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Overview of Productivity Analysis: History, Issues, and Perspectives

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The Oxford Handbook of Productivity Analysis
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Abstract and Keywords

This chapter provides a wide-ranging interdisciplinary overview of productivity analysis, which also serves to introduce the chapters in the Handbook. It begins with an exploration into the significance of productivity growth, for business, for the economy, and for social economic progress. The chapter continues with a treatment of how productivity is defined, measured, and implemented. It then addresses two important empirical issues. The first involves productivity dispersion, and the productivity dynamics that would either lead to a reallocation of resources that would reduce dispersion and increase aggregate productivity, or allow dispersion to persist behind barriers to productivity-enhancing reallocation. The second involves a search for the drivers of (or impediments to) productivity growth, some of which are organizational in nature and under management control, and others of which are institutional in nature and beyond management control but subject to public policy intervention.

Keywords: productivity, growth, measurement, dispersion, reallocation, management

1.1. Introduction

OUR objective in this chapter is to provide an overview of some important aspects of productivity analysis, many of which are addressed in subsequent chapters in this *Handbook*.

In section 1.2 we stress the economic significance of productivity growth. In subsections 1.2.1 and 1.2.2 we focus on the impact of productivity growth on business financial performance and on the growth of the aggregate economy, the two being linked by the fact that successful businesses grow, and their expansion drives growth in the aggregate economy. At each level, productivity growth has been a historically important driver of performance, although its degree of importance has varied with trends in other potential drivers and with external circumstances. In subsection 1.2.3 we assume that aggregate productivity growth occurs and ask whether this is sufficient for an improvement in economic welfare, a much broader concept than that of economic output such as gross domestic product (GDP). This leads us into the literature directed at the increasingly popular but stubbornly elusive concepts of social progress and inclusive growth.

In section 1.3 we explore definition, quantification, and implementation, the procedures through which productivity measures are obtained. In subsection 1.3.1 we define alternative measures of productivity and its rate of change, suggesting some properties that these measures might be asked to satisfy. In subsection 1.3.2 we review two approaches to quantifying productivity change: one, which we call *calculation*, (p. 4) based exclusively on quantity and price data, and the other, which we call *estimation*, based on quantity and price data augmented by economic theory. In subsection 1.3.3 we consider some implementation issues confronting statistical agencies responsible for constructing and disseminating productivity and related measures of economic activity.

In section 1.4 we introduce productivity dispersion among producers. Dispersion matters because aggregate productivity is inversely correlated with the extent of disaggregate dispersion. In subsection 1.4.1 we review the evidence, which shows productivity dispersion to be widespread. In subsection 1.4.2 we introduce productivity dynamics, which considers two possible consequences of productivity dispersion. In one scenario, market forces generate a reallocation of resources away from productivity laggards toward productivity leaders that narrows dispersion and raises aggregate productivity. In the other scenario, barriers to the working of market forces or other factors allow dispersion to persist.

In section 1.5 we consider some forces, both internal and external to business, which contribute to productivity and its dispersion. In subsection 1.5.1 we consider technology-based drivers, for which we need information on the underlying production technology. We define productivity change in terms of the technology, and we decompose productivity change into its technology-based drivers, historically the most significant of which has been technical progress, which is inferred from outward shifts in production technology.

In subsection 1.5.2 we analyze organizational and institutional drivers, the former being internal to the business and the latter being external to the business. The organizational drivers revolve around management and its practices, including human resource practices, and technology adoption strategies. The institutional drivers include various features of the business's operating environment that can enhance, as well as impede, productivity. Many of these drivers, such as the regulatory environment, are amenable to public policy intervention.

The lengthy list of references that follows is meant to serve as a readers' guide to the topics we discuss, and to encourage interdisciplinary reading.

1.2. The Significance of Productivity Growth

1.2.1. The Microeconomic Significance of Productivity Growth

Productivity growth enhances business financial performance, but its contribution is concealed by conventional financial statements expressed in current prices. This motivated Davis (1955), writing during a period of sharply rising price levels following World War II, to develop a common-price accounting framework, which he called (p. 5) "productivity accounting." This framework, in conjunction with the conventional current-price accounting framework, enabled him to isolate the contribution of productivity change from that of price change to business profit change, and it can be extended to alternative indicators of business financial performance.

Kendrick and Creamer (1961) and Kendrick (1984, 52) stressed the microeconomic significance of productivity growth, with Kendrick claiming that ". . . over the long run, probably the most important factor influencing profit margins is the relative rate of productivity advance. . . . In the short run, the effects of productivity trends may be obscured." The short-run phenomena include price movements, as Davis noted, and both Kendrick and Creamer, and Kendrick, used a variant of Davis's productivity accounting to separate the impacts of productivity advance from those of price changes. Much later, in his survey of the determinants of productivity, Syverson (2011, 327) embellished Kendrick's claim, referring to what he called a "robust" finding in the literature, namely that ". . . higher productivity producers are more likely to survive than their less efficient industry competitors . . ." and consequently productivity ". . . is quite literally a matter of survival for businesses."

However, as Davis and Kendrick noted, productivity change is not the only driver of change in business financial performance, particularly in the proverbial short run; price change matters as well, as minerals companies around the world have learned, to their joy and despair, since the year 2000. Davis (1955), Eldor and Sudit (1981), and Miller

(1984) developed models capable of decomposing change in business financial performance into the separate impacts of quantity changes and price changes, and to quantifiable changes in the operating environment as well.

Grifell-Tatjé and Lovell (2015) provide a theory-based approach to identifying the sources of change in business financial performance, an approach they summarize and extend in Chapter 9 of this *Handbook*. They first decompose profit change into quantity change and price change components. They then decompose the quantity change component into a productivity effect and a quantity margin, or replication, effect, and they decompose the price change component into a price recovery effect and a price margin, or inflation, effect. This identifies four distinct drivers of business financial performance. While the subject of this *Handbook* is productivity, a rich literature, highlighted perhaps by Winter and Szulanski (2001), stresses the significance of expansion through replication as a business strategy that has become the main driver of the financial performance of businesses such as Walmart, Starbucks, and fast food chains. Garcia-Castro, Ricart, Lieberman, and Balasubramanian illustrate the value of the replication effect for Southwest Airlines in Chapter 10 of this volume, although their replication effect differs analytically from that of Grifell-Tatjé and Lovell.

However, if profit is treated as the return to capital and expensed, as in national income accounting and in the investigation of the sources of US productivity growth by Jorgenson and Griliches (1967), and at the individual business level as advocated by Davis (1955), Kendrick and Creamer (1961), and Eldor and Sudit (1981), then the two margin effects disappear, leaving just two drivers of financial performance, productivity change and price recovery change, and replication is not an issue.

(p. 6) Lawrence, Diewert, and Fox (2006) develop an alternative analytical framework within which to analyze the impact of productivity change on change in business financial performance. They express business profit change in ratio form, and decompose it into the product of three components: productivity change, price recovery change, and change in the size of the business. Their analytical framework distinguishes primary inputs from intermediate inputs, defines business size in terms of its primary inputs, and treats profit as gross operating surplus, the difference between revenue and intermediate input expense. They apply their framework to the financial performance of Telstra, Australia's largest telecommunications provider, over the 1984–1994 decade, and find productivity growth to have been the sole driver of growth in Telstra's gross operating surplus, which was depressed by declines in the real prices of its telecommunication services. The fact that the productivity effect and the price effect work in opposite directions is not an uncommon finding, especially in extractive industries during boom and bust cycles; Topp, Soames, Parham, and Bloch (2008) recount the Australian mining experience.

From an analytical perspective, and assuming fixed prices, productivity growth leads either to an increase in output (and therefore revenue) per unit of input (and therefore cost), or to a reduction in input use (and therefore cost) per unit of output (and therefore revenue). In either case, productivity growth is lucrative, on several indicators: it increases unit revenue or it reduces unit cost; it increases profit and it increases profitability, the ratio of revenue to cost. Particularly when outputs are not under management control, it is appropriate to explore the impact of productivity change exclusively on cost or unit cost. An example is provided by the financial performance of regulated utilities that face exogenous demand and are allotted by the regulator a share of the profit they generate from cost-reducing productivity improvements.

In Chapter 15 of this *Handbook*, Cherchye, De Rock, Estache, and Verschelde trace the evolution of the use of frontier-based techniques in the analysis, and incentive-based regulation, of the performance of infrastructure industries. They provide a list of seven infrastructure industries that have been subjected to various forms of frontier-based incentive regulation in 21 countries. Of special interest is the attention they pay to the policy arenas within which incentive regulation has developed; the interaction among academics, regulators, operators, and policymakers has a long and continuing history. Against this background they propose a structural approach to performance measurement in regulated industries based on **E**conomic objectives of the participating agents, the structure of production **T**echnology, and **C**hallenges associated with information asymmetry (**ETC**). No component of ETC is known, of course, and each must be specified by the analyst, presumably constrained by the prerequisites enumerated by Agrell and Bogetoft in Chapter 16 of this volume.

Agrell and Bogetoft survey theory and techniques, predominantly frontier-based, used in regulatory benchmarking. They begin with a demanding list of prerequisites for regulatory benchmarking, a list that is relevant not just to regulatory benchmarking but to virtually all empirical economic analysis. They continue with an equally demanding list of elements underpinning the use of frontier techniques in regulatory (p. 7) benchmarking. In their dynamic yardstick model, the regulator compensates a regulated firm under evaluation with a lump sum payment minus actual cost plus a fraction of the frontier-based estimated cost savings, the latter defined as the difference between a cost norm calculated from a super-efficiency cost-frontier model based on all regulated firms, excluding the regulated firm under evaluation and the regulated firm's actual cost. The authors illustrate the workings of their models with several samples of European transmission and distribution system operators.[1]

Productivity growth also increases such commonly used financial performance indicators as return on assets (ROA) and return on equity. This extension is important because these two financial performance indicators feature prominently in the business press reporting of corporate financial performance. They also serve extensively in the academic literature, both as dependent variables in regressions attempting to identify significant drivers of business financial performance, such as ownership and governance structure, and also as independent variables in regressions attempting to quantify the impact of business financial performance on firm growth. Illustrating the latter line of research, Coad (2007) and Bottazzi, Secchi, and Tamagni (2008) provide empirical evidence bearing on the evolutionary principle of "growth of the fitter," derived from the works of

Schumpeter (1942), Alchian (1950), and Nelson and Winter (1982). The principle posits that relatively fit firms, being defined as being either more productive or more profitable than less fit firms, subsequently exhibit faster growth, thereby increasing their market share at the expense of less fit firms. Empirical support for both versions of the hypothesis is weak.

1.2.2. The Macroeconomic Significance of Productivity Growth

Microeconomic productivity growth aggregates to macroeconomic productivity growth. Fabricant (1961, xxxv) stressed the macroeconomic importance of productivity growth in stating that "[h]igher productivity is a means to better levels of economic well-being . . ." and that productivity ". . . affects costs, prices, profits, output, employment and investment, and thus plays a part in business fluctuations, in inflation, and in the rise and decline of industries." Kendrick (1961, 3) concurred, claiming that productivity growth has generated ". . . a large gain in the plane of living . . ." and an increase in ". . . the quality and variety of goods . . . while increasing provision was made for future growth. . . ."

Many scholars have studied the contribution of productivity growth to *output* growth. Schmookler (1952) attributed "about half" of growth in US output to productivity growth ("increased efficiency of resource use") over the period 1869–1938.[2] Kendrick (1961) attributed "about half" of growth in US output to productivity growth over the period 1899–1957. Denison (1962, 1974) attributed less than half of growth in US output to productivity growth over the periods 1929–1957 and 1950–1962. Something else has been driving US output growth, namely, input growth. The role of input growth in the studies (p. 8) cited in the preceding is apparent; in other studies it has been open to debate. The most-studied example may be the East Asian Miracle, in which rapid output growth in the regional economies since 1960 was, or was not, due primarily to rapid input growth, rather than impressive productivity growth. Hsieh (2002) and Felipe and McCombie (2017) summarize the debate, with the former focusing on the use of quantities or prices, and the latter focusing on the use of values related through an accounting identity, rather than quantities related through technological relationships, and concluding that the debate was "much ado about nothing."

Studies of the contribution of productivity growth to growth in *output per person* are also numerous. The relevance of output per person is emphasized by Gordon (2016), who interprets output per person as "the most accessible," though still flawed, definition of the standard of living. We return to the flaws in section 1.4. Gordon examines trends in output per person in the United States through the very long period 1890–2014. For the period 1890–1920, Gordon finds productivity growth to have accounted for approximately one-fourth of growth in output per person. This ratio tripled during the 1920–1970 period that he calls the "Great Leap Forward," and declined to approximately one-third during the 1970–2014 period, which led him to conclude that some inventions are more important than others. Crafts and O'Rourke (2013) study a number of countries over the very long period 1870–2007 and find two growth spurts, the larger, their 1950–1973 "Golden Age," roughly coinciding with the second half of Gordon's "Great Leap Forward," and the smaller during 1990–2007. Bergeaud, Cette, and Lecat (2016) also find two productivity waves over the very long period 1890–2012 in a sample of 13 advanced economies, the larger generally coinciding with Gordon's "Great Leap Forward" during 1920–1970 and the smaller occurring after 1995 and primarily in the United States. Both Gordon (2016) and Bergeaud, Cette, and Lecat (2016) emphasize that their respective larger productivity waves occurred long after the innovations that created them, such as the internal combustion engine, the assembly line, and electric light and power.

Their emphasis on lags recalls David's (1990) reaction, from the perspective of an economic historian, to Solow's (1987) famous "productivity paradox": avoid the "pitfall of unrealistic impatience," because it takes time for innovations, general-purpose technologies in particular, to diffuse through economies. Nonetheless, van Ark (2016, 4) reminds us that the productivity paradox is alive and well in the new digital economy, although he heeds the warnings of the economic historians by noting that we have not yet progressed from the installation phase to the deployment phase, ". . . when the new technological paradigm will have been widely diffused and will have become common practice across organizations, enabling its full potential in terms of economic and business growth, productivity, and profitability." Diffusion has become a recurring theme in much of the productivity literature.

In his "biography" of productivity, Hulten (2001) tracks output per person and total factor productivity (TFP) in the United States from 1779 to 1997. He finds a very different historical pattern, with the contribution of productivity growth to growth in output per person having varied widely by decade, with contributions ranging from (p. 9) 6.2% (1949–1959) to 161.7% (1859–1869). Earlier studies include Abramovitz (1956), who attributed 87% of growth in output per person in the United States to productivity growth from the 1869–1878 decade to the 1944–1953 decade, a share exactly the same as the more celebrated share calculated by Solow (1957) for growth in output per unit of labor (rather than per person, and the distinction can be economically significant) over the 1909–1949 period. The other driver of growth in output per person in these studies has been capital deepening, an increase in the capital intensity of production, although its role has been far smaller than that of input growth in studies of output growth.

One way to increase the role of input growth is to expand the list of inputs, perhaps by decomposing existing inputs. This is one approach followed in the new growth literature initiated by Romer (1986), Lucas (1988), and Mankiw, Romer, and Weil (1992), to name three of the more influential contributions. Romer emphasizes knowledge gained from an endogenous research technology, and the externalities associated with such knowledge. Lucas emphasizes human capital accumulated through education and learning by doing, and the externalities it creates. Mankiw, Romer, and Weil retain the elements of Solow's neoclassical growth model, and also emphasize human capital accumulation and the externalities it generates. Somewhat later, Hall and Jones (1999) augment physical and human capital with a host of endogenous institutions and government policies. Easterly and Levine (2001) stress the primacy of productivity growth over factor accumulation, and also emphasize the role of national policies and truly exogenous factors such as economic geography as potential growth determinants. Each of these factors, from human capital to national policies, continues to influence empirical studies of economic growth, and each appears in various chapters in the *Handbook*.

The cost-reducing impact of resource-saving improvements in technology mentioned in subsection 1.2.1 also aggregates to the macroeconomic level, where it has been used to analyze competitiveness among nations. The Organisation for Economic Co-operation and Development (OECD)[3] views a country's unit labor cost as ". . . a broad measure of (international) price competitiveness." Unit labor cost, the ratio of labor compensation to output, can be converted to the ratio of the wage rate to labor productivity. This conversion demonstrates that a country's competitiveness is dampened by increases in labor's wage (which may also be influenced by exchange rate movements) and enhanced by increases in labor productivity. Even within the European Union, with no exchange rate effect to complicate matters, competitiveness varies. German unit labor cost remained unchanged between 2001 and 2014 because increases in labor productivity compensated for increases in labor compensation per hour worked. Italian unit labor cost, on the other hand, increased by 2.3% per annum because labor productivity remained unchanged.[4] This labor-oriented concept of competitiveness extends easily to unit cost and multifactor productivity, although difficulties in measuring capital hamper its widespread application.

There is an alternative approach to evaluating the contribution of productivity change to change in a country's real income, with an analytical framework that inspired the framework developed by Lawrence, Diewert, and Fox (2006) for evaluating (p. 10) the contribution of productivity change to change in business financial performance that we discuss in subection 1.2.1. Based on the principle that an increase in a country's terms of trade (the ratio of an index of its export prices to an index of its import prices) should have a qualitatively similar impact on its real income as an increase in its productivity, Diewert and Morrison (1986) developed an analytical framework in which change in a country's real income is decomposed into the product of the value of productivity change, the value of terms of trade change, which in principle becomes more important as countries open up to international trade, and the value of primary input change. Diewert (2014) applies this model to aggregate US data over 1987–2011, and finds productivity growth and increases in primary inputs to have been the main drivers of growth in real income, with changes in the terms of trade contributing virtually nothing.

