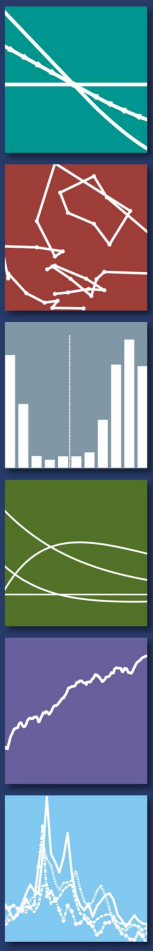
David Romer

Advanced Macroeconomics

Fifth Edition



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ADVANCED MACROECONOMICS

Fifth Edition

David Romer
University of California, Berkeley

ADVANCED MACROECONOMICS, FIFTH EDITION

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ABOUT THE AUTHOR

David Romer is the Royer Professor in Political Economy at the University of California, Berkeley, where he has been on the faculty since 1988. He is also co-director of the program in Monetary Economics at the National Bureau of Economic Research. He received his A.B. from Princeton University and his Ph.D. from the Massachusetts Institute of Technology. He has been a fellow of the American Academy of Arts and Sciences since 2006. At Berkeley, he is a three-time recipient of the Graduate Economic Association's distinguished teaching and advising awards; he received Berkeley's Social Sciences Distinguished Teaching Award in 2013–2014. Much of his research focuses on monetary and fiscal policy; this work considers both the effects of policy on the economy and the determinants of policy. His other research interests include the foundations of price stickiness, empirical evidence on economic growth, and asset-price volatility. His most recent work is concerned with financial crises. He is married to Christina Romer, with whom he frequently collaborates. They have three children, Katherine, Paul, and Matthew.

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EMPIRICAL APPLICATIONS

PREFACE TO THE FIFTH EDITION

Keeping a book on macroeconomics up to date feels Sisyphean. The field is continually evolving, as new events and research lead to doubts about old views and the emergence of new ideas, models, and tests. When the first edition of this book was published in 1996, financial crises and the zero lower bound on nominal interest rates were viewed as of only minor importance to macroeconomics; the main focus of work on monetary policy was its impact on average inflation, with little attention to its role in stabilization policy; each of the three equations of what is now the canonical new Keynesian model had only recently been developed, and they had not yet been brought together; and there had been almost no substantial empirical work on the role of institutions in cross-country income differences. All that—and much more in macroeconomics—has changed dramatically.

One result of the rapid evolution of the field is that each edition of this book is very different from the one before. At this point, the book has only a moderate resemblance to the first edition. Most of the material in this edition was either not present at all in the first edition or has been revised considerably. Indeed, a substantial majority of the papers cited in the current edition had not been written when the first edition was published.

Many of the changes since the first edition are new to this edition. The most important is the addition of a new chapter, Chapter 10, on financial markets and financial crises. The financial and macroeconomic crisis that began in 2008 showed the critical importance of financial markets to the macroeconomy. The new chapter covers the role of financial markets in Walrasian economies; investment under asymmetric information and the financial accelerator; the possibility of excess volatility in asset prices; the classic Diamond–Dybvig model of bank runs; and the macroeconomics of contagion and financial crises. In keeping with the increasingly central role of empirical work in macroeconomics, three sections of the chapter are devoted entirely to empirical applications.

There are also large changes to the rest of the book. Among the largest are the addition of a new section in Chapter 12 on the zero lower bound, which has been of first-order importance to macroeconomic developments over the past decade; a new section in Chapter 8 on buffer-stock saving, which provides an ideal vehicle for introducing both dynamic programming and a first look at the use of numeral methods; and a new section in Chapter 7

on the forward guidance puzzle, which starkly shows some of the limitations of the canonical new Keynesian model. I have also overhauled much of the presentation of empirical work on consumption in Chapter 8, pruned unnecessary or outdated material, and made revisions throughout to try to further improve the exposition. And I have continued to devote a great deal of attention to the end-of-chapter problems, which I view as invaluable for strengthening the reader's understanding of the material, concisely introducing extensions of the core material, and challenging the reader to develop important skills. Some of my favorites among the new problems are 1.10, 2.13, 8.16, 8.17, 9.4, and 10.10.

For additional reference and general information, please refer to the book's website at **www.mhhe.com/romer5e.** Also available on the website, under the password-protected Instructor Edition, is the *Solutions Manual*. Print versions of the manual are available by request only—if interested, please contact your McGraw-Hill Education representative.

This book owes a great deal to many people. The book is an outgrowth of courses I have taught at Princeton University, the Massachusetts Institute of Technology, Stanford University, and especially the University of California, Berkeley. I want to thank the many students in these courses for their feedback, their patience, and their encouragement.

