suggests the absence of any strong correlation between beginning of period levels of income and growth during the period.

Many studies have identified correlates of output and productivity growth. Investment-to-output ratios typically correlate positively with real GDP growth in cross-sectional studies (Dowrik and Nguyen 1989), as do various proxies for the stock of human capital, such as the literacy rate (Azariades and Drazen 1990; Romer 1989b) and the school enrollment rate (Baumol et al. 1989; Barro 1989b). Countries that export a large share of their output seem to grow faster than others (Michaely 1977; Feder 1982; Romer 1989c), as do countries with a low rate of population growth (Baumol et al. 1989). Romer (1989c) finds a positive correlation between the number of scientists and engineers employed in research and the growth rate of output in a sample of 22 of the most developed economies. Finally, a number of authors writing on the industrialization process in the less developed countries find a significant association between the rate of productivity growth and both the size of an economy and the share of its GDP generated by the manufacturing sector (e.g., see the survey article by Syrquin and Chenery 1989).

Historical data also link various government policies with exceptional growth performance. Countries with high shares of government consumption in GDP have grown on average more slowly than others (Landau 1983; Barro 1989a, b), whereas those with high rates of government investment have tended to grow more rapidly. High marginal tax rates are associated with slow growth in output, holding constant the average

1. This type of figure was first presented by Romer (1987). Ours is identical to figure 1 in Barro (1989a), except that the sample has been augmented to include all countries in the Summers-Heston data set, save a few of the centrally planned economies. We thank Robert Barro for his help in preparing this figure.

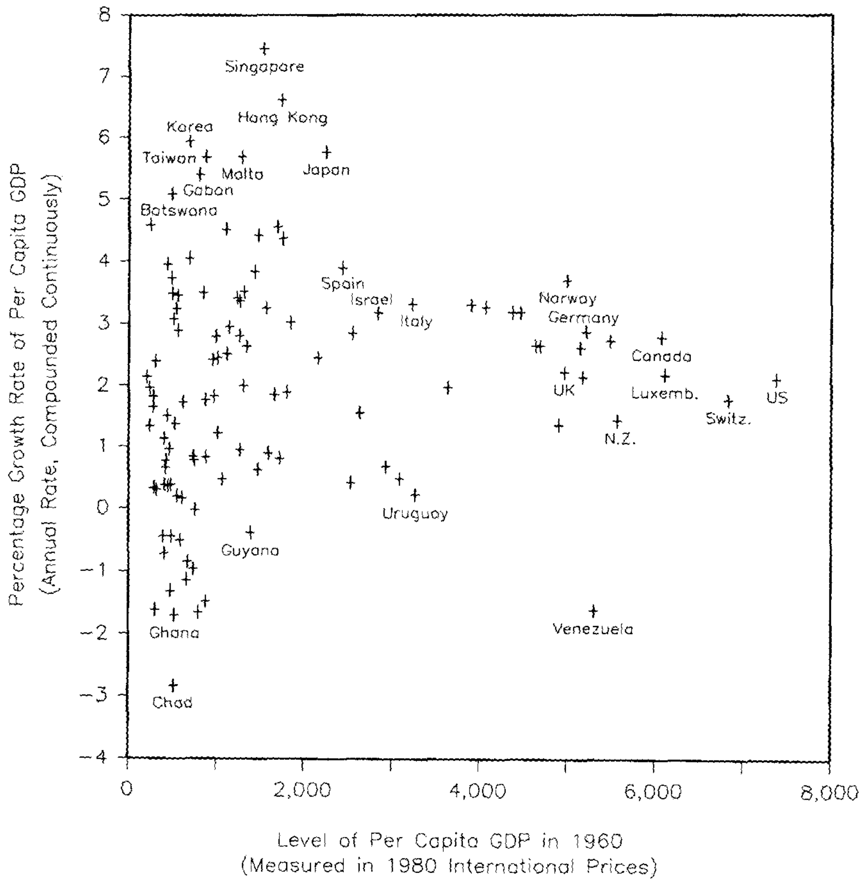

Figure 1.1
Growth rates for 114 countries between 1960 and 1985. Source: Summers and Heston (1988).