1.2.3. The Significance of Productivity Growth for Social Economic Progress

Baumol, Blackman, and Wolff (1989, 9–10) claim that "[i]n terms of human welfare, there is nothing that matters as much *in the long run*" as productivity (emphasis in the original). Prefacing their brief survey of the long run, they stress that ". . . the magnitude of the changes [in living standards] is so great that they resist comprehension." Notice that they write broadly of human welfare and living standards, not narrowly of some measure of national income, or even of national income per capita.

Productivity growth increases aggregate output, but what is its impact on broader measures of national well-being that might incorporate leisure, environmental quality, or the distribution of the national income as well as its magnitude? This question was the subject of a lively debate that occurred subsequent to the Great Depression concerning what constituted "economic progress." One group, led by Ayres (1944), defined economic progress narrowly as productivity-driven output growth. The other group, including Clark (1940) and Davis (1947), defined economic progress more broadly to augment productivity-driven output growth with rapid re-employment of resources (primarily labor) displaced by resource-saving productivity improvements, a minimum inequality in the distribution of the income created by productivity growth, the imposition of minimal social costs, and various other criteria. *The Economist* (2016b) provides a good historical introduction to "the machinery question," which refers to productivity growth that displaces labor by machinery, and which it traces back to the nineteenth-century writings of David Ricardo.

The subject of economic progress resurfaced in the 1970s with the Nordhaus and Tobin (1972) "measure of economic welfare," which adjusts aggregate output for environmental and other impacts, and has resurfaced again recently, most notably in the writings of Stiglitz, Sen, and Fitoussi (2009) on social progress, the OECD (2014, 2016a) on inclusive growth, and Gordon (2016, Chapters 1 and 18) on the conceptual gap between conventional measures of aggregate output and the standard of living, and the (p. 11) "headwinds" threatening to expand the gap in the near future. Both concepts include the impacts of productivity growth on leisure, the environment, and income inequality, as well as on output. The basic idea is unchanged: the contribution of productivity growth to output, which is measurable, can exceed or fall short of its contribution to some measure of national well-being, which is far more difficult to measure. We call change in this measure of national well-being *social economic progress*, combining the early concept of economic progress with the recent concept of social progress.[5]

In Chapter 23 of this volume, Pyo explores the complex relationships linking productivity growth and economic development, which he distinguishes from both economic growth and inclusive growth, although it has much in common with the latter concept. The distinction turns largely on the impact of productivity growth on inequality in the distributions of income and wealth, and on the extent of poverty. Although productivity, distribution, and poverty are empirically correlated, the strength of the correlation is contextual, and causality is difficult to establish. In addition, inequality and poverty are also influenced by geography, demography, and the quality of institutional arrangements such as the security of property rights, barriers to investment in physical and human capital, access to credit, and the structure (and efficacy) of the tax system. Pyo provides a detailed survey of theoretical developments and empirical evidence on the productivity–development connection.

Whatever the name, the challenge is to develop business and public policies that counter Gordon's headwinds. Banks (2015), Hsieh (2015), and the OECD (2015a, 2015b) propose a suite of public policies to promote productivity. The list is long and unsurprising, including labor and product market reforms that would lower barriers to entry and exit; promoting business investment in research and development (R&D), information and communications technology (ICT), and other forms of knowledge-based capital; promoting reforms to the financial sector that would increase access to, and reduce the cost of, capital; promoting investment in public infrastructure; lowering tariff and nontariff barriers to promote cross-border trade and investment; promoting the transfer of resources from public to private ownership; and adopting policies that would encourage the transfer of resources from the informal sector to the formal sector, particularly in poor countries where the informal sector is large. The OECD (2015a, 2015b) also recognizes that some pro-growth policies have unintended adverse consequences for the environment and economic equality, to which we now turn.

1.2.3.1. The Environment

When the environment is involved, two issues arise in relation to productivity growth. Both issues involve the question: Productivity growth increases national income, but if it has adverse environmental impacts, what is its contribution to social economic progress?

First, suppose production activity has adverse environmental impacts, such as air and water pollution, and the natural environment serves as a receptacle for the disposal of pollutants, perhaps but not necessarily because disposal is free, or priced beneath marginal abatement cost. Productivity measures that exclude these impacts generally differ (p. 12) from measures that incorporate them. On what grounds do we prefer one to the other? And how might environmental impacts be incorporated into a holistic model of productivity change? Several writers, from Førsund (2009) and Lauwers (2009) through Dakpo, Jeanneaux, and Latruffe (2016) and the studies contained in Kumbhakar and Malikov (2018), critically survey existing models and find them lacking for their neglect of the materials balance condition, which states, in Førsund's words in Chapter 8 of this volume, that "[i]f all the material inputs into an activity are not embedded in the products the activity is set up to deliver, then the difference must be contained in residuals discharged to the environment." Dakpo, Jeanneaux, and Latruffe develop a model that incorporates the generation of residuals in a way that respects the materials balance condition, and facilitates productivity measurement incorporating residuals.

In Chapter 8, Førsund surveys the literature devoted to incorporating environmental impacts in productivity modeling, critically evaluating the standard approach based on the concept of weak disposability of residuals and sketching a new approach that dispenses with the weak disposability assumption. The preferred new approach is influenced by the work of Ragnar Frisch (1965) and is still being developed. Its four key features are the following: (i) a decomposition of the output vector into intended outputs and residuals that may pollute the environment; (ii) a decomposition of the input vector into non-materials inputs used to produce the intended outputs and materials inputs that contribute to the production of the intended outputs and also are responsible for generation of the residuals; (iii) satisfaction of the materials balance condition defined earlier; and (iv) a multi-equation system derived from a pair of linked production technologies, one for the intended outputs and the other for the residuals.

After developing the model, Førsund surveys alternative regulatory approaches to environmental impacts. In this context he dismisses as "Panglossian" the Porter (1991) hypothesis, which states, loosely, that sufficiently strict environmental regulation may induce polluting firms to innovate to such an extent that pollution diminishes and, simultaneously, profit increases, making environmental regulation a win-win strategy. Albrizio, Kozluk, and Zipperer (2017) provide empirical evidence bearing on the impacts of environmental regulation on productivity. They use data from 19 OECD countries during 1990–2010 to develop an index of environmental policy stringency, which they relate to multifactor productivity at three levels of aggregation: economy, industry, and firm. At the economy level they find a negative announcement effect that is offset within three years of the imposition of more stringent environmental regulations. At the industry level they find a temporary productivity boost from an increase in regulatory stringency for technologically advanced country-industry pairs, with the effect diminishing with declining levels of advancement. At the firm level, the focus of the Porter hypothesis, they find that only the most technologically advanced firms enjoy a productivity boost from more stringent environmental regulations; the less productive third of all firms experience productivity declines.

Second, suppose natural resources such as coal, petroleum, or natural gas are used as inputs in the production process. A number of issues have been raised concerning natural resource depletion, including (i) developing environmental accounts that (p. 13) would incorporate natural resource stocks, including land and sub-soil assets, that would support environmental productivity accounting; (ii) modeling and measuring the impacts of changes in natural resource stocks on estimates of productivity change; and (iii) addressing the intergenerational issue of whether these stocks are being depleted in some optimal sense. The first issue is addressed by Førsund in Chapter 8; by Nordhaus and Kokkelenberg (1999), who trace the history to date of national income and product accounts, augmented national accounts, and integrated accounts in the United States; and by Bartelmus (2014), who refers to conventional measures of aggregate output as "environmentally and socially blind," and who relates progress, or lack thereof, in the development of an integrated System for Environmental and Economic Accounting (SEEA) at the United Nations. Bartelmus (2015) continues by noting that SEEA incorporates the interaction between the economy and natural resource depletion, and bemoans the current lack of a system of accounts that incorporates the interaction between the economy and both natural resource depletion and environmental degradation.

The second issue is addressed by Topp and Kulys (2014), who show that declines in quality-adjusted stocks of (renewable and nonrenewable) natural resources reduce estimated rates of productivity growth when the resource is both an input to and the output of a production activity. Examples include fishing and mining, in which, as resource depletion makes constant quality stocks more difficult to access, additional amounts of other inputs are required to produce a given amount of fish or mineral output, and measured productivity declines. Brandt, Schreyer, and Zipperer (2017) use a standard growth accounting framework to show that, when natural capital is not included among the inputs, input growth is under- (over-)estimated by the traditional measure when the natural input grows faster (slower) than the included inputs, and consequently productivity growth is biased upward (downward). They illustrate their analysis with data from the OECD Productivity Database, augmented with natural capital data sourced from the World Bank.

The third issue is ongoing, and recalls the famous 1980 wager, made in the wake of the "Limits to Growth" movement, between biologist Paul Ehrlich and economist Julian Simon on whether the real price of a bundle of resources would rise or fall between 1980 and 1990. The real price of the bundle of resources fell, and Simon won the bet.

1.2.3.2. Inequality

The second prominent strand in the economic progress and inclusive growth literature concerns the distribution of the fruits of productivity growth. The general question remains: Productivity growth increases national income, but if it increases inequality in the distribution of income, what is its impact on social economic progress?

Gini coefficients have increased around the world, leading to the hypothesis that productivity growth exacerbates inequality in the distribution of income. Credible evidence must distinguish between correlation and causation, and OECD (2014, 2015b, 2016a) appears to assert causation, identifying several drivers of rising income inequality, the most important being (i) skill-biased technical progress that has caused (p. 14) increasing dispersion in wages and salaries and displacement of less-skilled labor; (ii) regulatory reforms that have increased product and labor market flexibility also have contributed to increased wage inequality; and (iii) rising shares of nonwage income from capital have increased income inequality. Before exploring these three drivers, however, it is worth noting that the OECD[6] also believes that productivity growth has slowed since the global financial crisis (GFC), while inequality of income and opportunity has been growing. This admittedly short-term trend suggests a negative correlation between the two, which in turn offers cause for optimism if productivity growth reverts to trend. Nonetheless, the McKinsey Global Institute (2016), in a study of 25 advanced economies, find that two-thirds of households were in segments of the income distribution whose real incomes were flat or declined in the decade to 2014, and conclude that today's younger generation is at risk of ending up poorer than their parents. They suggest enactment of government tax and regulatory and welfare policies, but they also recommend business policies aimed at increasing productivity and growth, and reducing inequality.

Recommended business policies include adoption of existing best practices and pursuit of technological and operational innovations that expand best practices.[7]

Rising Gini coefficients are a cause for concern, but they need to be interpreted carefully. We have noted that the OECD has documented rising Gini coefficients within OECD economies. Lakner and Milanovic (2016) also document rising Gini coefficients within each of five world regions, with three more regions having incomplete data. However, they also find a declining global Gini coefficient, the ostensible conflict being attributable to the rapid growth of per capita incomes in still-low-income China and India.

Capital-skill complementarity exists, as Griliches (1969) pointed out long ago, and it is by no means a recent phenomenon, as Goldin and Katz (1998) have demonstrated. In addition, improvements in technology tend to be biased, using capital and skilled labor and saving less-skilled labor, as demonstrated by Krussell, Ohanian, Ríos-Rull, and Violante (2000). This combination of bias and complementarity motivates the first driver of rising income inequality mentioned in the previous paragraph. Brynjolfsson and McAfee (2014) express optimism for skilled labor but pessimism for less-skilled labor. Frey and Osborne (2013) paint a gloomy picture, predicting that computerization will put at risk of displacement nearly half of US employment, the half performing manual and/or routine tasks, a prediction that has earned them the moniker “techno-pessimists.” Autor (2015) and Mokyr, Vickers, and Ziebarth (2015) review the history of automation, unemployment, and re-employment, and take a different view. While automation, through computerization, robotics, and artificial intelligence, does displace labor, it also complements labor, eventually raising output, the demand for (different types of) labor, and employment. Autor usefully distinguishes jobs from tasks, noting that while manual and routine tasks disappear, many jobs that require multiple tasks that cannot easily be unbundled survive. The OECD (2016a) traces the second driver to the fact that labor market liberalization creates nonstandard forms of work having relatively low wages and benefits, thereby putting upward pressure on inequality. *The Economist* (p. 15) (2016a) emphasizes the third driver, arguing that the productivity dividend is being hoarded, ending up as business retained earnings rather than being invested in growth- and employment- boosting activities, an observation that is repeated frequently.

In a fascinating juxtaposition of rock & roll and economics, Krueger (2013)[8] provides a wealth of secondary information on income distribution in the music industry and in the US economy. He views the music industry as a microcosm of the economy, buffeted by technological changes, scale, luck, and an erosion of social norms, which compress prices and incomes, all of which have contributed to an increasingly skewed artist income distribution. As for the economy, he finds (i) all family income quintiles experienced over 2% annual growth during 1920–1979, but only the top quintile experienced over 1% annual growth during 1979–2011, and the bottom quintile experienced a decline; (ii) the share of income earned by the top 1% has roughly tripled, to 18%, since 1970; (iii) the ratio of CEO to average worker compensation has increased tenfold, to over 200-to-1, since 1970; and (iv) profitable companies pay all employees well, janitors as well as managers, suggesting that growing inequality originates between companies rather than within them. He concludes by expressing concern that rising inequality may have adverse consequences for future economic growth.

Song, Price, Guvenen, Bloom, and Wachter (2015) develop an analytical framework that enables them to decompose wage dispersion into between-firm and within-firm wage components. Their empirical findings, obtained from a matched employer-employee data set covering all US firms during 1978–2012, reinforce Krueger's final point; rising aggregate wage inequality is due exclusively to increasing inter-firm wage dispersion, since within-firm wage dispersion has been stable. The authors do not take the obvious next step of inquiring whether firms paying higher wages are also more productive. Doing so might shed light on the productivity dispersion literature we discuss in section 1.4.

In Chapter 9 of this volume, Grifell-Tatjé and Lovell adopt a standard growth accounting framework for measuring productivity change, the mirror image of which is a framework for analyzing the distribution of the value created by productivity change. Productivity growth creates value, which is distributed to consumers (in the form of product price reductions), to labor and other input suppliers (in the form of increased remuneration), and to the business itself (in the form of increased profit, which management allocates to interest, taxes, depreciation, amortization (ITDA) and retained earnings). Product price reductions and input price increase spur growth, as does business investment arising from profit increases. Distribution of the fruits of productivity growth was the principal concern of Vincent (1968), the French public institution CERC (Centre d'Études des Revenus et des Coûts) (1969), and other prominent French scholars who studied distribution at French public firms such as Electricité de France. Grifell-Tatjé and Lovell (2015) survey the extensive French literature. This growth accounting framework supports an analysis of the impacts of price changes on the functional distribution of income, which in turn forms the basis of an analysis of trends in the inequality of the functional distribution of income that can address the drivers identified by OECD and the hoarding issue raised by *The Economist*.

(p. 16) We conclude the discussion of income distribution by acknowledging that the income distribution dual to the productivity model characterizes the *functional* distribution of income among groups who perform a productive service that contributes to value creation, whereas much of the income inequality evidence pertains to the *size* distribution of income among groups of individuals, income deciles for example, regardless of what, if any, function they perform. The US Bureau of Labor Statistics (BLS)[9] reports that labor's share of value added in the US private business sector has declined from 0.67 to 0.62 from 1987 to 2014, a decline of nearly 7%, which documents a declining labor share in the functional distribution of income, but says very little about rising inequality in the size distribution of income in the United States. At the other extreme, the OECD (2014, 2016a, 2016b) provides extensive documentation of rising inequality in the size distribution of income in most OECD countries using a Gini coefficient based on "equivalised household disposable income," which, conversely, says very little about trends in the functional distribution of income within countries. Garvy (1954) attempted to reconcile the differences between the two concepts of income distribution, and Fixler and Johnson (2014) search for evidence on the size distribution of income in the US national accounts. Additional research that would reduce, or at least clarify, the gap between the two measures of income distribution would enlighten the inequality debate.

1.3. Productivity Measurement

Evaluating the significance of productivity growth, as in section 1.2, requires defining productivity and then quantifying it, which in most instances can be achieved in either of two quite different ways. We consider how to define productivity in subsection 1.3.1, and we consider two approaches to quantification of productivity change in subsection 1.3.2. In subection 1.3.3 we consider how productivity measurement is implemented by statistical agencies, and we discuss two important measurement problems that must be addressed.

1.3.1. Definitions

In general, productivity is defined as a ratio of output to input Y/X, with Y an output aggregator and X an input aggregator. An index of productivity change can be expressed as the ratio of an output quantity index Y^{t+1}/Y^t to an input quantity index X^{t+1}/X^t, with t a time indicator, or as a rate of growth $G_{Y/X} = G_y - G_x$, with G a growth rate. Setting $X = X(L)$ generates a popular partial productivity measure $Y/X(L)$, with $X(L)$ either a scalar (e.g., hours worked) or a scalar-valued aggregate of various characteristics of labor. Setting $X = X(K, L)$ in a value added context or $X = X(K, L, E, M, S)$ in a gross output context generates a pair of multifactor productivity (MFP) measures $Y/X(K, L)$ (p. 17) and $Y/X(K, L, E, M, S)$. In each case, an index of productivity change is defined as in the preceding. Balk (2009) and OECD (2001a) explore the relative merits of the value added and gross output MFP indices. As Eldridge, Sparks, and Stewart note in Chapter 3 of this *Handbook*, the BLS publishes KLEMS-based MFP tables for US manufacturing and non-manufacturing sectors and industries for the period 1987–2014.[10]

In Chapter 20 of this volume, Jorgenson provides an introduction to the World KLEMS Initiative and its regional components for making international productivity comparisons at the industry level. Jorgenson relates the history of the Initiative, and provides details on the KLEMS framework for productivity measurement, including procedures for developing constant quality indices of the primary labor and capital inputs. A critical component of the Initiative, not relevant to intra-country data construction exercises, is the use of purchasing power parities, as distinct from market exchange rates, to link international currencies. He provides an empirical application of the Initiative with an industry-level productivity comparison of Japan and the United States. Inklaar uses the EU KLEMS database in his study of productivity and convergence in Chapter 22 of this volume.