Four people have provided detailed, thoughtful, and constructive comments on almost every aspect of the book over multiple editions: Laurence Ball, A. Andrew John, N. Gregory Mankiw, and Christina Romer. Each has significantly improved the book, and I am deeply grateful to them for their efforts. In addition, I am indebted to Laurence Ball and Kinda Hachem for their extremely valuable guidance and feedback concerning the material that is new to this edition.

Many other people have made valuable comments and suggestions concerning some or all of the book. I would particularly like to thank James Butkiewicz, Robert Chirinko, Matthew Cushing, Charles Engel, Mark Gertler, Robert Gordon, Mary Gregory, Tahereh Alavi Hojjat, A. Stephen Holland, Hiroo Iwanari, Frederick Joutz, Jinill Kim, Pok-sang Lam, Gregory Linden, Maurice Obtsfeld, Jeffrey Parker, Stephen Perez, Kerk Phillips, Carlos Ramirez, Robert Rasche, Joseph Santos, Peter Skott, Peter Temin, Henry Thompson, Patrick Toche, Matias Vernengo, and Steven Yamarik. I am also grateful to the many readers who have written to point out specific typos, inconsistencies, and ambiguities. Jeffrey Rohaly once again prepared the superb *Solutions Manual*. Benjamin Scuderi updated the tables and figures, provided valuable assistance and feedback concerning many aspects of the new material, and helped with the proofreading. Finally, the editorial and production staff at McGraw-Hill did an excellent job of turning the manuscript into a finished product. I thank all these people for their help.

INTRODUCTION

Macroeconomics is the study of the economy as a whole. It is therefore concerned with some of the most important questions in economics. Why are some countries rich and others poor? Why do countries grow? What are the sources of recessions and booms? Why is there unemployment, and what determines its extent? What are the sources of inflation? How do government policies affect output, unemployment, inflation, and growth? These and related questions are the subject of macroeconomics.

This book is an introduction to the study of macroeconomics at an advanced level. It presents the major theories concerning the central questions of macroeconomics. Its goal is to provide both an overview of the field for students who will not continue in macroeconomics and a starting point for students who will go on to more advanced courses and research in macroeconomics and monetary economics.

The book takes a broad view of the subject matter of macroeconomics. A substantial portion of the book is devoted to economic growth, and separate chapters are devoted to the natural rate of unemployment, monetary policy, and budget deficits. Within each part, the major issues and competing theories are presented and discussed. Throughout, the presentation is motivated by substantive questions about the world. Models and techniques are used extensively, but they are treated as tools for gaining insight into important issues, not as ends in themselves.

The first four chapters are concerned with growth. The analysis focuses on two fundamental questions: Why are some economies so much richer than others, and what accounts for the huge increases in real incomes over time? Chapter 1 is devoted to the Solow growth model, which is the basic reference point for almost all analyses of growth. The Solow model takes technological progress as given and investigates the effects of the division of output between consumption and investment on capital accumulation and growth. The chapter presents and analyzes the model and assesses its ability to answer the central questions concerning growth.

Chapter 2 relaxes the Solow model's assumption that the saving rate is exogenous and fixed. It covers both a model where the set of households in

the economy is fixed (the Ramsey model) and one where there is turnover (the Diamond model).

Chapter 3 presents the new growth theory. It begins with models where technological progress arises from the allocation of resources to the development of new ideas, but where the division of resources between the production of ideas and the production of conventional goods is taken as given. It then considers the determinants of that division.

Chapter 4 focuses specifically on the sources of the enormous differences in average incomes across countries. This material, which is heavily empirical, emphasizes two issues. The first is the contribution of variations in the accumulation of physical and human capital and in output for given quantities of capital to cross-country income differences. The other is the determinants of those variations.

Chapters 5 through 7 are devoted to short-run fluctuations—the year-to-year and quarter-to-quarter ups and downs of employment, unemployment, and output. Chapter 5 investigates models of fluctuations where there are no imperfections, externalities, or missing markets and where the economy is subject only to real disturbances. This presentation of real-business-cycle theory considers both a baseline model whose mechanics are fairly transparent and a more sophisticated model that incorporates additional important features of fluctuations.

Chapters 6 and 7 then turn to Keynesian models of fluctuations. These models are based on sluggish adjustment of nominal prices and wages, and emphasize monetary as well as real disturbances. Chapter 6 focuses on basic features of price stickiness. It investigates baseline models where price stickiness is exogenous and the microeconomic foundations of price stickiness in static settings. Chapter 7 turns to dynamics. It first examines the implications of alternative assumptions about price adjustment in dynamic settings. It then turns to dynamic stochastic general-equilibrium models of fluctuations with price stickiness—that is, fully specified general-equilibrium models of fluctuations that incorporate incomplete nominal price adjustment.