rate of taxation (Koester and Kormendi 1989). Kuznets (1988) tries to identify the common features in the successful growth performances of Japan, Taiwan, and South Korea and concludes that all three countries have pursued a policy of encouraging the corporate sector and of removing regulatory restrictions on business activity. Finally, several researchers find a strong relationship between a country's trade policy regime and its dynamic performance. Syrquin and Chenery (1989) report that in a sample of over one hundred countries, those with an outward orientation achieved an average output growth rate of 5.22 percent per annum from 1952 to 1983, and average growth in total factor productivity of 2.2 percent per annum, while those with an inward orientation grew at an average rate of 4.28 percent per annum during the same period and experienced average productivity growth of only 1.6 percent per year. This general finding of a positive association between "openness" and growth rates is corroborated by the more detailed case studies of individual countries reported in, for example, Krueger (1978), Corbo et al. (1985), and Kuznets (1988).

How do the facts that positive growth rates have been sustained for long periods and that growth rates vary systematically from country to country bear upon the theorist's attempt to understand and explain the process of economic growth? Classical writers such as Mill and Marx speculated that standards of living could not rise indefinitely unless advances in technology served to augment the productivity of resources. This proposition received analytical support from the neoclassical growth theorists, who elaborated a model of growth based on capital accumulation. As we shall discuss in chapter 2, if production of output is characterized by diminishing returns to the accumulated factors, the incentive to invest may disappear in the long run in the absence of productivity gains. The fact that investment has continued for more than two hundred years since the industrial revolution suggests that technical change has played a major role in the growth process.

The systematic relationship between output and productivity growth rates and a number of economic variables suggests moreover that technological progress probably is not a purely random process but rather one guided by market forces. Early writers on the sources of technological change saw scientific discoveries as the primary, stimulating force behind innovation. Since scientific advances largely reflect the interests and resources of a community of researchers operating outside the profit sector of the economy, a scientific basis for most industrial innovation would remove technological progress from the realm of economic analysis. But

Schmookler (1966) took exception to this view of the way that technologies evolve in his influential study of almost a thousand inventions in four different industries.

> Despite the popularity of the idea that scientific discoveries and major inventions typically provide the stimulus for inventions, the historical record of important inventions in petroleum refining, paper making, railroading, and farming revealed not a single, unambiguous instance in which either discoveries or inventions played the role hypothesized. Instead, in hundreds of cases, the stimulus was the recognition of a costly problem to be solved or a potentially profitable opportunity to be seized; in short, a technical problem or opportunity evaluated in economic terms. (p. 199)

Schmookler argued in great detail that it is the expected *profitability* of inventive activity, reflecting conditions in the relevant factor and product markets, that determines the pace and direction of industrial innovation. Schumpeter (1942) had expressed a similar view more than twenty years earlier.

> Was not the observed performance [of technological progress] due to that stream of inventions that revolutionized the technique of production rather than to the businessman's hunt for profits? The answer is in the negative. The carrying into effect of those technological novelties was of the essence of that hunt. And even the inventing itself, as will be more fully explained in a moment, was a function of the capitalist process which is responsible for the mental habits that will produce inventions. It is quite wrong... to say, as so many economists do, that capitalist enterprise was one, and technological progress a second, distinct factor in the observed development of output; they were essentially one and the same thing or, as we may also put it, the former was the propelling force of the latter. (p. 110)

If Schumpeter and Schmookler are correct[2], then it would not be surprising to find productivity growth related to an economy's structure and policies, or to find variation in growth experiences in different parts of the world. It then becomes an important task of any theory of growth to explain the links between industrial innovation and economic growth, on the one hand, and between market conditions and innovation rates, on the other.

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2. Mowery and Rosenberg (1989) see a greater role of scientific discovery in the process of technological innovation. Still, they cite many examples to show that "technological exploitation of new scientific understanding often requires considerable time because of the need for additional applied research before the economically useful knowledge can be extracted from a new but abstract formulation" (pp. 25–26). Similarly Dosi (1988) concludes, in his survey of sources and patterns of industrial innovation, that technical change reflects an interplay of technological opportunities created by scientific discoveries and inducements for applied research that emerge from market opportunities.