MFP measures are generally preferred to partial productivity measures, but there are exceptions to the general rule. The most prominent exception occurs when labor is the only measurable input comparable across producers, as is frequently the case with international comparisons. A second exception occurs when the focus is on inequality in the size distribution of income, in which case labor productivity may be the relevant productivity indicator. These two exceptions intersect in OECD (2016b), in which declining labor productivity growth rates are contrasted with rising labor income inequality in both OECD and non-OECD countries.

Firfiray, Larraza-Kintana, and Gómez-Mejía offer a third exception in Chapter 11. They study family-controlled firms, in which non-economic objectives are important. These objectives include an emotional attachment to the firm, a desire to maintain control of the firm, and a desire to hand the firm down to future generations, a practice that Caselli and Genaioli (2013) call "dynastic management"; these objectives are collectively referred to as the protection of socioemotional wealth (SEW). The authors develop a framework in which SEW protection may be a significant factor explaining differences in labor productivity between family and nonfamily firms, and among family firms of varying sizes. They hypothesize that varying SEW priorities lead to variations in leadership styles, capital investment decisions, the role of nonfamily managers, and human resource management (HRM) practices, which combine to generate labor productivity dispersion; on productivity dispersion, see also subection 1.4.1, and on HRM practices see also subsection 1.5.2.

Grifell-Tatjé and Lovell (2004) offer another motivation for using labor productivity. Following the cooperative literature inspired by the Illyrian firm of Ward (1958) and the Soviet collective farm of Domar (1966), they analyze the dividend-maximizing behavior of Spanish cooperative financial institutions. The dividend each employee receives consists of a wage plus the share of each employee in profit after taxes and interest. Change in the dividend decomposes into the product of labor productivity change, input deepening change, and price changes, making labor productivity change a driver of change in cooperative financial performance.

(p. 18) Bryan (2007, 1) proposes an intriguing indirect motivation for the use of labor productivity. He notes that the most valuable assets a firm has are not tangible physical assets but intangible assets such as ". . . the knowledge, relationships, reputations and other intangibles created by talented people and represented by investments in such activities as R&D, marketing and training." Unlike most writers on intangible capital, Bryan treats this asset as a component of the labor input, rather than of the capital input. This motivates him to propose replacing the popular return on (tangible physical) assets financial indicator with return on employees, because talent embedded in a company's employees is the ultimate profit driver. It is easy to show, using a modified duPont triangle approach, that profit per employee can be expressed as the product of the conventional profit margin on revenue and the revenue productivity of labor. For more on revenue productivity, see section 1.4.

The standard MFP concept can be extended to the concept of dynamic productivity. The essential difference is that in a standard productivity model, resources available in a period are used exclusively to produce final outputs in that period, whether or not the productive capacity of those resources is fully utilized, whereas a dynamic productivity model allows a reallocation of resources through time, with some resources available in a period being withheld from current production and made available for use in producing final outputs in a subsequent period. Another feature of a dynamic productivity model is its incorporation of intermediate inputs; produced outputs in a period can be consumed as final output, as in a standard productivity model, or saved and used as intermediate inputs in a subsequent period. A third feature of a dynamic productivity model is its property of time substitution, which allows firms to choose when to begin and cease production, and how intensely to produce; for example, technical progress encourages firms to delay production. The definition of productivity change remains unchanged as $G_{Y/X} = G_y - G_x$, although the contents of Y and X are modified to incorporate the elements of dynamic productivity.

In Chapter 5 of this volume, Färe, Grosskopf, Margaritis, and Weber build on previous work of Shephard and Färe (1980), and Färe and Grosskopf (1996), to develop a dynamic production technology and to define standard and dynamic performance measures that allow for reallocation of resources through time. They derive a dynamic productivity index, decompose it into measures of dynamic efficiency change and dynamic technical change, and relate dynamic efficiency change to standard efficiency change. They provide an empirical application to 33 OECD countries over the period 1990–2011. A comparison of dynamic and standard productivity indices shows slightly faster dynamic productivity growth, due to faster dynamic technical progress. The authors refer to related research, to which additional empirical work would add value.

1.3.2. Quantification

Once productivity is defined, it must be quantified, which requires specification of functional forms in two quite different contexts. In one context, quantities and prices are (p. 19) observed, and we require a functional form that combines them. In the other context, economic theory constrains the behavior of quantities, or of quantities and prices, and we require a functional form that also incorporates the constraints imposed by theory.

1.3.2.1. Calculation

One approach to quantification is through *calculation*, which involves the use of market prices, or proxies for them, to weight individual output and input quantity changes in the calculation of aggregate output and input quantity indices. This procedure generates price-based *empirical* productivity indices (the most popular being the asymmetric Laspeyres and Paasche indices, and the symmetric Edgeworth-Marshall, Fisher, and Törnqvist indices). Mills (1932), Fabricant (1940), Kendrick (1961), and many others have calculated productivity change using quantities and prices to construct empirical indices of output, input, and productivity. Mills used Fisher indices, while Fabricant and Kendrick used Edgeworth-Marshall indices.

In Chapter 2 of this *Handbook*, Balk explores empirical quantity and price indices, so named because they can be calculated directly from observable quantities and prices. He specifies a set of desirable properties that empirical quantity and price indices should satisfy, including non-negativity, monotonicity, homogeneity, and units-invariance. He uses quantity and price indices to decompose change in profitability, the ratio of revenue to cost, into the product of an MFP index *Y/X* and a price recovery index *P/W*, and he relates this decomposition of profitability change to growth accounting techniques. He discusses the relationship between gross output and value added productivity indices, he relates partial productivity indices to MFP indices, and he discusses aggregation of productivity indices over producers.

Empirical index numbers are expressed in ratio form, and are employed throughout the *Handbook*. However, Bennet (1920) demonstrated that it is also possible to express quantity change, price change, and productivity change in difference form as quantity, price, and productivity indicators. Bennet’s indicators can be expressed as the difference analogue to Fisher’s indices. In Chapter 2, Balk specifies a set of desirable properties that empirical quantity and price indicators should satisfy, analogous to those that empirical quantity and price indices should satisfy; Balk (2008) provides details. He then uses quantity and price indicators to decompose change in profit, the difference between revenue and cost, into the sum of a productivity indicator and a price recovery indicator. In Chapter 9 of this volume, Grifell-Tatjé and Lovell relate productivity indicators, expressed in difference form as value changes, to productivity indices, expressed in ratio form as pure numbers. This relationship has the virtue of translating an index of productivity change to its contribution to a firm’s bottom line, as Davis (1955) first showed.

1.3.2.2. Estimation

An alternative way of quantifying productivity growth is through *estimation* of some underlying technological relationship involving quantity and/or price data, which generates estimates of *theoretical* productivity indices and indicators. Estimation relies heavily on developments in economic theory that suggest particular functions to be (p. 20) estimated, and their properties to be imposed or tested, typically monotonicity, curvature, and homogeneity. Estimation can be based on either econometric techniques popular in economics or mathematical programming techniques popular in management science, and both techniques are utilized in the *Handbook*. Thus scholars have estimated functional forms for production functions and dual-value functions such as cost, revenue, and profit functions to obtain estimates of theoretical indices of output, input, and productivity. Each of these functions can be extended to frontiers that bound, rather than intersect, the data, thereby providing an additional potential source of productivity change or variation, namely change or variation in the efficiency with which any assumed economic objective is pursued. The econometric approach to frontiers, known as stochastic frontier analysis (SFA), was pioneered by Aigner, Lovell, and Schmidt (1977) and Meeusen and van den Broeck (1977), and the mathematical programming approach, known as data envelopment analysis (DEA), was pioneered by Charnes, Cooper, and Rhodes (1978). Sickles and Zelenyuk (forthcoming) develop a frontier framework for productivity measurement and estimation using both SFA and DEA methodologies and their extensions, and for both primal and dual approaches.

In Chapter 4 of this volume, Russell explores theoretical productivity indices, so named because they are defined on well-behaved but unobserved production technology and must therefore be estimated. He discusses the properties that a well-behaved technology satisfies, defines Shephard’s (1953, 1970) distance functions on the technology, and enumerates properties satisfied by distance functions, including monotonicity and homogeneity. He uses distance functions to define the technical efficiency of production, and to define technical efficiency change and technical change, the product of which can be interpreted as a theoretical index of productivity change. He defines and decomposes two different productivity indices named after the Swedish statistician Sten Malmquist. He also defines and decomposes a dual, cost-based, productivity index, which has the virtue of allowing change in allocative, as well as technical, inefficiency to be a driver of productivity change.

Productivity growth, whether calculated or estimated, accounts for a variable share of economic growth. Debates among researchers on the primary sources of economic growth and development have often been centered on two basic explanations rooted in the decomposition of economic growth sources: factor-accumulation and productivity-growth components. Kim and Lau (1994), Young (1992, 1995) and Krugman (1994), among others, pointed out that rapid economic growth in the emerging areas of the world such as East Asia was largely explained by the mobilization of resources. Alternative explanations to the neoclassical growth model explain economic growth not only in terms of intensive and extensive utilization of input factors, but also due to factors that impact the degree to which countries can appropriate the productivity potential of world technical innovations. Factors such as governmental industrial policies, trade liberalization policies, and political, religious, and cultural institutions are often viewed as central to the ability of countries to catch up with a shifting world production possibilities frontier.

(p. 21) Exogenous productivity growth was the prevailing modeling assumption until the endogenous growth model put forth by Romer (1986) took hold in the late 1980s. The sources of the endogenous growth, often expressed in a reduced form equation that shifts the production function over time, were typically spillovers of one sort or another. For example, if R is such a variable or set of variables, then the production function can be written as $Y = A(R)f(K, L, R)$. The various possible sources of the spillover differentiate much of the endogenous growth literature, at least at the macroeconomic level. For example, Arrow (1962) emphasized learning by doing. For Romer (1986) the endogeneity came from the stock of research and development. For Lucas (1988) it was the stock of human capital. A major source of post–World War II economic growth has been innovation in the form of technological change.

There is, however, another interpretation for the reduced-form endogenous technology term in the modern productivity model, specifically the presence of inefficiency. Suppose one defines the endogenous factor in productivity growth as simply a country's or firm's differential ability to loosen the constraints on the utilization of the existing world technology. With this interpretation of endogenous productivity effects, Sickles and Cigerli (2009) show that TFP growth is determined by the efficiency with which the existing technology (inclusive of innovations) is utilized.

Production spillovers have important implications for economic growth and for its management. If any type of investment whose gains are not internalized by private agents impacts long-run growth, then there is no unique long-run growth path and thus no so-called golden rule. From a public policy perspective, spillovers provide a clear role for government intervention. Government intervention may take many forms if investment is too low from society's perspective. Investment tax credits or R&D grants are two traditional forms of government intervention. However, government intervention may also take the form of relaxing constraints on businesses via deregulatory reforms, reduced red tape, private-sector market reforms, or any other aspect of the institutional and political mechanism established in a country and its markets that increase A(R) in the production function. The latter set of external effects can be summed up as governmental actions that reduce constraints, or efficiency-enhancing investments. If one examines the new growth paradigm more closely, it must be recognized that it is indistinguishable empirically from the stochastic frontier model wherein A is an efficiency term. A substantial engine of economic growth has been efficiency change. As pointed out by Abramovitz (1986), Dowrick and Nguyen (1989), and Nelson and Wright (1992), among many others, the major sources of country growth differentials in the developed countries after World War II can be explained by the neoclassical growth model amended to include such endogenous factors as knowledge spillovers, technological diffusion, and convergence to a best-practice production process (Smolny 2000). The "new growth theory" implicitly recognizes the role of efficiency in production. One set of papers that provides an explicit efficiency interpretation of this growth process is Hultberg, Nadiri, Sickles, and Hultberg (1999), Ahn, Good, and Sickles (2000), and Hultberg, Nadiri, and Sickles (2004), who introduce inefficiency into the growth (p. 22) process. Of course the standard neoclassical model without explicit treatment of efficiency has been used by many authors in examining growth and convergence.

Endogenous growth also has been addressed using formal spatial econometric specifications based on both average production/cost models as well as frontier production/cost models. Models that extend the multiplicative spillover effects by expanding A(R) by framing production in a spatial autoregressive setting in order to address network effects or trade flows among countries have been formulated by Ertur and Koch (2007) and Behrens, Ertur, and Koch (2012). More general stochastic frontier treatments that do not force efficiency on the productive units, whether they are countries, states, or firms, have been introduced by Druska and Horrace (2004) in the cross-sectional setting, and for the panel model in a series of papers by Glass, Kenjegalieva, and Paez-Farrell (2013), Glass, Kenjegalieva, and Sickles (2016a, 2016b), and Han, Ryu, and Sickles (2016).

1.3.3. Implementation

Statistical agencies around the world *implement* the measurement of productivity and related economic variables. They have their choice of calculation or estimation approaches, and they make budget-constrained choices concerning what approach(es) to use, what variables to include, and what sectors of the economy to cover.

In Chapter 3 of the *Handbook*, Eldridge, Sparks, and Stewart discuss how labor productivity and MFP indices are constructed at the BLS.[11] The BLS also publishes related data on labor compensation, unit labor costs, and labor's share, and is engaged in a number of projects designed to expand its range of data products, as outlined in Chapter 3. The OECD (2001a) covers similar ground in much greater detail, and also provides links to a number of national statistical agencies that provide similar services.[12]

Long ago, Denison (1962, 1974) pointed to a factor that confronts implementation of productivity measurement, namely variation in the quality of inputs. He decomposed growth of the labor input into several sources, including hours worked, the age-sex composition, and educational attainment, and he decomposed growth in the capital input into inventories, structures and dwellings. These adjustments previewed those currently employed at the BLS, which decomposes growth in the labor input into hours and a composition effect (accounting for age, education, and gender), and decomposes growth in the capital input into productive capital stock and a composition effect (accounting for the contributions of information processing equipment, R&D, all other intellectual property products and all other capital services). Over the 1987–2015 period in the US private business and nonfarm business sectors, the two composition effects account for about 40% of total input growth.[13] Eldridge, Sparks, and Stewart show the contributions of the two composition effects to labor productivity growth in the private business sector over the 1987–2014 period and several subperiods. Eldridge, Sparks, and Stewart explain the two quality-adjustment procedures employed by the BLS, and the (p. 23) OECD (2001a) devotes two chapters to the adjustment of labor and capital inputs for variation in various measures of quality.

Bushnell and Wolfram (2009) provide an empirical example based on the performance of the operators of five US power plants, demonstrating the importance of variation in the quality of a single key employee, the plant operator, for power plant performance. The plant operator is responsible for the monitoring and control of the combustion process, an integral element of the conversion of potential energy in fuel into electrical energy that also includes processing and monitoring of emissions and other waste products. Using hourly data on fuel burned and power output for individual plant operators, they find a statistically significant positive "operator effect" on fuel efficiency, the ratio of electricity output to fuel input, and they calculate that if all operators at these five plants improved to best practice, fuel cost savings of $3.5 million per year could be achieved. This operator effect is analogous to the "good captain hypothesis" explored by Alvarez and Schmidt (2006) and Wolff, Squires, and Guillotreau (2013) for captains of Spanish and French fishing vessels. This hypothesis asserts that differences in catches among vessels are due to differences in the skill of skippers, rather than to luck and other factors such as weather. Although the analytical framework varies across the three studies, in each study variation in labor quality is not accounted for prior to the empirical exercise. Rather, since quality is difficult or impossible to measure, it is inferred from empirical findings. Power-plant operator and fishing-vessel skipper performance provide ex post measures of variation in the quality of a crucial input.

The quality issue is equally relevant on the output side, as Fabricant (1940, 1961) emphasized. The BLS accounts for quality change in outputs in a number of ways, as described in Chapter 3.[14] The importance of accurate output measurement was highlighted by the Boskin Commission Report (Boskin et al. 1996), which argued that the US rate of inflation had been overestimated, and consequently the rate of real output growth had been underestimated, by 0.6% per annum prior to 1996 due to a failure to incorporate new outputs and improvements in the quality of existing outputs in a timely fashion. The qualitative impact this has on productivity measurement is clear, and to imagine the quantitative impact, try compounding 0.6% per annum over a generation. Output measurement accounting for quality change was the main focus of the contributions to the Griliches (1992) volume, each of which focused on a segment of the growing service sector. The general finding of these studies mimics that of the Boskin Commission Report: the inability to fully account for quality change in continuing products and the introduction of new goods leads to an understatement of output growth and productivity growth.

In some sectors, output measurement is notoriously difficult. Griliches (1994) lamented the fact that these "unmeasurable" sectors were growing, which made productivity measurement increasingly difficult. Indeed outputs in these sectors are difficult to define, much less measure. Education, health care, financial services, the judiciary (Peyrache and Zago 2016), tax agencies (Alm and Duncan 2014), the provision of public safety (Carrington, Puthucheary, Rose and Yaisawarng 1997), and municipal solid waste collection and disposal (Pérez-López, Prior, Zafra-Gómez, and Plata-Díaz 2016) are (p. 24) prominent examples, most of which occur in the public, or non-market, segment of the economy. In these sectors the definition of the service being provided is unclear, and quality concerns loom large. The Atkinson Report (2005) and Schreyer (2012) explore various measurement options.