The analysis in the first seven chapters suggests that the behavior of consumption and investment is central to both growth and fluctuations. Chapters 8 and 9 therefore examine the determinants of consumption and investment in more detail. In each case, the analysis begins with a baseline model and then considers alternative views. For consumption, the baseline is the permanent-income hypothesis; for investment, it is q theory.

The analysis of consumption and investment leads naturally to an examination of financial markets, which are the subject of Chapter 10. Financial markets are where households' supply of saving and firms' demand for investment meet to determine the division of the economy's output between consumption and investment and the allocation of investment among alternative projects. More importantly, imperfections in financial markets can both amplify the effects of shocks elsewhere in the economy and be an

independent source of disturbances. In the extreme, convulsive changes in financial markets can lead to financial and macroeconomic crises. All these topics are explored in the chapter.

Chapter 11 turns to the labor market. It focuses on the determinants of an economy's natural rate of unemployment. The chapter also investigates the impact of fluctuations in labor demand on real wages and employment. It examines two types of models: traditional efficiency-wage and contracting theories that focus on forces preventing wages from falling to the level that equates supply and demand, and modern search and matching models that emphasize the crucial role of heterogeneity in the labor market.

The final two chapters are devoted to macroeconomic policy. Chapter 12 investigates monetary policy and inflation. It starts by explaining the central role of money growth in causing inflation and by investigating the effects of money growth. It then considers the use of monetary policy for macroeconomic stabilization. This analysis begins with the microeconomic foundations of the appropriate objective for stabilization policy, proceeds to the analysis of optimal policy in backward-looking and forward-looking models, and concludes with a discussion of a range of issues in the conduct of policy and an analysis of the implications of the zero lower bound on nominal interest rates for monetary policy. The final sections of the chapter examine how excessive inflation can arise either from a short-run output-inflation tradeoff or from governments' need for revenue from money creation.

Finally, Chapter 13 is concerned with fiscal policy and budget deficits. The first part of the chapter describes the government's budget constraint and investigates two baseline views of deficits: Ricardian equivalence and tax-smoothing. Most of the remainder of the chapter investigates theories of the sources of deficits. In doing so, it provides an introduction to the use of economic tools to study politics. The chapter concludes with a discussion of the costs of deficits and a model of sovereign debt crises.

Macroeconomics is both a theoretical and an empirical subject. Because of this, the presentation of the theories is supplemented with examples of relevant empirical work. Even more so than with the theoretical sections, the purpose of the empirical material is not to provide a survey of the literature; nor is it to teach econometric techniques. Instead, the goal is to illustrate some of the ways that macroeconomic theories can be applied and tested. The presentation of this material is for the most part fairly intuitive and presumes no more knowledge of econometrics than a general familiarity with regressions. In a few places where it can be done naturally, the empirical material includes discussions of the ideas underlying more advanced econometric techniques.

Each chapter concludes with a set of problems. The problems range from relatively straightforward variations on the ideas in the text to extensions that tackle important issues. The problems thus serve both as a way for readers to strengthen their understanding of the material and as a compact way of presenting significant extensions of the ideas in the text.

The fact that the book is an *advanced* introduction to macroeconomics has two main consequences. The first is that the book uses a series of formal models to present and analyze the theories. Models identify particular features of reality and study their consequences in isolation. They thereby allow us to see clearly how different elements of the economy interact and what their implications are. As a result, they provide a rigorous way of investigating whether a proposed theory can answer a particular question and whether it generates additional predictions.

The book contains literally dozens of models. The main reason for this multiplicity is that we are interested in many issues. Features of the economy that are crucial to one issue may be unimportant to others. Money, for example, is almost surely central to inflation but not to long-run growth. Incorporating money into models of growth would only obscure the analysis. Thus instead of trying to build a single model to analyze all the issues we are interested in, the book develops a series of models.

An additional reason for the multiplicity of models is that there is considerable disagreement about the answers to many of the questions we will be examining. When there is disagreement, the book presents the leading views and discusses their strengths and weaknesses. Because different theories emphasize different features of the economy, again it is more enlightening to investigate distinct models than to build one model incorporating all the features emphasized by the different views.

The second consequence of the book's advanced level is that it presumes some background in mathematics and economics. Mathematics provides compact ways of expressing ideas and powerful tools for analyzing them. The models are therefore mainly presented and analyzed mathematically. The key mathematical requirements are a thorough understanding of single-variable calculus and an introductory knowledge of multivariable calculus. Tools such as functions, logarithms, derivatives and partial derivatives, maximization subject to constraint, and Taylor-series approximations are used relatively freely. Knowledge of the basic ideas of probability—random variables, means, variances, covariances, and independence—is also assumed.