This is the starting point for our study. We focus on technological progress that results from *intentional* industrial innovation, that is, from the allocation of resources to research and other information-generating activities in response to perceived profit opportunities. Our goal is to understand how country characteristics and policy interventions affect this allocation, and also how global technological competition impinges upon the growth process in interdependent economies.

1.2 The Contribution of Industrial Innovation

It is difficult enough to measure the contribution of technological progress to improvements in standards of living, let alone to isolate the part of technological progress that is due to intentional industrial innovation. The most common method used by economists to decompose output growth into its various "sources" follows an approach developed by Abramovitz (1956) and Solow (1957) and later refined by Denison (1967) and others. "Growth accounting" begins with measurement of factor accumulation and then imputes output expansion to the inputs that have been accumulated by assuming that market factor prices reflect value marginal products. The part of output growth that cannot be attributed to the accumulation of any input—the famous "Solow residual"—is ascribed to technological progress.

Early growth accounting exercises left more than half of growth unaccounted for, and thus implicitly assigned a large role to technological progress (see Solow 1957; Kendrick 1961; Denison 1967). Some more recent efforts have substantially reduced the size of the residual by incorporating estimated changes in the quality of factor inputs (e.g., Jorgenson et al. 1987). Table 1.1, taken from Maddison (1987), gives the results from an especially careful, recent study. The table still shows a sizable contribution of total factor productivity gains to output growth in a number of countries, especially in the early postwar period.

There are several well-known problems that arise in interpreting results from growth-accounting exercises. First, GDP growth may not accurately measure growth in economic output because increases in the *quality* and *variety* of goods and services available to consumers are only imperfectly reflected in the national income accounts. The measurement of the contribution of new and improved varieties to real output growth requires the implementation of sophisticated index number procedures. It is generally believed that reported price indexes often underestimate the economic

Table 1.1
Solow residuals for six countries (annual average compound growth rates)

	1913–50			1950–73			1973–84		
	GDP	TFP	ATFP	GDP	TFP	ATFP	GDP	TFP	ATFP
France	1.06	1.42	0.61	5.13	4.02	3.11	2.18	1.84	0.93
Germany	1.30	0.81	0.19	5.92	4.32	3.61	1.68	1.55	1.13
Japan	2.24	1.10	0.04	9.37	5.79	4.69	3.78	1.21	0.43
Netherlands	2.43	1.25	0.53	4.70	3.35	2.38	1.58	0.81	0.14
United Kingdom	1.29	1.15	0.38	3.02	2.14	1.53	1.06	1.22	0.64
United States	2.78	1.99	1.19	3.72	1.85	1.05	2.32	0.52	−0.27

Source: Tables 11 and 20 from Maddison (1987). TFP (total factor productivity) equals GDP growth minus the imputed contributions of labor accumulation, residential capital accumulation and nonresidential capital accumulation. ATFP (augmented total factor productivity) equals TFP minus the imputed contributions of increases in labor quality and capital quality.

benefits from product innovation (e.g., see Griliches 1973; Bresnahan 1986; Trajtenberg 1990), in which case growth accounting will understate the extent of output growth attributable to advances in technology.

Second, the imputed figure for the contribution of factor accumulation to output growth will accurately measure the extra output that the accumulated factors actually can produce only if factors are paid their value marginal products. If product or factor markets are imperfectly competitive, manufacturing processes are subject to increasing returns to scale, or externalities are generated in factor use, then the Solow residuals will be biased measures of productivity growth (see Hall 1988, Caballero and Lyons 1989).

Third, and perhaps most critical, it may be simply inappropriate to use decomposition methods based on accounting identities to draw inferences about the underlying *causes* of economic growth. What does it mean, for example, that capital accumulation "accounted" for a certain proportion of output growth? Can we infer that investors would have chosen to install more machinery and equipment in the absence of any increases in the productivity of capital? The answer is no. It is certainly possible that managers' desires to further mechanize the production process provided the impetus for capital accumulation. But it is equally possible that the investments were made in response to improved technological conditions, either because extra equipment was needed to produce newly invented goods or because innovative manufacturing techniques made it profitable to install more (or different) machines. In these cases the accumulation of capital cannot be taken as the underlying source of output expansion. Lach