Zieschang discusses productivity measurement in sectors with hard-to-measure output in Chapter 6. He follows the OECD to define these sectors to include high technology industries, real estate, and services, which in turn include distributive services, financial services, health care, and education. He cites three central elements of these sectors: difficulties defining the characteristics associated with outputs, a scarcity of information on the production and accumulation of intellectual property assets, and a lack of sufficiently frequent transactions to permit market valuation. He then uses a capacity utilization function to develop a Fisher-perspective quality-adjusted MFP index that is conditioned on these elements, and he discusses some properties of this index. He then develops a translog approximation, which is exact under certain conditions. He also discusses issues raised by new and disappearing products, and changes in the scope of output, intermediate input, and primary services.

Diewert discusses productivity measurement in the public sector in Chapter 7, with a micro orientation toward individual service providers. He analyzes three scenarios: (i) neither output quantities nor output prices are available; (ii) output quantity information is available but output price information is not; and (iii) both output quantity and output price information are available. In the first scenario he proposes to set output growth equal to input growth, in which case productivity growth is zero by construction. In the second scenario he proposes to value outputs either at their unit costs of production, which confronts a difficult cost allocation challenge, or at purchasers' valuations, which he interprets as quality adjustment factors. Both output valuation options allow for non-zero productivity change. In the rare third scenario conventional productivity measurement techniques are applicable. He devotes most of his attention to the first and second scenarios, in which conventional techniques cannot be applied, and ingenuity is required. In this context he places particular emphasis on the challenges confronting productivity measurement in the education, health care, infrastructure, distribution, and public transportation sectors.

In Chapter 17 Lefebvre, Perelman, and Pestieau adopt both micro and macro orientations toward public-sector performance assessment. At the micro level they contrast output, input, and exogenous data that are available for productivity measurement with "ideal" data in rail transport, waste collection, secondary education, and health care.

Unsurprisingly, they find available data to be deficient, particularly for their lack of quality information and their failure to incorporate institutional features. At the macro level, they discuss the evaluation of the performance of 28 European welfare states and their evolution through time. The welfare state is a subset of the public sector, with its performance evaluated by indicators of poverty, inequality, unemployment, early school leavers, and life expectancy. Performance is defined as a function of these five indicators, without regard for welfare spending, so that performance coincides with a quantity index of outcomes only. The authors construct three performance indices, one based (p. 25) on simple unweighted aggregation of scaled indicators used in the original Human Development Report, and a pair of “benefit of the doubt” indices obtained from variants of DEA, in which countries are evaluated on the basis of their ability to maximize the provision of the five welfare-enhancing indicators. They use these indices to estimate change in welfare outcome through time, which grows slightly faster prior to the GFC than after it, and which they use to allocate performance change to improvements in best practice and to catching up, respectively, an exercise related to the “distance to frontier” literature we discuss in subsection 1.4.2. They continue by conducting a test of the cross-country convergence hypothesis, with convergence referring to welfare outcome performance rather than productivity performance, as Inklaar discusses in Chapter 22. They reject the welfare outcome convergence hypothesis.

When public sector output quantities are available but output prices are not, one strategy suggested by the Atkinson Report, and reiterated by Diewert in Chapter 7, is to use unit costs of production as proxies for output prices. Grifell-Tatjé and Lovell (2008) study productivity and financial performance at the US Postal Service (USPS) over the period 1972–2004. The USPS reports revenue and an output quantity index, and cost and input quantity indices, which Grifell-Tatjé and Lovell use to construct implicit output and input price indices; as there is a single output quantity index, the cost allocation problem is avoided. They also estimate an efficient unit cost index as an alternative to the implicit output price index to test if the implicit output price index reflects (diminishing) monopoly power. They find the difference between the two proxies to have been small and statistically insignificant over the period 1972–2004.

There is another scenario in which unit costs have been used to weight outputs, namely in the private sector when output prices are available but are thought to be distorted, by market power or cross-subsidization, for example. Caves, Christensen, and Swanson (1980) used the neoclassical growth accounting framework to contrast two estimates of US railroad productivity growth during 1951–1974: (i) the conventional approach based on growth in outputs weighted by observed revenue shares that reflect cross-subsidization of passenger service by freight service; and (ii) growth in outputs weighted by estimated cost shares that reflect the structure of production technology. They found, exactly as economic theory predicts, that the replacement of observed revenue share weights with estimated cost share weights reduced the estimated rate of productivity growth from 3.6% per annum to 1.5% per annum.

Ironically, a decade after Griliches (1994) lamented the growing “unmeasurable” sector and the publication of the Boskin Commission Report (1996) on difficulties in output measurement, Corrado, Haltiwanger, and Sichel (2005) argued that the fraction of capital that is difficult to measure, accounted for by intangible capital rather than physical capital, which itself is difficult enough to measure, also was growing through time, and also makes accurate productivity measurement increasingly difficult. Measurement difficulties have led the national accounts to treat expenditure on most components of intangible capital as an intermediate expense rather than as investment, which Corrado, Haltiwanger, and Sichel note has potentially serious implications for empirical analyses of business performance and the sources of aggregate economic growth.

(p. 26) Corrado, Hulten, and Sichel (2005) identify three categories of intangible capital: business investment in computerized information (computer software), innovative property (scientific and non-scientific R&D), and economic competencies (brand equity and firm-specific resources such as organizational capital). Well-established complementarities among various types of intangible capital, and between them and various types of labor skills, mean that organizational capital and skilled labor tend to be bundled in successful businesses, making productivity measurement even more challenging. Nonetheless Corrado, Hulten, and Sichel (2009) accept the challenge by constructing time series data for intangible capital and its three categories, and estimating their contributions to labor productivity growth in the US nonfarm business sector. They find intangible capital deepening to have accounted for about one-quarter of the 1.63% annual labor productivity growth during 1973–1995, and to have accounted for the same share of the much more rapid 3.09% annual labor productivity growth during the subsequent 1995–2003 period. Corrado and Hulten (2014) find similar results for US private industry over the longer 1980–2011 period, with intangible capital deepening accounting for 27% of labor productivity growth.

Niebel, O’Mahoney, and Saam (2017) adopt a similar approach to estimating the contribution of “new intangibles” to sectoral labor productivity growth in the European Union during 1995–2007. Their new intangible assets are distinct from ICT assets, and include scientific R&D, firm-specific human capital, and expenditure on market research and advertising, among other components. Their data exhibit considerable variation in the contribution of new intangible assets to labor productivity growth across sectors and countries. Their econometric growth accounting exercise generates statistically significant elasticities of new intangibles on the order of 0.12–0.18, with these estimated elasticities exceeding their factor shares, suggesting the potential for productivity-enhancing resource reallocation.

1.4. Productivity Dispersion

Productivity dispersion originates at the individual firm, or even plant, level. Its analysis can be traced back to Schultz (1964, 1975), who studied the ability to rectify disequilibria, departures from satisfaction of first-order optimization conditions. A popular measure of dispersion is a "productivity gap," expressed as a ratio or a difference, between best and worst performance, or between 90th and 10th deciles, or the interquartile range. Another popular measure is the second moment of the productivity distribution. Productivity dispersion is important because it constrains aggregate productivity; in a widely cited illustration, Hsieh and Klenow (2009) calculate that if productivity dispersion in China and India were reduced to that found in the United States, aggregate productivity would increase by 30%–50% in China and by 40%–60% in India. Much of the literature is devoted to the identification of the sources of productivity dispersion and the promulgation of policies aimed at its reduction.

(p. 27) In Chapter 18 of the *Handbook*, Bartelsman and Wolf survey alternative measures of productivity dispersion and discuss statistical and economic issues involved in measuring it. They distinguish the preferred physical MFP measure (TFPQ) from the more common revenue factor productivity measure (TFPR) imposed by the data constraint, and they discuss sources and consequences of divergence between the two measures. The problem is that TFPQ (when establishment-level output prices are observed) is an empirical productivity index, but TFPR (when establishment-level output prices are unobserved, and are replaced by an industry output price index common to all producers) is not an empirical index number but often is the only available measure. Revenue productivity is a value rather than a physical concept, which can lead to erroneous inferences about productivity and its dispersion if individual producer prices vary. They also discuss a range of statistical issues that arise in estimating productivity and its dispersion, including endogeneity of input choice and how to deal with it, the use of cost elasticities in growth accounting methods when first-order conditions are violated, the use of stochastic frontier techniques, and how to reduce sensitivity to ubiquitous measurement error. They also provide new evidence of productivity dispersion derived from US and European data. They find similarly large interquartile ranges in the United States and Europe, and less dispersion in gross-output productivity measures than in value-added productivity measures. They attribute much of the observed productivity dispersion to country and industry fixed effects. The productivity dispersion literature is not alone in searching for institutional and other factors behind country, industry, and time fixed effects. The entire productivity literature is, typically of necessity, inundated with unobserved heterogeneity controls, and consequently so is this chapter. Their replacement with variables reflecting the institutional and other sources of these effects would add considerable insight to empirical studies of productivity and its dispersion.

The distinction between TFPQ and TFPR arises frequently in the large sample segment of the productivity dispersion literature. Collard-Wexler and De Loecker (2015) show that dispersion and reallocation findings can be extremely sensitive to whether or not one controls for establishment-level price variation, which they suggest would signal variation in mark-ups reflecting market power rather than variation in productivity. They, and Andrews, Criscuolo, and Gal (2016), employ a mark-up correction developed by De

Loecker and Warzynski (2012) to convert estimates of TFPR to estimates of TFPQ. Andrews, Criscuolo, and Gal (2016) find differential mark-ups to have accounted for a small portion of the rising productivity gap between frontier and laggard firms in the OECD since 2000. A similar consideration (and an analogous correction) arises on the input side, although the input side remains less frequently studied. De Loecker, Goldberg, Khandelwal, and Pavcnik (2016) develop an analogous framework for correcting for input price variation in a context in which trade reform influences mark-ups through both output and input tariff reductions. Bartelsman and Wolf refer to the issue in Chapter 18.[15]

Price variation need not reflect variation in market power. Another possibility, frequently discussed in the management literature, is that price variation may reflect variation in the willingness to pay of consumers for customized products, which in turn (p. 28) reflects the business strategy of the seller(s). Niche markets are common, with mobile telephones a prominent recent example highlighted in *The Economist* (2016c). The willingness-to-pay approach to business strategy was introduced by Brandenburger and Stuart (1996), with the difference between consumers' willingness to pay and sellers' opportunity cost providing a measure of the value created by businesses and its distribution, a subject we discuss in subsection 1.2.3. From this broad perspective based on business strategy, it is not surprising to find evidence of productivity dispersion. Business seeks profit-driven survival, to which end alternative business strategies generate varying productivities. It would be useful to confine an investigation into productivity dispersion to businesses following similar strategies, since then observed productivity dispersion would reflect varying success in implementing similar strategies, and would signal varying financial performance. This is essentially the approach followed in the productivity convergence literature, with convergence being either unconditional or conditioned on country-specific variables, as exemplified by Rodrick (2013). In this case, conditioning would be on variables characterizing alternative business strategies.

However it is measured and whatever its sources, evidence of productivity dispersion has accumulated for over a century, leading Syverson (2011) to characterize inter-plant and inter-firm productivity gaps as "ubiquitous, large and persistent." We survey this evidence in subsection 1.4.1. In subsection 1.4.2 we explore productivity dynamics, the intertemporal behavior of productivity dispersion. In some circumstances, market forces lead to a *reallocation* of resources that reduce productivity dispersion, while in others dispersion can be long-lasting, or *persistent*, and even increase.

1.4.1. Evidence

The BLS began publishing its *Monthly Labor Review* in 1915. Early issues contained numerous empirical studies of (usually labor) productivity dispersion at the plant and company levels. In one study covering 11 sawmills and five production processes, Squires (1917) found inter-plant labor productivity gaps within narrowly defined processes (e.g., tree felling and log-making) in excess of 5 to 1, and unit labor cost gaps ranging from 4 to 1 to 12 to 1. Stewart (1922, 3), US commissioner of labor statistics at the time, summarized numerous similar inter-plant studies across a range of industries and reported comparable dispersion in labor productivity. He concluded by pondering, reasonably, "One asks how a mine that gets but 30.1 pounds per man per day can exist as against a mine securing 371 pounds per day, but with this economic problem we have nothing to do at this time." Much of the current research on productivity dispersion is aimed at investigating precisely this economic problem.

Summarizing several studies across a wide range of industries dating from the 1930s and 1940s, Salter (1960) found similarly large variation in labor productivity, part of which he attributed to "delay in the utilisation of new techniques," as measured by variation in plant construction date. This vintage effect is a component of the quality of the (p. 29) capital input we mention in subsection 1.3.3, but it is difficult to quantify and its variation is frequently, and unfortunately, missing from lists of potential sources of productivity dispersion.

For a decade during the 1950s and 1960s, the European Productivity Agency published *Productivity Measurement Review.* The *Review* contained numerous studies of inter-plant and inter-firm comparisons, usually of labor productivity or its reciprocal, with substantial productivity dispersion being the norm and high/low gaps of 5 to 1 not infrequent. Some studies reported the impact of productivity dispersion on unit labor cost or unit cost, and occasionally on operating ratios such as ROA, demonstrating once again the impact of productivity on business financial performance.

Recent evidence on productivity dispersion comes in two complementary forms: large sample evidence, popular in economics, and focused sample evidence, popular in industrial relations and human resource management. The latter approach, also known as insider econometrics, has three steps: (i) interview managers, workers, and others in a firm or firms; (ii) gather relevant data; and (iii) conduct an econometric investigation to test hypotheses of the factors that generate behavior reflected in the data. The focused sample approach complements the large sample approach in two ways: (i) it contains precise measures of dependent and independent variables of interest, including management practices, and (ii) it contains detailed controls for sources of heterogeneity, many of which are unobserved in large sample studies. Shaw (2009) provides a valuable introduction to the focused sample approach, and Ichniowski and Shaw (2012) provide a comprehensive overview.

Productivity dispersion has been documented in many large sample studies, including but not limited to Foster, Haltiwanger, and Krizan (2001) [US manufacturing plants in Census of Manufactures years 1977, 1982, 1987 and 1992; US automotive repair shops, 1987–1992]; Eslava, Haltiwanger, Kugler, and Kugler (2004, 2010) [Colombian manufacturing plants, 1982–1998]; Foster, Haltiwanger, and Syverson (2008) [US manufacturing plants in five Census of Manufactures years]; Bartelsman, Haltiwanger, and Scarpetta (2009, 2013) [establishment-level data across several countries and varying time periods]; Midrigan and Xu (2014) [South Korean manufacturing establishments, 1991–1999]; Asker, Collard-Wexler, and De Loecker (2014) [nine firm-level data sets spanning 40 countries and varying time periods]; and Collard-Wexler and De Loecker (2015) [US steel plants, 1963–2002]. The motivations and issues considered vary widely across studies, but the unanimous finding is one of substantial productivity dispersion whenever and wherever one looks.

Productivity dispersion has been documented in many focused sample studies as well, including Ichniowski, Shaw, and Prennushi (1997) [complementarities among human resource practices at steel production lines]; Lazear (2000) [piece rate pay and hourly pay at a firm that installs windshields in cars]; Bartel, Ichniowski, and Shaw (2004) [complementarities among ICT and HRM practices at US valve-making plants]; and Bartel, Ichniowski, Shaw, and Correa (2009) [more complementarities at US and UK valve-making plants]. The last two studies are illustrative of the focused sample approach and its emphasis on the use of specific ICT and HRM practices. Valve-making (p. 30) consists of three sequential processes—setup time, run time, and inspection time—and requires three types of computer-based technology and three types of HR practices. Findings indicate that (i) some technologies significantly raise productivity (reduced time) in some processes and not in others; (ii) some HR practices significantly raise productivity in some processes and not in others; (iii) complementarities exist between some IT and HR indicator pairs; and (iv) increases in the use of IT increases the demand for skilled labor (computer skills, programming skills, and engineering skills). In sharp, and useful, contrast to the first finding, Bartel, Ichniowski and Shaw (2004) show that a conventional econometric productivity analysis of the same US valve-making plants based on Census of Manufactures data shows aggregate capital to have no effect on aggregate output (value of shipments less change in inventories), thereby illustrating a virtue of focused-sample studies. We return to focused sample studies in Section 1.5.2, where we consider HRM practices as productivity drivers.

In Chapter 10 Garcia-Castro, Ricart, Lieberman, and Balasubramanian provide a somewhat different approach to a focused sample study in which they develop a value-creation and value-capture business model and apply it to the disruptive low-cost no-frills business model of Southwest Airlines, a popular subject of management research, perhaps second only to Toyota.[16] Their model, based on Lieberman, Garcia-Castro, and Balasubramanian (2017), is structurally similar to that of Grifell-Tatjé and Lovell in Chapter 9, although terminology differs and content differs in one important way. Their value capture, or price, effect reflects changes in buyers' willingness to pay and suppliers' opportunity costs. Their value creation, or quantity, effect consists of an innovation, or productivity, effect, but no replication, or margin, effect, because they expense profit; see our discussion in subsection 1.2.1. Thus the contribution of replication, which plays such an important role at Southwest Airlines through expansion achieved by adding new routes, occurs outside rather than within their analytical framework. Although replication does not increase productivity at Southwest Airlines, it can lead to an increase in industry productivity if it occurs at the expense of less productive carriers, which provides a link to the reallocation literature we discuss in subsection 1.4.2. In their evaluation of the performance of Southwest Airlines, they find replication to have been the dominant, albeit declining, source of value creation, and they find it has increased market share relative to that of the legacy carriers, thereby raising industry productivity. Not surprisingly in light of its business model, they also find growth in value created to have been captured primarily by customers initially, and eventually by employees. They conclude by discussing some changes that Southwest Airlines has been making to its "aging" business model.

Focused sample studies can be thought of as successors to business histories that were once so popular and so influential. Since businesses generate productivity growth or decline, and create or destroy value, it is unfortunate that productivity analysts spend so little time studying, and learning from, business history. To provide a few examples, classic and modern: (i) Tarbell (1904) chronicled the rise of the Standard Oil Company, which soon thereafter the US Supreme Court found in violation of the Sherman Antitrust Act; (ii) Chandler (1962) chronicled the development of organizational (p. 31) structures at duPont, General Motors, and the Standard Oil Company (New Jersey) (a creation of the Supreme Court's 1911 decision) over a century ago; (iii) in a book widely ignored in the new management practices literature that we explore in subsection 1.5.2, Sloan (1964) chronicled the management practices he developed while CEO of General Motors for nearly a quarter of a century; (iv) the studies collected in Temin (1991) catalogue the uses of information to address organizational problems in largely nineteenth-century businesses; (v) Helper and Henderson (2014) trace the decline of General Motors from 1980 to its bankruptcy in 2009 to its deficient productivity and its inflexible management practices, particularly to its management of relational contracts with its suppliers and employees; and (vi) Brea-Solís, Casadesus-Masanell, and Grifell-Tatjé (2015) study the financial performance of Walmart, contending that Walmart's business model did not change over a 36-year study period, but variation in the way it was implemented under successive CEOs generated variation in productivity and profit.

1.4.2. Productivity Dynamics

Productivity dispersion leads, or might be expected to lead, to a reallocation of resources away from less productive units to more productive units, thereby raising aggregate productivity. This is an old expectation, voiced by Stewart (1922) and explored by Denison (1962, 1974). However evidence suggests that some gaps are stubbornly persistent. The intertemporal nature of this expectation has spawned the phrase "productivity dynamics" to characterize the study of changes in productivity dispersion through time. Warning: productivity dynamics is a different concept from that of dynamic productivity introduced by Färe, Grosskopf, Margaritis, and Weber in Chapter 5.

The microeconomic branch of this literature explores firm productivity dynamics that incorporate entry, exit, and reallocation among incumbents. Industry productivity can increase if market shares of more productive incumbent firms increase at the expense of those of less productive incumbent firms. Industry productivity also can increase, even without an increase in the productivity of any incumbent firm, if productivity levels of new entrants exceed those of incumbent firms, or if productivity levels of incumbent firms exceed those of exiting firms.

The macroeconomic branch explores what might be called country productivity dynamics, covering a wide range of topics such as the process of catching up, forging ahead and falling behind (Abramovitz 1986); international productivity convergence or divergence (Baumol 1986; Bernard and Jones 1996a) and whether it is unconditional or conditional, depending on institutions and other country- and time-specific factors (Rodrick 2013); the significance of natural resource endowments, distance to the equator, and other features of geography (Hall and Jones 1999); and the rhetorical question of why are we so rich and they so poor? (Landes 1990). Wolff (2013) surveys the macroeconomic literature, with an emphasis on the convergence hypothesis.

The productivity convergence literature addresses two recurring issues. The first issue is convergence of productivity to what? One measure is provided by a time series of the (p. 32) standard deviation of individual country productivity levels about the mean productivity level of all countries in the sample (σ-convergence, in the jargon). This measure reveals whether country productivities are converging to a common path, which could result from catching up by laggards or falling behind by leaders, or a combination of the two. Another measure is provided by the coefficient of a regression of productivity growth rates on their initial values (β-convergence). This measure reveals whether countries with relatively high initial productivities tend to grow relatively slowly, and conversely. Inklaar and Diewert (2016) propose a third measure of convergence, a time series of the ratio of actual world productivity, defined as a share-weighted average of individual country productivity levels, to frontier productivity, defined as the maximum productivity level over all countries and all years up to the current year (E-convergence). This measure reveals whether country productivities are converging to (catching up with) best practice in the sample; it combines the flavor of Debreu's (1951) coefficient of resource utilization with that of the sequential Malmquist productivity index of Tulkens and Vanden Eeckaut (1995), Shestalova (2003), and Oh, Oh, and Lee (2017), although frontier productivity has been defined in other ways, as we discuss in the following.

The second issue concerns the identification of those sectors of the economy that are driving or constraining convergence, since identification can direct policies toward the right sectors. Empirical findings have varied with countries, sectors, time periods, currency conversion procedures, and the general quality of data. Using the first convergence measure, Inklaar and Timmer (2009) find support for the finding of Bernard and Jones (1996a) of both labor productivity and TFP σ-convergence in market services, but not in manufacturing, among a sample of advanced OECD countries since 1970. Inklaar and Diewert (2016) study productivity convergence across 38 economies from 1995 to 2011, distinguishing between traded goods and nontraded goods sectors. They find evidence of σ-productivity convergence (especially in the traded sector), but in combination with E-divergence, the latter attributed in part to a compositional shift caused by the growth of China and India.

As markets worldwide become less regulated, it becomes increasingly possible and timely to establish the presence of an empirical relationship between convergence, or changes in the relative position countries find themselves in relative to the world frontier, and market forces compelling countries and agents therein to economize. The foundation for the theory of dynamic adjustment that can be broadened into convergence or efficiency analysis has been established utilizing an axiomatic approach by Silva and Stefanou (2003), who laid out a set theoretic approach that was then extended in Silva and Stefanou (2007). Elaboration on the foundation for an adjustment-cost framework by switching to the dynamic directional distance function approach allowed Silva, Lansink, and Stefanou (2015) to deal with an even broader characterization of efficiency and productivity notions. Building on the Luenberger-based approach (using the dynamic directional distance function), Stefanou and his colleagues develop the relationship between the primal and dual forms of productivity (Lansink, Stefanou, and Serra, 2015). Econometrically implementable frameworks for the dynamic adjustment model that address asymmetric dynamic adjustment appear in the review by (p. 33) Hamermesh and Pfann (1996). Specification and estimation of asymmetric adjustment rates for quasi-fixed factors of production, similar in spirit to the Sickles and Streitweiser (1998) model, are found in Chang and Stefanou (1988), while Luh and Stefanou (1991) provide the modeling setup for estimating productivity growth within a dynamic adjustment framework. Previous efforts to estimate productivity growth in a dynamic adjustment model essentially ignored the adjustment/disequilibrium component of the productivity decomposition.

Tests of convergence originating in the economic growth literature (Baumol 1986), determine whether or not there is a closing of the gap between inefficient and efficient firms over time. One approach regresses the firms' average growth rates in technical efficiency on the log of the carriers' efficiency scores at the beginning of the sample period. A negative coefficient indicates β-convergence. In other words, the higher a firm's initial level of efficiency, the slower that level should grow. This phenomenon is the result of the public good–nature of technology, which causes spillover effects from leaders to followers as the laggards learn from the innovators and play “catch-up.” One can also utilize a more sophisticated approach involving the Malmquist productivity index procedure. This method, based on the geometric mean of two Malmquist indices, can account for changes in both technical efficiency (catching up) and changes in frontier technology (innovation). In a study of industrialized countries, Färe, Grosskopf, Norris, and Zhang (1994) note that this decomposition allows for a more comprehensive measure of productivity growth convergence since earlier endeavors failed to distinguish between these two components. Badunenko, Henderson, and Zelenyuk apply this framework to macroeconomic data in Chapter 24, and an application to microeconomic data of the sort used by Andrews, Criscuolo, and Gal (2015, 2016) is a logical extension. Whereas our earlier comparisons of the different methods of calculating technical efficiency necessitated an intertemporal production set, the Malmquist index requires the contemporaneous version. Thus, due to rank considerations, only the DEA approach can be used to calculate the index.

The existence of a technology gap may present an additional source of growth, but if nations differ in ability to adopt and absorb new knowledge, then country institutional heterogeneity must also be examined. If follower nations exhibit both a technology gap and a low absorption capacity, then technology's influence on productivity growth will be ambiguous. The importance of technology transfer has been explored previously. For example, Hultberg, Nadiri, Sickles, and Hultberg (1999) show that technology gaps relative to the United States significantly contribute to follower nations' aggregate productivity growth in the postwar period. It has also been shown that growth is affected by country heterogeneity, which in turn is highly correlated with various institutional variables. Theoretical studies also point to the importance of openness in accelerating the rate of technology transfer or technology adoption (Parente and Prescott 1993). Bernard and Jones (1996a, 1996b) use a model of TFP that includes the productivity differential within a sector from that of the most productive country. Their results are, again, that manufacturing has not contributed significantly to the overall convergence in OECD countries. Cameron, Proudman, and Redding (1999) expand on the Bernard and Jones model to include a term that is comparable to our efficiency term. They (p. 34) look carefully at even more disaggregated data in terms of openness and technology transfers, but only consider the relationship between United Kingdom and the United States. Their results are that the technology gap to the United States plays an important role in UK technology advancement.

In Chapter 22, Inklaar surveys the convergence literature and conducts three wide-ranging empirical investigations into the σ-convergence hypothesis. In the first he uses the EU KLEMS database to quantify and to examine the sources of trans-Atlantic productivity convergence (actually, divergence). He finds the source to have been in the ICT-producing sector, in which productivity has grown faster in the United States than in the EU-10. In the second investigation he traces the industry origins of changes in productivity dispersion for a broader set of countries. He finds that productivity convergence has been almost entirely driven by convergence in manufacturing. In the third investigation he examines the extent to which trends in productivity dispersion can be explained by several drivers of productivity change, one of which is a measure of distance to frontier. The other explanatory variables are related to R&D expenditure, the role of high-tech labor and capital, foreign direct investment, and market competition. He finds proximity to the frontier to dampen productivity growth and most of the remaining explanatory variables to enhance productivity growth, though not always significantly. However, the impacts of the remaining explanatory variables do not vary depending on distance to the frontier, suggesting that, for this data set, they do not have an impact on convergence.

A variant on the identification of the sectors of the economy that drive or constrain convergence is the identification of the geographic regions of the economy that drive or constrain economic activity in general, convergence in particular. Gennaioli, La Porta, Lopez-de-Silanes, and Shliefer (2013, 2014) study over 1,500 subnational regions from a large number of countries over varying time periods, exploring the influence of geography, natural resource endowments, institutions, human capital, and culture on regional productivity and development. They characterize regional convergence as “slow” and “puzzling,” although they find regional convergence faster in richer countries and in countries with better-regulated capital markets and lower trade barriers.

Dispersion, whether inter-firm or inter-regional, reduces the aggregate value of whatever is dispersed. Hsieh and Moretti (2015) apply a spatial equilibrium model to data on 220 US metropolitan areas. This enables them to infer rising inter-city productivity dispersion from rising inter-city wage dispersion, which they attribute to increasing housing supply constraints that limit the ability of workers to reallocate to cities with higher wages and, presumably, higher productivity. They estimate that lowering these constraints to those of the median city would lead to a spatial reallocation of labor that would increase US GDP by 9.5%.

Nordhaus (2006) provides insight into the potential value added for productivity research of having detailed spatial data on economic activity. He introduces the G-Econ database (http://gecon.yale.edu) to test a variety of hypotheses concerning the impact of geography on economic activity, including the geographic impacts of global warming on output, which he finds to be larger than previously estimated.

(p. 35)

1.4.2.1. Reallocation

One of many approaches to the analysis of reallocation is based on a productivity change decomposition proposed by Balk (2003), who reviews the approach in Chapter 2. In this approach, aggregate productivity change is decomposed into four sources: entry of new firms, exit of old firms, productivity change in continuing firms, and redistribution of market shares among continuing firms. If entering firms have above-average productivities, or if exiting firms have below-average productivities, or if the productivities of continuing firms increase, or if market shares of continuing firms are redistributed away from less productive firms toward more productive firms, aggregate productivity increases. One definition of the contribution of reallocation is the sum of entry of new firms, exit of old firms, and redistribution of market shares among continuing firms. As Balk notes, competing decompositions exist, but this is Balk’s preferred decomposition, and it nicely characterizes the reallocation mechanism and its potential to enhance aggregate productivity. Among the competing decompositions, perhaps the most popular is that of Olley and Pakes (1996), whose decomposition contains an additional “cross” component that captures the covariance between changes in incumbents’ productivity and changes in their market share, the objective being to determine whether firms experiencing productivity growth (decline) gain (lose) market share.

Empirical evidence of the workings of the reallocation mechanism is widespread and, generally speaking, encouraging; as one would expect, reallocation makes a positive contribution to aggregate productivity growth. A brief summary of three studies illustrates the empirical relevance of the reallocation mechanism.

The OECD (2001b) reports findings for several European countries over the 1985–1994 decade. In eight countries, aggregate labor productivity growth has been due primarily to labor productivity growth within continuing establishments, with the role of reallocation being small and variable across countries. However, in five countries, aggregate MFP growth has been due primarily to reallocation, driven by both net entry and redistribution. Foster, Haltiwanger, and Krizan (2006) report findings for a large number of establishments in the US retail trade sector for three census years. The data exhibit large and stable interquartile dispersion in labor productivity across establishments. Nearly all labor productivity growth is attributable to net entry, making reallocation the driving force behind aggregate labor productivity growth. The richness of their data allows the authors to decompose entry into entry by new firms and entry by continuing firms (opening additional establishments), and to decompose exit into exit by firms leaving the sector and exit by continuing firms (closing establishments). The main contributors to net entry were continuing firms opening new establishments and exiting firms leaving the sector altogether. Conditional on survival, they find substantial persistence in terms of relative productivity rankings. Foster, Haltiwanger, and Syverson (2008) report findings for a large number of US establishments in seven-digit manufacturing product categories in five census years. The primary drivers of MFP growth have been growth by continuing establishments, followed by net entry, with reallocation explaining between one-fourth and one-third of aggregate productivity growth.

(p. 36) Two frontier-based approaches to the investigation of productivity dynamics, reallocation, and convergence have emerged, although there appears to be no cross-fertilization between the two literatures.

One frontier-based approach uses macroeconomic data, frequently sourced from the Penn World Tables (PWT), and its analytical foundation is provided by one of the two Malmquist productivity indices we discuss in subsection 1.3.2. This approach seems to have originated with Kumar and Russell (2002), who use PWT data on output, capital, and labor from 57 countries over 1965–1990 to estimate a Malmquist productivity index. An assumption of constant returns to scale enables them to estimate labor productivity change and decompose it into the contributions of catching up, technical change, and capital deepening. They attribute most of the aggregate productivity growth to capital deepening, with technical progress and catch-up together accounting for about 20% of the total. They find evidence of convergence to the global frontier, but no evidence of convergence of developing countries to developed countries. They also find a trend in the labor productivity distribution from unimodal to bimodal to be due entirely to the effect of capital deepening.

In Chapter 24, Badunenko, Henderson, and Zelenyuk use updated PWT data covering various countries during varying time periods to extend this Malmquist-based global frontier approach to productivity dynamics and convergence. In one extension they follow the new growth theory by incorporating human capital change as an additional driver of labor productivity change. In another they incorporate a financial development change indicator. Throughout they focus on the sources and convergence of labor productivity growth, using statistical methods to test various hypotheses. They also provide a comprehensive literature survey of the new growth theory and of the Malmquist-based global frontier approach to productivity dynamics and convergence.

An alternative frontier-based approach uses microeconomic data, is based on a distinction between "frontier" firms and "laggard" firms, and examines trends in productivity gaps between the two categories of firm. In this approach, forging ahead by frontier firms and catching up by laggard firms both raise aggregate productivity, but have the opposite effects on productivity gaps. The framework is enriched by the existence of two frontiers, a national frontier and a global frontier. The approach is reminiscent of the macroeconomic "catching up, forging ahead and falling behind" thesis of Abramovitz (1986). It is also conceptually similar to the Malmquist productivity index approach, but analytically very different.

The construction of national and global frontiers is crucial to the approach. Rather than use econometric or mathematical programming techniques to construct frontiers, this literature defines national frontier firms loosely as "best in nation." Thus Iacovone and Crespi (2010) define national frontier firms as those in the top quartile of the domestic productivity distribution, and the global frontier as an ill-defined envelope of the best national frontiers. Andrews, Criscuolo, and Gal (2015, 2016) define national and global frontiers in both absolute and percent terms, with fixed and variable number of frontier firms, and report little difference in findings. (p. 37) Bartelsman, Dobbeleare, and Peters (2015) define frontier firms as belonging to the upper quantiles of the relevant productivity distribution.

Empirical evidence obtained from the frontier model of reallocation is relatively scant, but encouraging. Bartelsman, Dobbeleare, and Peters (2015) study a large sample of firms in Germany and the Netherlands over 2000–2008 and report findings across a range of industries. A common but not unanimous finding is one of positive complementarity between both investment in human capital and investment in product innovation and proximity to the frontier. Andrews, Criscuolo, and Gal (2015) study firms belonging to two-digit industries for 23 OECD countries over 2001–2009. They find firms at the global productivity frontier to be on average more productive, larger, more export-oriented, and more profitable than nonfrontier firms, productivity being measured as both labor productivity and MFP. Moreover, they find productivity gaps widening through time. This raises the (unanswered) question of why frontier technologies do not diffuse more rapidly, both from global frontier firms to national frontier firms, and from national frontier firms to domestic laggard firms. Among positive findings, gaps between national and global frontiers vary with educational quality, product and labor market regulations, the quality of markets for risk capital, and the extent of R&D collaboration, each of which is subject to public policy influence. Andrews, Criscuolo, and Gal (2016) apply the frontier model to analyze the recent global productivity slowdown, using the OECD-Orbis data base.[17] They find increasing productivity among global frontier firms, and increasing divergence between frontier and nonfrontier firms, in both manufacturing and services, even after including various controls. This leads them to attribute the global productivity slowdown to a slowdown in the diffusion process. They note that diffusion has been slowest in sectors where pro-competitive market reforms have been least extensive, and they also consider the roles of adjustment costs of adopting new technologies, rising entry barriers, and declining contestability of markets in slowing the diffusion process.

OECD (2015b, 2016a) and Berlingieri, Blanchenay, and Criscuolo (2017) provide details of the distance to the frontier approach and additional findings, and OECD (2015b, 2016a) discusses the role of public policy directed toward raising aggregate productivity growth, in large part by enhancing diffusion. As Andrews, Criscuolo, and Gal (2015) note, this literature is "very small." Its growth is to be encouraged, particularly if it incorporates some of the analytical advances appearing in the frontier and Malmquist literature.

The concept of distance to the frontier has been adopted by the World Bank as an essential component of its evaluation of the performance of economies in its annual *Doing Business* reports. The 2017 report covers 190 economies, using 41 indicators for 10 topics, each topic representing a dimension of the cost of doing business (e.g., starting a business, getting credit). Economies receive normalized scores for each indicator within a topic, which are then averaged to create 10 topic scores. Topic scores are then averaged to obtain aggregate "ease of doing business" scores. Distance to frontier is measured as the difference between an economy's score and the best score attained since a given year. (p. 38) Finally, economies are ranked according to their distance to frontier scores, for each topic and for the aggregate ease of doing business.[18]

This unweighted averaging approach to the construction of composite indicators is widespread but controversial. Cherchye, Moesen, Rogge, and Van Puyenbroeck (2007) criticize the approach and propose a DEA-based "benefit of the doubt" alternative that allows countries to attach different weights to indicators. Underlying data are available at www.doingbusiness.org, and enable one to employ frontier techniques to aggregate indicators into topics, and to aggregate topics into an ease of doing business index, and then to use Malmquist productivity indices to construct annual best-practice frontiers and to measure performance variation across economies and performance change through time. Lefebvre, Perelman, and Pestieau use the benefit-of-the-doubt approach in their evaluation of the welfare performance of the public sector in 28 EU economies in Chapter 17.

1.4.2.2. Persistence

The evidence cited in the preceding that reallocation raises aggregate productivity is compelling, and provides evidence of market forces at work. However, this evidence also shows that reallocation does not eliminate productivity dispersion, suggesting the presence of barriers to the working of market forces. The primary finding in this regard is that, conditional on survival, substantial productivity dispersion persists through varying lengths of time. Persistence is measured by assigning units to productivity quantiles through time, which requires long panels. If units remain in the same productivity quantile, or perhaps move no further than to an adjacent productivity quantile, persistence of productivity dispersion is inferred. Andrews, Criscuolo, and Gal (2015) attribute persistence in the OECD to slow diffusion of new global frontier technologies to laggard firms. OECD (2016a) cites a particular example: the uptake of cloud computing in OECD countries has been low, particularly among small firms. OECD (2016a) also emphasizes within-country spatial productivity dispersion, and a slowdown in convergence.

This combination of productivity-enhancing reallocation and productivity-constraining persistence prompts a search for the sources of persistence. Banerjee and Moll (2010) mention four potential sources: (i) finance constraints, either inadequate access to financing or adequate access at exorbitant interest rates; (ii) firms of varying productivity self-select into the formal (and taxed) and informal sectors; (iii) political connections enable low-productivity firms to survive; and (iv) a regulatory environment that discriminates against large firms. We discuss some of these sources in subsection 1.5.2.

Gibbons and Henderson (2012a, 2012b) suggest another reason why best practices do not diffuse more readily. Their explanation is that many management practices are not based on formal contracts, but on relational contracts involving ". . . a shared understanding of each party's role in and rewards from achieving cooperation." These contracts are hard to build and change, causing slow diffusion and persistent productivity gaps. They illustrate with three examples, the "fair" bonus system at (p. 39) Lincoln Electric, the employee-operated andon cord on the assembly line at Toyota, and the pro-publication philosophy at Merck. Helper and Henderson (2014) apply the relational contract concept to the search for explanations for the decline of General Motors.

Yet another possible source of persistence is that business models vary across firms, with some pursuing a financial objective by emphasizing productivity, and others pursuing the same or a different financial objective by pursuing replication, a strategy emphasized by Garcia-Castro, Ricart, Lieberman, and Balasubramanian in Chapter 10. Variation in the quality of management practices, which we discuss in subsection 1.5.2, is another likely source.

1.5. Productivity Drivers

Productivity varies across plants and firms and through time, but not randomly. Productivity dispersion has sources, or drivers. It is important to identify drivers in order to adopt business strategies and public policies designed to reduce dispersion and increase aggregate productivity. Two quite different approaches to the identification of drivers of productivity dispersion have developed in the literature, and have been used in two quite different contexts.

1.5.1. Technology-Based Drivers

One approach to the identification of the forces driving productivity change is technology-based, specifies two or more drivers, and is typically, although not necessarily, applied to the estimation and decomposition of productivity change through time.

In this approach, productivity change is decomposed into technical change (a shift in the best-practice frontier, perhaps caused by the introduction of a new form of ICT) and efficiency change (a movement toward or away from the best-practice frontier, perhaps caused by the diffusion of the new form of ICT). The concept of a best-practice frontier is an essential component of the technology-based approach, but this frontier is typically unobserved, and must be estimated. The search for technology-based drivers thus fits into the "Estimation" part of subsection 1.3.2.

If best-practice technology is represented by a production frontier, efficiency change is technical efficiency change. Data requirements are relatively undemanding: output quantities and input quantities for a panel of production units. Analysis is based on distance functions that provide the basis for either of two Malmquist (1953) productivity indices that Russell analyzes in Chapter 4. The Malmquist productivity index proposed by Caves, Christensen, and Diewert (1982) is more popular than the Malmquist productivity index anticipated by Hicks (1961) and Moorsteen (1961), and subsequently proposed by Diewert (1992) and Bjurek (1996), although the latter index (p. 40) has more desirable properties. O'Donnell (2012) demonstrates that the Malmquist productivity index proposed by Diewert and Bjurek is a "multiplicatively complete" productivity index because it can be expressed as the ratio of a well-behaved output quantity index to a well-behaved input quantity index, with good behavior requiring the indices to be non-negative, nondecreasing and homogeneous of degree one. He also shows that a multiplicatively complete productivity index can be exhaustively decomposed into the product of three drivers. He illustrates by decomposing the Diewert-Bjurek productivity index into the product of (i) technical change that measures a shift in the production frontier; (ii) technical efficiency change that measures movements toward or away from the production frontier; and (iii) scale-mix efficiency change that measures movements along the production frontier associated with changes in the input mix, the output mix, and the scale of production. However, since the Malmquist productivity index proposed by Caves, Christensen, and Diewert cannot be expressed as the ratio of an output quantity index to an input quantity index without imposing severe restrictions on the structure of technology, it is not generally multiplicatively complete and cannot be exhaustively decomposed into the product of three drivers.

If best-practice technology is represented by a cost (or revenue) frontier, efficiency change is cost (or revenue) efficiency change, and it is complemented by technical change measuring a shift in the cost (or revenue) frontier and scale-mix change that measures movements along the cost (or revenue) frontier. Data requirements are somewhat more demanding: output quantities, input prices, and expenditure on inputs for estimation of a cost frontier, and input quantities, output prices and revenue from outputs for estimation of a revenue frontier, as Russell shows in Chapter 4. Grifell-Tatjé and Lovell (2013) propose several analyses of business performance based on the concept of a cost frontier, one of which generalizes cost variance analysis in management accounting.

Additional options are available, corresponding to alternative specifications of objectives of and constraints facing firms. In one appealing specification, management is given a budget and told to spend it wisely, a specification that can be traced back to Shephard (1974) and thought of as combining primal and dual approaches. Wise expenditure might be directed toward maximizing output or revenue or ROA. In this case, an output quantity index is based on changes in output quantities as usual, and use of revenue or ROA requires constructing an implicit output price index as well. However, an indirect input quantity index is based on changes in budget-deflated input prices, since input quantities are endogenous choice variables constrained by the exogenous budget and input prices. An indirect productivity index is the ratio of an output quantity index to an indirect input quantity index. The analytical details of (cost or revenue) indirect productivity measurement are available in Färe and Grosskopf (1994). Potential applications are numerous, particularly in the provision of public services such as education, in which agencies receive operating budgets and are expected to maximize outputs such as educational outcomes; Grosskopf, Hayes, Taylor, and Weber (1997) provide an application to public schools. Johnson (1975, 1978) (p. 41) recounts a private sector example, in which managements at duPont and General Motors allocated funds across product lines with an objective of maximizing the return on these funds.

In Chapter 19, Diewert and Fox combine the analytical framework of Shephard (1974) with the analytical framework of Lawrence, Diewert, and Fox (2006), which we mention in section 1.2, to develop a macroeconomic decomposition of value-added growth into an extended set of drivers. They define a cost-constrained value-added function as the maximum value added that can be obtained from a flexible primary input budget. They then develop an analytical decomposition of growth in cost-constrained value added into the product of six drivers: (i) growth in cost-constrained value added efficiency; (ii) growth in net output prices; (iii) growth in primary input quantities; (iv) growth in primary input prices; (v) technical change; and (vi) scale economies. They illustrate their decomposition with data from the corporate and non-corporate nonfinancial sectors of the US economy over the period 1960–2014. Among their findings is a decline in value-added efficiency during recessionary periods when output declines but quasi-fixed inputs cannot be adjusted optimally. They conclude by considering a pair of procedure for aggregating the two decompositions to the entire nonfinancial sector, a top-down approach and a bottom-up approach, which they implement.

1.5.2. Organizational and Institutional Drivers

An alternative approach to the identification of the factors driving productivity change is based on the productivity dispersion analysis in section 1.4, and is typically, although not necessarily, applied to an investigation of the sources of productivity variation across producers. Drivers are sorted into two types: organizational factors that originate within the firm and are in principle under management control, and institutional or structural features that are external to the firm and presumably are beyond management control but subject to public policy. We review a few of the more prominent drivers of each type, with an acknowledgement that many of the organizational drivers are strongly correlated, and all could be labeled management practices.

1.5.2.1. Organizational Drivers

1.5.2.1.1. Management Practices

The distinguished management consultant Peter Drucker (1954, 71) asserted that ". . . the only thing that differentiates one business from another in any given field is the quality of its management on all levels. And the only way to measure this crucial factor is through a measurement of productivity that shows how well resources are utilized and how much they yield."

In a global research agenda stretching over the past decade, Bloom, Van Reenen, and colleagues have developed the World Management Survey (WMS).[19] The survey currently contains data on management practices from over 11,000 firms, primarily in manufacturing but also in retail trade, health care, and education, in 34 countries (p. 42) through four different survey waves from 2004 to 2014. Data include quality indices (normalized and ranked from one for worst practice to five for best practice) for 18 management practices in three categories: monitoring, target setting, and people management. Aggregating these quality indices provides an empirical measure of Drucker's management quality (although recall our reference to benefit of the doubt weighting in subsection 1.4.2). It also enhances the likelihood of discovering the previously missing input in productivity studies noted by Hoch (1955), who called it "entrepreneurial capacity," and by Mundlak (1961) and Massell (1967), who called its omission "management bias."

More significantly, the WMS data enable one to test hypotheses concerning the drivers of management quality and, in turn, the impact of management quality on various indicators of firm performance. It is dangerous to summarize what is by now a large and rapidly growing body of work, but a few findings are common to the vast majority of studies: (i) there is large cross-country variation, and even larger within-country dispersion, in the quality of management practices; (ii) product market competition is an important driver of the quality of management practices; (iii) ownership matters, with the quality of management practices higher in the private sector than in the public sector, higher in multinational firms than in domestic firms, and higher in professionally managed family firms than in family-managed family firms, particularly primogeniture family firms; (iv) the quality of management practices is positively associated with a range of measures of firm performance, including productivity, profitability as measured by return on capital employed, sales and sales growth, market value as measured by Tobin's Q, and the probability of survival; and (v) at least a quarter of country productivity gaps with the United States are accounted for by gaps in the quality of management practices. Among the more recent studies based on the WMS, each of which provides references to earlier studies, are Bloom, Genakos, Sadun, and Van Reenen (2012), Bloom, Lemos, Sadun, Scur, and Van Reenen (2014), and Bloom, Sadun and Van Reenen (2016).

The WMS contains limited information on American firms. However, Bloom, Brynjolfsson, Foster, Jarmin, Patnaik, Saporta-Eksten, and Van Reenen (2014) report findings based on a recent Management and Organizational Practices Survey (MOPS) of over 30,000 US manufacturing establishments conducted by the US Census Bureau. Their findings complement those based on the WMS, and include (i) enormous dispersion in the quality of management practices; (ii) high correlations between the quality of management practices and firm size, firm location, firm export status, firm employee education, and the intensity of ICT use; and (iii) a high correlation between the quality of management practices and firm performance as measured by productivity (labor productivity and MFP), profitability (operating profit divided by sales), employment growth, and innovation (R&D and patent intensity). In Chapter 12, Benner expresses reservations about the impact of management practices on innovation, suggesting that they may promote relatively minor process innovation at the expense of potentially major product innovation.

(p. 43) The evidence from both surveys is compelling: management matters, for productivity, for financial performance, and for survival. The evidence also identifies several drivers of the quality of management practices, some such as ICT adoption and the use of incentives being organizational in nature, and others such as product market competition and the regulatory environment being institutional in nature.

We have mentioned earlier the old notion of management as the missing input. This may have prompted Bloom, Lemos, Sadun, Scur, and Van Reenen (2014) and Bloom, Sadun, and Van Reenen (2016) to consider two alternative views of management, one with management as design from organizational economics, and the other with management as intangible capital, as an input in production technology. With their preferred view of management as intangible capital, they write $Y = F(A, K, L, M)$, in which M is management. Treating intangible capital as a separate input in the production technology is subtly different from treating it as a part of K (Corrado, Hulten, and Sichel 2005) or as a part of L (Bryan 2007). However, the once missing input is no longer missing, and although the interpretation of M is clear, it remains a composite indicator subject to the same concerns we express in subsection 1.4.2 in relation to the construction of distance to the frontier indicators used by the OECD and the World Bank.

1.5.2.1.2. Human Resource Management Practices

Human resource management (HRM) practices vary across firms and countries, as does productivity, which prompts a search for a relationship, and perhaps causality. HRM practices are similar to the people management component of management practices, but we treat the topic separately for three reasons: (i) an independent literature exists, (ii) much of its empirical content consists of focused sample studies rather than large sample studies found in the management practices literature; and (iii) large sample studies rarely isolate the impact of the people management component of management practices on productivity.

In an early focused sample study, Ichniowski, Shaw, and Prennushi (1997) study 36 homogeneous steel production lines at 17 companies over several months. In their panel, both HRM practices and productivity vary widely. Consistent with economic theory (e.g., Milgrom and Roberts 1990, 1995), they find that clusters of innovative work practices, including incentive pay, teams, flexible job assignments, employment security, and training, have a significant positive effect on productivity, while changes in individual practices have little or no impact on productivity. They also find that clusters of innovative work practices raise product quality. Finally, they find support for two explanations for the failure of best HRM practices to diffuse more widely: slow diffusion of knowledge about the performance of HRM systems, and both pecuniary and nonpecuniary barriers to change at older lines.

Lazear (2000) reports the findings of his study of a large auto glass company in which workers install auto windshields, and which gradually changed its compensation from hourly wages to piece-rate pay. Based on a sample of 3,000 workers over a 19-month period, he finds (i) the switch to piece-rate pay led to a 44% gain in output (p. 44) per worker; (ii) the company shared the productivity gains with workers in the form of a 10% increase in pay; (iii) the variance in worker productivity increased due to the incentive provided to ambitious workers; and (iv) company earnings increased, although this may have been caused by other factors in addition to the productivity increase.

Several focused sample studies find complementarities, not just among HRM practices, but between them and the adoption of various information technologies. Bartel, Ichniowski and Shaw (2004, 2007) find complementarities between HRM practices and computer-based information technologies to increase productivity in terms of reducing setup time, run time, and inspection time at US valve-making plants, and Bartel, Ichniowski, Shaw, and Correra (2009) report similar findings at a larger sample of US and UK valve-making plants. Note the association of productivity with time.

In a study of 629 Spanish manufacturing plants, Bayo-Moriones and Huerta-Arribas (2002) attempt to identify determinants of the adoption of production incentives for manual workers. Among the determinants they consider are product market conditions, plant characteristics, work organization, and unions. They find recent increases in product market competition and public ownership to significantly reduce the probability of adoption. They also find the way work is organized, expressed in terms of the number of tasks per job and the share of manual workers in autonomous work teams, and the extent of union influence over workers, to significantly increase the probability of adoption. The extent of plant automation and the magnitude of recent technical changes have no significant impact on the probability of adoption. The authors do not attempt to identify complementarities, and they do not explore the impact of the adoption of production incentives on productivity, but if such incentives tend to raise productivity, then they have uncovered some indirect influences on productivity.

In a related study of over 800 Spanish manufacturing plants over six years, Bayo-Moriones, Galdon-Sanchez, and Martinez-de-Morentin (2013) ask whether pay-for-performance practices are likely to be adopted for six occupations, ranging from top executives to sales and production workers. They find sales workers and top executives to be the occupations most likely to adopt such practices, although the nature of pay-for-performance practices varies across occupations. Such practices are less likely to be adopted for production and administrative workers. The idea of adoption of a common pay-for-performance program across all occupations is rejected.

Although studies of the impact of HRM practices on productivity are predominantly focused sample studies, a few large sample studies have been conducted. In one such study, which incorporates many attributes of a focused sample study, Black and Lynch (2004) use the Educational Quality of the Workforce National Employers Survey administered by the US Bureau of the Census to construct 1996 cross-section and 1993/1996 panel data sets at the individual establishment level. They find that the use of high-performance work practices such as self-managed teams, re-engineering, incentive pay, profit sharing, and employee voice, in conjunction with the adoption of information technologies, including the share of equipment less than four years old and the proportion of non-managers using computers, positively impacts labor productivity. Unlike (p. 45) many other studies, they are unable to detect any significant complementarities in the cross section and just one in the panel, between unionization and employee voice, as hypothesized by Freeman and Medoff (1984).

To the extent that HRM practices can be separated from other management practices, it is expected that good HRM practices enhance producer performance. To the extent that complementarities exist, the impact is magnified. However, there is compelling evidence that many findings are contextual rather than general.

1.5.2.1.3. Adoption of New Technology

Even before Salter analyzed vintage effects, Griliches (1957) documented the slow and variable rate of adoption of a new (and currently controversial) agricultural technology, hybrid seed corn, which he attributed to varying profitability of adoption. More generally, David (1990) and Crafts (2004) offer economic historians’ responses to Solow’s “productivity paradox” by providing a broad historical perspective on diffusion lags in the adoption of general-purpose technologies and their consequent delayed impact on productivity. Draca, Sadun, and Van Reenen (2007) summarize what even then was a voluminous literature, breaking it down into macroeconomic studies, industry-level studies, and firm-level studies. Their interpretation of the literature is that it reveals a positive and significant association (but not causality) of ICT with productivity, primarily at the firm level, and largely through complementarities with labor skills and organizational capital, the role of which we discuss in subsection 1.3.3.

In Chapter 12, Benner adopts an interdisciplinary approach to propose a managerial resolution to the productivity paradox, a resolution whose roots go back at least to the work of Abernathy (1978). Following Adler, Benner, Brunner, MacDuffie, Osono, Staats, Takeuchi, Tushman, and Winter (2009) and Benner and Tushman (2015), she contends that popular incremental process innovations such as Six Sigma and ISO 9000 convey marginal near-term productivity gains, but at the expense of uncertain but more substantial longer-term productivity gains that might have resulted from successful product innovations. In this view, the opportunity cost of the resources allocated to the adoption of “process management practices” that yield improvements to the existing technology is the possibility of developing an innovative new technology. To the extent that management practices, including HRM practices, can be associated with process innovation, Benner's analysis bears directly, and critically, on the management practices literature we summarize in the preceding. The pursuit of best management practices appears to raise productivity, but at a potentially high cost; by directing attention away from product innovation, it may preclude the discovery of a radical new product. To paraphrase Gordon (2016), some innovations are more important than others.

Benner also provides a useful link to the reallocation literature we survey in subsection 1.4.2 by suggesting that incumbents tend to pursue process innovations, while potential entrants are more likely to pursue product innovations, some successfully. Or, as she puts it so eloquently, ". . . as a firm engages in concerted efforts to produce Blackberries more efficiently, it is actually less likely to create the iPhone. . . ."

(p. 46) Following up on the product-process innovation distinction, Hall (2011) and Mohnen and Hall (2013) survey the empirical evidence, which suggests that product innovation exerts a statistically significant positive impact on revenue productivity, but process innovation, while it tends to improve business financial performance, has an ambiguous effect on revenue productivity. These incomplete findings have encouraged further research. Product innovation can increase revenue productivity in either of two ways, by increasing output quantities or output prices, and identification is a challenge. Process innovation has an ambiguous effect on revenue productivity, perhaps because it is not intended to raise revenue productivity, but rather is aimed at improving productive efficiency, the impact showing up as an improvement in cost productivity through a reduction in input use.

In Chapter 13, Cassiman and Golovko apply the distinction between product innovation and process innovation to explore the complex linkage among the participation of firms in international trade, their innovation activity, and their productivity. They hypothesize that product (but not process) innovation raises productivity and induces firms to self-select into exporting and, eventually, foreign direct investment. They also explore the reverse hypothesis of learning by exporting, which can result from intense competition in foreign markets and from knowledge spillovers from foreign buyers, suppliers, and competitors. This learning can lead to further increases in innovative activity and productivity. As a logical extension, they explore the hypothesis that product innovation and exporting activities are complementary determinants of future productivity growth. After exploring the learning by importing relationship, they explore export–import complementarities on product innovation and productivity. They illustrate these relationships with a large panel of small and medium-sized Spanish manufacturing firms in 20 industries during 1991–2009, and find a "complex dynamic" relating exporting, importing, innovation, and productivity.

In a large sample study, Bloom, Brynjolfsson, Foster, Jarmin, Patnaik, Saporta-Eksten, and Van Reenen (2014) relate the use of information technology (IT) to business performance, with management practices providing the intermediate link. Using MOPS, they find three measures of IT usage (IT investment, IT investment per worker, and percent of sales delivered over electronic networks) to be positively correlated with the quality of management practices, which in turn is positively correlated with a variety of business performance indicators. Along similar lines in a pair of focused sample studies Bartel, Ichniowski, and Shaw (2007) and Bartel, Ichniowski, Shaw, and Correa (2009) find strong complementarities between human resource practices and the adoption of new information technologies in enhancing productivity growth. In light of the findings on product versus process innovations, it is worth noting that in each of these studies the technologies being adopted are process, rather than product, technologies.

Raymond, Mairesse, Mohnen, and Palm (2015) explore the R&D-to-innovation-to-productivity relationships in a pair of unbalanced panels of Dutch and French manufacturing firms from three waves of the Community Innovation Survey. They find evidence of a lagged positive impact of R&D on innovation, a positive impact of innovation on labor productivity, ambiguous evidence of persistence in innovation, and (p. 47) strong evidence of persistence in productivity. They also find numerous differences in the relationships between the Netherlands and France.

Bos, van Lamoen, and Sanders (2016) also use the Community Innovation Survey, limited to Dutch manufacturing firms, to extend previous work of Mairesse and Mohnen (2002) by specifying and estimating a knowledge production frontier. In their production technology, the innovation output is sales from new or improved products, their innovation inputs consist of a knowledge stock of accumulated innovation expenditures and research labor engaged in R&D activities, and they control for other inputs, cooperation with other institutions, and government funding. They find their innovation inputs to be jointly significant drivers of innovation output, but most of the inter-firm variation in innovation output is unexplained by innovation inputs and controls, and is ascribed to inter-firm variation in innovation efficiency (or innovativeness, or productivity) in the conversion of innovation inputs to innovation output. The finding of innovation inefficiency justifies the extension of the Mairesse and Mohnen knowledge-production function to a knowledge-production frontier, and the finding of innovativeness dispersion is consistent with the widespread finding of productivity dispersion we survey in subsection 1.4.1.

Statistics Netherlands (2015) contains a number of firm-level studies exploring various linkages between ICT and productivity. In one study of the impact of ICT capital on sales per worker, ICT capital is disaggregated into eight components. Another distinguishes among product innovation, process innovation, and organizational innovation, and incorporates e-commerce intensity. A third examines the impact of ICT intensity on industry dynamics. Yet another examines the role of ICT in global value chains, distinguishing among ICT-producing firms, ICT-using firms, and non-ICT firms. Findings vary across studies, but a general conclusion is that ICT use enhances productivity, although findings can be sensitive to the definition of productivity, some types of ICT have greater impact than others, and the impact of ICT investment may depend on simultaneous investment in organizational changes.

It is apparent that adoption of new ICT investment increases productivity, especially if it is combined with complementary HRM practices. The finding seems subject to two unresolved concerns, however, one involving the distinction between product and process innovation, and the other involving the efficiency with which innovation is adopted and incorporated into business practices.

1.5.2.1.4. Downsizing

Global food giant Nestlé SA has embarked on a "Cost and Capital Discipline" program, which it claims has reduced operating cost by CHF1.6 billion in 2014 and 2015 through waste reduction and the leveraging of size and complexity, with an objective of improving return on invested capital.[20]

Businesses frequently make similar cost-cutting pronouncements, typically in conjunction with quarterly earnings announcements, the objective being to increase competitiveness. It is possible to cut costs in several ways, through the introduction of new resource-saving technology, by reducing waste, by right-sizing, and by recontracting (p. 48) with suppliers to gain lower input prices. Only the first two strategies are certain to increase productivity, although the third might. Theory suggests that all four are likely to enhance business financial performance, but the empirical evidence is inconclusive.

Attitudes toward cost-cutting vary. *The Economist* (2016a) complains that cost-cutting announcements rarely are followed by plans to pass the resulting gains on to consumers or employees, thereby exacerbating inequality in the distribution of income. Economists approve of improvements in technology, waste reduction, and right-sizing as components of optimizing behavior, although empirical evidence on their effects, particularly on productivity, is surprisingly mixed. In their study of a sample of US manufacturing plants, Baily, Bartelsman, and Haltiwanger (1996) find productivity gains among plants that increase employment, as well as among plants that reduce employment. In their study of a sample of German firms, Goesaert, Heinz, and Vanormelingen (2015) find that, subsequent to downsizing, both productivity and profitability are largely unchanged, both among downsizing firms responding to a business downturn and, surprisingly, among waste-reducing firms attempting to increase efficiency. In their provocatively titled study of US manufacturing firms, Guthrie and Datta (2008) find downsizing to be negatively correlated with firm profitability, particularly (and unsurprisingly) in growing and R&D-intensive industries. Gandolfi and Hansson (2011) survey the management literature on the causes and consequences of downsizing, and conclude that it has negligible to adverse effects on business financial and organizational outcomes, and largely adverse human impacts, on executioners, victims, and survivors, particularly if downsizing involves shrinking job-training budgets.

Perhaps the evidence on the consequences of downsizing is mixed at best because cost-cutting can have adverse unintended consequences within the firm. Fisher and White (2000) adopt a social network view of the firm to show how inefficient cost-cutting can deplete organizational capital, erase organizational memory, and reduce organizational performance, an argument that is easy to support with anecdotal evidence. Schenkel and Teigland (2017) survey the organizational downsizing literature and develop an analytical framework that integrates the concepts of downsizing, social capital, dynamic capabilities, and business performance and competitiveness. Usefully for our purposes, they discuss how ICT capital can be employed to reduce the negative impacts of downsizing.

1.5.2.1.5. Offshore Outsourcing and Global Value Chains

Presumably businesses engage in offshore outsourcing to reduce production costs, thereby enhancing their financial performance. If the cost reduction takes the form of an input price reduction, it is likely that offshore outsourcing has no impact on business productivity. Although most of the literature on offshore outsourcing examines its impact on domestic employment, and almost none examines its impact on financial performance, a few studies examine its impact on productivity, and the evidence is mixed. Olsen (2006) surveys the extant literature at aggregate and plant levels, using both labor productivity and MFP, and finds no clear pattern of how the practice affects productivity, with much depending on sector and firm specifics. He does find modest support (p. 49) for a positive productivity effect, depending on what is outsourced (materials inputs or services inputs, the MS in KLEMS), who is doing the outsourcing (manufacturing or service businesses), and a host of controls for heterogeneity. Amiti and Wei (2009) find a significant positive effect of service offshoring, and a smaller insignificant positive effect of materials offshoring, on both MFP and labor productivity in US manufacturing industries during 1992–2000. Bournakis, Vecchi, and Venturini (2018) examine the productivity impacts of offshore outsourcing in high-tech and low-tech industries in eight OECD countries during 1990–2005. As in previous studies, they find weak support for productivity-enhancing offshore outsourcing, with results varying by industry and whether materials or services are outsourced. Interestingly, they also find some indirect support for Benner's conjecture in Chapter 12: they find little support for the impact of offshore outsourcing on R&D activities, which they attribute to business' myopic behavior, and ". . . which focuses more on short-term cost gains rather than on restructuring and diverting resources towards more innovative activities."

Offshore outsourcing can be an end in itself or, increasingly, it can be a link in a larger global value chain (GVC). To illustrate, an example of a GVC is the iPod, which prior to its discontinuation was designed in the United States, assembled in China by Taiwanese companies using more than 100 components manufactured around the world, with logistics handled in Hong Kong.[21] Reijnders, Timmer, and Ye (2016) and Timmer and Ye in Chapter 21 examine alternative characteristics of GVCs. General findings are similar in both advanced and emerging economies, and include (i) increasing fragmentation of production; (ii) a strong bias to technical change that favors capital (particularly ICT capital) and high-skill labor; (iii) increasing specialization; and declining low-skill labor value-added shares. These findings within GVCs are consistent with domestic findings of capital-skill complementarity reinforced by skill-biased technical change we discuss in subsection 1.2.3 in the context of growing inequality.

In Chapter 21, Timmer and Ye show how to analyze production, technical change and its bias, factor demand elasticities and their cost shares, and productivity change in GVCs, illustrating their methodology using a KLEMS approach and the World Input-Output Database. They provide two empirical applications, one to the GVC of German automobiles and the other to 240 manufacturing GVCs, both during 1995–2007. In the former application they are able to allocate GVC productivity growth of 0.99% to the German automobile industry itself (0.73%) and to other industries in the GVC (0.26%). In the latter application they find, consistent with non-GVC studies, strong complementarity between capital and high-skill labor. They also attribute growing cost shares of capital and high-skill labor, and declining cost shares of low- and medium-skill labor, primarily to biased technical change, with input price effects being small. This decomposition of changes in cost shares into driving sources is important in its own right, and has widespread potential applicability.

Recent evidence suggests that offshoring is a two-way street, with reshoring, the practice of returning production to the home country, becoming more common. De Backer, Menon, Desnoyers-James, and Moussiegt (2016) summarize the economic factors at work and survey the evidence. The factors favoring reshoring include an eroding (p. 50) offshore cost advantage, increasing supply risk in longer and more complex GVCs, the need to be close to markets, lagging domestic innovation, and endangered intellectual property. However, they find limited impacts on the home country of reshoring to date, with the major finding being that reshoring leads to a large increase in investment in high-tech capital and a small increase in employment, with most of that being of high-skill labor. Many home country jobs that were offshored are gone forever.

Adidas, a German sporting goods firm, provides an excellent recent example. It has outsourced the manufacture of sport shoes, primarily to Asian countries, for many years. However, growing labor shortages and rising labor costs, in conjunction with GVCs that can take up to 18 months from design to delivery, have prompted Adidas to reshore production to Germany. Reshoring will exploit advanced technology (including robotic cutting, 3D printing, and computerized knitting) to shorten the supply chain to less than a week, with a potentially large impact on productivity; once again, productivity is measured in terms of time to completion.[22]

Not all production fragmentation involves offshoring, with or without reshoring. Using data from the 2007 US Census of Manufactures, Fort (2017) finds a positive relationship between a firm’s use of ICT and its decision to fragment production, either offshore or domestically. She also finds domestic fragmentation to be far more prevalent than offshoring, a finding she attributes to complementarities between ICT and worker skill, which is generally higher in the United States than in countries to which US firms tend to offshore services.

1.5.2.2. Institutional Drivers

We know that some business practices enhance productivity, but what institutional features enhance or retard their adoption and diffusion?

The work of North (1990), co-recipient of the 1993 Nobel Prize in Economic Sciences "for having renewed research in economic history by applying economic theory and quantitative methods in order to explain economic and institutional change" (The Royal Swedish Academy of Sciences 1993). has inspired research into the impact of policies and institutions, including public infrastructure, on economic performance, including private productivity. Hall and Jones (1999) argue that ". . . the primary, fundamental determinant of a country's long-run economic performance is its social infrastructure," consisting of institutions and government policies. The challenge, of course, is to define and construct an index of social infrastructure. They construct such an index, and show that it exerts positive impacts on a variety of indicators of economic performance, including capital accumulation, educational attainment, and productivity, and therefore on per capita income. Easterly and Levine (2001) also emphasize the role of policies, such as legal systems, property rights, infrastructure, regulations, and taxes, that influence both factor accumulation and productivity, and they note that policy differences do not have to be large to matter, since "[s]mall differences can have dramatic long run implications." More recently, Ègert (2016) examines the effect variation in the quality of institutions, essentially the rule of law and law enforcement, on productivity, using a panel of OECD countries. He shows that higher quality institutions amplify the (p. 51) productivity-enhancing impact of R&D spending, although why R&D spending should provide the conduit is left unexplained. Hopenhayn (2014) provides an analytical framework for investigating the impact of institutions on economic performance, and surveys some of the more prominent institutions that retard performance. We touch on some of these institutional features in the following.

1.5.2.2.1. Competition

Perhaps the most prominent finding to emerge from Bloom and Van Reenen (2007) and their subsequent studies is the importance of product market competition as a determinant of the quality of management practices, and thus of the economic and financial performance of firms. This finding is robust to alternative measures of product market competition, including domestic competition, international competition, and competition as perceived by management.

Van Reenen (2011, 306), quoting Adam Smith ("Monopoly . . . is a great enemy to good management"), discusses the common finding that increased product market competition raises aggregate productivity growth, and a less common finding that it does so without substantially reducing productivity dispersion, to which we refer in section 1.4. He also claims that "[p]erhaps the most common form of a competition shock is from trade liberalization" (314). The OECD (2015b, 48) lists three channels through which trade exposure raises productivity: (i) trade openness increases competition, which promotes the productivity-enhancing reallocation we discuss in subsection 1.4.2; (ii) trade and foreign direct investment promote knowledge flows among global suppliers and customers, and within multinational firms, enhancing productivity convergence toward global frontiers; and (iii) trade openness increases effective market sizes, which raises potential productivity gains and profits from adoption of foreign technologies. The empirical literature investigating these channels is voluminous. To cite one recent example, Eslava, Haltiwanger, Kugler, and Kugler (2013) examine the impact of trade liberalization that reduced both the average level and the inter-industry variation in effective tariffs, on manufacturing plant productivity in Colombia during 1982–1998. They find liberalization to have increased exit, raised productivity within continuing plants, and improved resource allocation among continuing plants, all of which combined to raise aggregate productivity. The data constraint prevents them from considering nontariff barriers or the impact of tariff reform on entry.

In Chapter 14, De Loecker and Van Biesebroeck survey the recent literature. They consider a range of approaches to estimate the impact of changes in international competition, perhaps but not exclusively through reduced tariff barriers, on productivity. A vast empirical literature suggests that trade liberalization raises aggregate productivity in two ways that overlap with the three channels identified by the OECD (2015b): (i) by raising the minimum level of productivity necessary for survival, and (ii) by reallocating resources toward more productive firms. However, three related themes pervade their discussion. One is yet another warning of the danger in using deflated revenue as an output indicator when measuring productivity, a danger we first encountered in subsection 1.4.1. A second is the difficulty in separating the impacts of increased (p. 52) competition on output quantities and output prices, and the development of strategies for decomposing revenue productivity change into a mark-up change component and a productivity change component. They develop three such strategies, borrowed from the theoretical industrial organization and international trade literatures. The third theme is that, while trade liberalization, by enlarging the relevant market, has the potential to increase competition, and hence productivity, whether it actually has this effect is contextual.

1.5.2.2.2. Regulation

Regulation can affect productivity in three ways: (i) regulation in an industry can affect productivity in the same industry, (ii) regulation in an industry can affect productivity in other industries using the product of the regulated industry as an input, and (iii) labor market regulation can affect productivity in industries employing regulated labor. In each case, the regulatory impact can take either of two forms: it can lower the mean or increase the dispersion of the productivity distribution.

Andrews and Cingano (2014) construct a sample of over 800 country-industry observations across 21 OECD countries in 2005, with an objective of exploring the impact of cross-country variation in product market, labor market, and credit market regulations on cross-country productivity distributions. They find positive relationships between productivity dispersion among existing producers and each of employment protection legislation, product market regulations, and restrictions on foreign direct investment. However, credit market imperfections work differently, lowering the mean of the productivity distribution rather than increasing its dispersion, implying that financial frictions influence entry decisions rather than the productivity distribution of incumbent producers. They conclude that reducing product and labor market entry barriers in each country to the lowest levels observed in the European Union would reduce misallocation by half and increase aggregate labor productivity by 15%.

Égert and Wanner (2016) describe the OECD’s suite of indicators of anti-competitive regulation in the economy, REGIMPACT. Components include an economy-wide product market regulation indicator, seven network industry regulation indicators, four professional services regulation indicators, and a retail trade regulation indicator. Each of these indicators varies widely across OECD countries, and all decline through time—two features that make them useful in studies of the impact of cross-country variation in regulation on cross-country productivity distributions. Across a range of regressions, REGIMPACT has a statistically significant negative impact on labor productivity, and a negative impact that is frequently statistically significant on MFP. Each of the following studies uses this database.

Bourlès, Cette, Lopez, Mairesse, and Nicoletti (2013) use REGIMPACT to examine the indirect impact of regulation in one industry on the productivity of industries using that industry’s product. Based on a panel of 20 industries in 15 OECD countries over a 24-year period, they find strong evidence that upstream regulation retards downstream productivity. Additionally, using the distance to the frontier concept, they find the adverse impact to be greatest for firms closest to the global frontier, creating a catch-up (p. 53) effect for laggard firms. Égert (2016) adds two additional potential productivity drivers, innovation intensity and trade openness, to a similar panel. He finds a negative impact of labor market regulations and positive impacts of innovation intensity and trade openness, and complementarity between labor and product market regulations. Cette, Lopez, and Mairesse (2016) study another similar panel, examining the impacts of product and labor market regulations on productivity in downstream industries. They find potential long-term productivity gains on the order of 2.5% and 1.9%, respectively, if all countries adopted "lightest-practice" regulations, defined as the mean of the three lowest regulatory burdens in their sample. In a subsequent study Cette, Lopez, and Mairesse (2017) examine the impact of upstream regulatory burden indicators on downstream MFP in 15 OECD countries, and they find a statistically significant negative impact. They also find a mostly significant negative impact of upstream regulatory burden on downstream investment in ICT and R&D capital.

Empirical findings across a wide range of data sets are consistent, with one another and with the predictions of economic theory. Anti-competitive product and labor market regulations, and constraints on access to or the cost of capital, all have adverse consequences for productivity, either direct or indirect, by affecting either the mean or the dispersion of the productivity distribution. Evidence on the negative impact of upstream regulation on downstream productivity is particularly compelling.

1.5.2.2.3. Financial Frictions and Credit Constraints

Midrigan and Xu (2014) study financial frictions such as borrowing constraints, arguing that they reduce aggregate productivity through two channels: (i) they distort entry and technology adoption decisions, reducing the productivity of those producers, and (ii) they generate different rates of return to capital across producers, causing misallocation and further reducing productivity. Using establishment data from Korea, with its well-developed financial system, and China and Columbia, both with less-developed financial systems, they find the first channel to be more important than the second, reinforcing the finding of Andrews and Cingano (2014). They attribute the relatively small misallocation effect among incumbents to the ability of financially constrained but nonetheless more productive incumbents to exploit retained earnings as a source of capital. Moll (2014) also emphasizes the ability of accumulated internal funds to moderate capital misallocation caused by financial frictions. Banerjee and Duflo (2014) trace the persistent misallocation of capital among borrowing firms in India to the withdrawal and subsequent reimposition of credit constraints, although their focus is on profits rather than productivity, and they also find the extent of misallocation to be sensitive to the ability to self-finance.

Ferrando and Ruggieri (2015) argue that the impact of financial frictions on a firm's productivity depends on its financial structure. They use the Amadeus database[23] to construct a sample of over 5 million firm-year observations across nine sectors in eight Euro-area countries during 1995–2011, a period that includes the GFC. They construct a synthetic indicator of firm financial constraint as a function of financial leverage, debt burden, cash holdings, and firm controls. They find significant negative impacts of their (p. 54) financial constraint indicator on labor productivity across most sectors and countries, with the impacts being most severe in "innovative" industries. Fernandes and Ferreira (2017) examine the impact of tightening financing constraints caused by the GFC on firm employment decisions, using Portuguese linked employer–employee data during 2000–2012. They construct a similar indicator of firm financial constraint as a function of external finance dependence, asset tangibility, importance of trade credit, reliance on short-term debt, and a firm size-age index. Firm employment decisions are expressed as the share of workers hired on short-term contracts. Their main finding is that, subsequent to the crisis, firms with above-median financial constraint increased the share of short-term hires in total hires. The authors also suggest that this decision has productivity implications, since relatively constrained firms prefer the flexibility of short-term contracts to the higher productivity associated with permanent contracts. To test this conjecture, they regress labor productivity on the share of short-term workers and a host of firm controls, and they find a statistically negative impact.

Caselli and Gennaioli (2013) follow Burkhart, Panunzi, and Shliefer (2003) by linking institutional failures such as financial frictions with ownership. We have noted the finding of Bloom and Van Reenen (2007), repeated in many subsequent studies, that family-owned firms having a family CEO chosen by primogeniture have much lower quality of management practices than other firms, and consequently underperform other firms on a range of economic and financial indicators. Caselli and Gennaioli do not rely on primogeniture, but they do study the intergenerational transfer of management in family firms, a practice they call “dynastic management,” and Firfiray, Larraza-Kintana, and Gómez-Mejia call the “protection of socioemotional wealth” in Chapter 11. They argue that financial frictions hinder the market for corporate control by deterring lending and investment, restricting financing opportunities to both talented outsiders and talented descendants, who would otherwise invest more in the family firm than their less talented siblings. As a result, poorly functioning financial institutions reward less talented descendants, thereby adversely affecting productivity in dynastic family firms, which predominate in developing countries.

Financial constraints plague global supply chains, and have motivated the growth of a non-bank “fintech” industry designed to relax these constraints. Nonetheless, *The Economist* (2017) reports that the vast majority of global supply chains lack an adequate financing program, which, by raising transaction costs, reduces their productivity.

Financial constraints also influence modes of production. Using a large panel of US manufacturing plants, Andersen (2017) finds that credit constraints distort the asset mix toward tangible assets that can serve as collateral. This in turn leads to a quantitatively large and statistically significant increase in pollution emissions, an effect that is pronounced in industries that rely on external financing.

Unlike other studies, Blancard, Boussemart, Briec, and Kerstens (2006) use the frontier techniques we mention in subsection 1.3.2 to estimate the impact of credit constraints on the financial performance of a sample of French farmers. They find financially unconstrained farmers (whose credit constraint is not binding) to be larger, more efficient, and more successful financially than those having binding credit constraints. (p. 55) Their use of frontier techniques also enables them to estimate shadow prices of the constraints.

1.5.2.2.4. Costs of Doing Business

We have discussed regulation and finance constraints, both of which impose costs that reduce business productivity. There are other costs of doing business, and an associated literature examining the mechanisms through which these costs influence productivity.

The World Bank's Doing Business project was initiated in 2002 and provides objective measures of business regulations and their enforcement. The 2017 edition includes 11 indicators, each with several components, most of which are available for most of 190 economies. The 11 indicators measure the (money and time) costs of starting a business, dealing with construction permits, getting electricity, registering property, getting credit, protecting minority investors, paying taxes, trading across borders, enforcing contracts, resolving insolvency, and labor market regulation.

Barseghyan (2008) uses the World Bank's Cost of Doing Business data set to examine the impact of cross-country variation in entry costs on productivity. He regresses output per worker and TFP on an entry cost indicator, including all official fees that must be paid to complete legal procedures for starting a business, and incorporates a number of institutional controls. He finds that higher entry costs significantly reduce labor productivity, primarily by reducing its MFP component. Moscoso Boedo and Mukoyama (2012) also use the Cost of Doing Business data set, and they add exit costs, consisting of the cost of advance notice requirements, severance payments and penalties due when terminating a worker, to their entry cost indicator, consisting of the monetary and time costs of starting and licensing a business. Both costs and their components vary dramatically across countries, and both reduce productivity. Entry costs lower productivity by keeping low-productivity establishments in business, and exit costs lower productivity by dampening the reallocation of labor from low-productivity to high-productivity establishments. The authors calculate that raising the two costs from their US levels to those of the average low-income countries reduces aggregate GDP by as much as one-third.

Industrial policies that keep low-productivity firms in business, and discourage more productive firms from investing, have led to the "zombie firm" phenomenon. Caballero, Hoshi, and Kashyap (2008) study the phenomenon during the Japanese macroeconomic stagnation of the 1990s. They define zombie firms as potentially receiving subsidized bank credit, and they focus on credit misallocation resulting from zombie lending, which they attribute to relationship banking and regulatory forbearance, both of which keep zombie firms from exiting. In a large sample of Japanese firms, they find an increase in the share of zombies in an industry to be associated with a decline in investment and employment growth for non-zombies, and a widening productivity gap between non-zombies and zombies. Adalet McGowan, Andrews, and Millot (2017) define zombie firms as being at least 10 years old with an interest coverage ratio (the ratio of operating income to interest expense) of less than one for the preceding three years. In a large sample of OECD firms, they find (i) zombie firms to have increased (p. 56) in number and market share since 2000; (ii) the increasing survival of zombie firms congests markets, restricting exit, constraining the growth of more productive incumbent firms and raising barriers to entry for new firms; (iii) resources devoted to zombie firms reduce productivity-enhancing resource allocation that constrains investment and employment in more productive firms; and (iv) an increased productivity gap between zombie firms and more productive firms; all of which lead to (v) reduced potential output through two channels, business investment and MFP growth. Their primary policy prescription is to reduce credit and other barriers to the exit of zombie firms.

Complementarities can be positive, as with combinations of HR practices and types of ICT adoption, but they can be negative as well. Bergoeing, Loayza, and Piguillem (2016) contend that entry barriers and exit barriers are complements; each imposes costs, and they reinforce each other's negative impact on productivity. They use the Cost of Doing Business data set to estimate the impact of these barriers on the gap between US and developing country per capita output. They find entry and exit barriers to account for roughly half of the gap between the United States and the median developing country, half of which is accounted for by complementarities. The policy implication is that removal, or lowering, of both entry and exit barriers have a greater productivity impact than removing or lowering either of them separately.

Entry costs and other costs of doing business have a second depressing effect on productivity. Several writers have documented that high costs of doing business divert business from the formal sector to the informal sector, where productivity is lower than in the formal sector, due in part to the small size and inefficiencies of enterprises in the informal sector. D'Erasmo and Moscoso Boedo (2012) argue that high costs of doing business reduce aggregate MFP by encouraging the growth of the informal sector, where firms tend to be small and less productive than their formal-sector counterparts. This misallocation of capital reduces aggregate MFP; based on World Bank Cost of Doing Business data, they calculate this reduction to be "up to 25%." La Porta and Shleifer (2014) emphasize the fundamental differences between firms in the formal and informal sectors, arguing that informal firms are long-lived and rarely move to the formal sector, and that informality is reduced only by economic development.

1.5.2.2.5. Home Production

Becker's (1965) analysis of household time allocation was in large part responsible for his receipt of the 1992 Nobel Prize in Economic Sciences for ". . . having extended the domain of microeconomic analysis to a wide range of human behaviour and interaction, including non-market behaviour" (Royal Swedish Academy of Sciences 1992). We know that much non-market economic activity, home production in particular, is not captured by the national accounts. For our purposes, the relevant questions are how to measure the productivity of home production and whether incorporation of home production into the national accounts would have an impact on aggregate productivity, and then on social economic progress, as we discuss in subsection 1.2.3.

The OECD (2002, Annex 2) defines household production for own use as comprising ". . . those activities that are carried out by household unincorporated enterprises that (p. 57) are not involved in market production. By definition, such enterprises are excluded from the informal sector" (which is engaged in market production). Bridgman (2016) summarizes the efforts of the US Bureau of Economic Analysis to construct satellite accounts that estimate the value of household production. These accounts suggest that including home production raises GDP by 37% in 1965 and by 23% in 2014, the decline being attributable to increasing female labor force participation. Poissonnier and Roy (2015) report on the development of a satellite household account for France. Their findings suggest that incorporating household production in the national accounts would increase GDP by a third while reducing its rate of growth, and increase disposable income by half. They also conduct sensitivity analyses of various methodological issues, including the use of gross or net wages, and minimum or living wages, to value household labor.

The OECD (2011) provides preliminary estimates of the value of household production of non-market services, with the ultimate objective of comparing material well-being across countries. Among their many findings, they conclude that national estimates are acutely sensitive to the valuation of household labor using replacement cost or opportunity cost methodologies, although international comparisons are not. Schreyer and Diewert (2014) apply Becker's household time allocation model to determine the conditions under which the replacement cost or opportunity cost approaches are the appropriate way to value household labor, and they develop a cost of living index for Becker's full income and full consumption (of market goods, work at home, hired labor services, and leisure). This leads them to an international comparison of GDP growth rates with, and without, household production included. They characterize the differences as "not-insignificant." Their work constitutes an important analytical step toward household productivity measurement, although much more analytical and empirical work is needed.

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Notes:

(1.) Blázquez Gómez and Grifell-Tatjé (2011) find the Spanish regulator to have exhibited a pro-industry, anti-consumer bias during the 1988–1998 period, with the estimated value of the intended fraction having been outside [0, 1] for the majority of electricity distribution companies.

(2.) Here and henceforth we refer to all aggregate output measures such as GDP and GNP as "output," except when a precise definition is necessary.

(3.) https://data.oecd.org/lprdty/unit-labour-costs.htm (accessed October 24, 2016).

(4.) http://stats.oecd.org/# (accessed October 24, 2016).

(5.) For more on social economic progress, see Grifell-Tatjé, Lovell, and Turon (2016).

(6.) http://www.oecdobserver.org/news/fullstory.php/aid/5548/The_productivity_and_equality_nexus.html (accessed October 24, 2016)

(7.) This example is one of many suggesting potential complementarities between academics and consultancies such as the McKinsey Global Institute. Lewis (2004) provides a readable account of the Institute's forays into the measurement of productivity and its determinants, at both firm and country levels.

(8.) Alan B. Krueger served as chairman of President Obama's Council of Economic Advisors from 2011 to 2013.

(9.) http://www.bls.gov/mfp/data.htm (accessed October 24, 2016).

(10.) http://www.bls.gov/mfp/mprdload.htm (accessed October 24, 2016).

(11.) See also www.bls.gov/bls/productivity.htm (accessed October 24, 2016).

(12.) See http://www.oecd.org/economy (accessed October 24, 2016).

(13.) See http://www.bls.gov/news.release/pdf/prod3.pdf (accessed October 24, 2016).

(14.) See also www.bls.gov/ppi/qualityadjustment.pdf (accessed October 24, 2016).

(15.) Haltiwanger (2016) provides a critical overview of the TFPQ/TFPR literature.

(16.) A December 30, 2016, Google Scholar search for "the Toyota production system" turned up about 257,000 results.

(17.) http://www.bvdinfo.com/en-gb/our-products/company-information/international-products/orbis (accessed January 4, 2017).

(18.) This brief summary masks many details, which are available at www.doingbusiness.org/data/distance-to-frontier (accessed November 22, 2016).

(19.) http://worldmanagementsurvey.org (accessed November 1, 2016).

(20.) http://www.nestle.com/asset-library/documents/library/presentations/investors_events/investor-seminar-2016/nis-2016-14.pdf (accessed January 31, 2017).

(21.) Timmer, Erumban, Los, Stehrer, and de Vries (2014) attribute this example to Dedrick, Kraemer, and Linden (2010), who also estimate how profit is distributed along the GVC.

(22.) www.adidas-group.com//en/group/stories-copy/specialty/adidas-future-manufacturing/

(23.) http://www.bvdinfo.com/en-gb/our-products/company-information/international-products/amadeus (accessed January 4, 2017).

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