No mathematical background beyond this level is needed. More advanced tools (such as simple differential equations, the calculus of variations, and dynamic programming) are used sparingly, and they are explained as they are used. Indeed, since mathematical techniques are essential to further study and research in macroeconomics, models are sometimes analyzed in greater detail than is otherwise needed in order to illustrate the use of a particular method.

In terms of economics, the book assumes an understanding of microeconomics through the intermediate level. Familiarity with such ideas as profit maximization and utility maximization, supply and demand, equilibrium, efficiency, and the welfare properties of competitive equilibria is presumed. Little background in macroeconomics itself is absolutely necessary. Readers with no prior exposure to macroeconomics, however, are likely to find some

of the concepts and terminology difficult, and to find that the pace is rapid. These readers may wish to review an intermediate macroeconomics text before beginning the book, or to study such a book in conjunction with this one.

The book was designed for first-year graduate courses in macroeconomics. But it can be used (either on its own or in conjunction with an intermediate text) for students with strong backgrounds in mathematics and economics in professional schools and advanced undergraduate programs. It can also provide a tour of the field for economists and others working in areas outside macroeconomics.

Chapter 1
THE SOLOW GROWTH MODEL

1.1 Some Basic Facts about Economic Growth

Over the past few centuries, standards of living in industrialized countries have reached levels almost unimaginable to our ancestors. Although comparisons are difficult, the best available evidence suggests that average real incomes today in the United States and Western Europe are between 5 and 20 times larger than a century ago, and between 15 and 100 times larger than two centuries ago.[1]

Moreover, worldwide growth is far from constant. Growth has been rising over most of modern history. Average growth rates in the industrialized countries were higher in the twentieth century than in the nineteenth, and higher in the nineteenth than in the eighteenth. Further, average incomes on the eve of the Industrial Revolution even in the wealthiest countries were not dramatically above subsistence levels; this tells us that average growth over the millennia before the Industrial Revolution must have been very, very low.

Recent decades have seen an important departure from this general pattern of increasing growth. Beginning in the early 1970s, annual growth in output per person in the United States and other industrialized countries averaged about a percentage point less than its earlier level. After a brief rebound in the second half of the 1990s, average growth over the past decade has been even lower. Whether the recent period of low growth will be long-lasting is unclear.

There are also enormous differences in standards of living across parts of the world. Average real incomes in such countries as the United States, Germany, and Japan appear to exceed those in such countries as Bangladesh

[1] Estimates of average real incomes for many parts of the world over long periods are available from the Maddison Project (Bolt and van Zanden, 2014). Most of the uncertainty about the extent of long-term growth concerns the behavior not of nominal income, but of the price indexes needed to convert those figures into estimates of real income. Adjusting for quality changes and for the introduction of new goods is conceptually and practically difficult, and conventional price indexes do not make these adjustments well. See Nordhaus (1997) and Boskin, Dulberger, Gordon, Griliches, and Jorgenson (1998) for two classic discussions of the issues involved and analyses of the biases in conventional price indexes.

and Kenya by a factor of about 15.[2] As with worldwide growth, cross-country income differences are not immutable. Growth in individual countries often differs considerably from average worldwide growth; that is, there are often large changes in countries' relative incomes.

The most striking examples of large changes in relative incomes are *growth miracles* and *growth disasters*. Growth miracles are episodes where growth in a country far exceeds the world average over an extended period, with the result that the country moves rapidly up the world income distribution. Some prominent growth miracles are Japan from the end of World War II to around 1990, the newly industrializing countries (NICs) of East Asia (South Korea, Taiwan, Singapore, and Hong Kong) starting around 1960, and China starting around 1980. Average incomes in the NICs, for example, have grown at an average annual rate of over 5 percent since 1960. As a result, their average incomes relative to that of the United States have roughly quintupled.

Growth disasters are episodes where a country's growth falls far short of the world average. Two very different examples of growth disasters are Argentina and many of the countries of sub-Saharan Africa. In 1900, Argentina's average income was only slightly behind those of the world's leaders, and it appeared poised to become a major industrialized country. But its growth performance since then has been dismal, and it is now near the middle of the world income distribution. Sub-Saharan African countries such as Niger, Guinea, and the Central African Republic have been extremely poor throughout their histories and have been unable to obtain any sustained growth in average incomes. As a result, their average incomes have remained close to subsistence levels while average world income has been rising steadily.

Other countries exhibit more complicated growth patterns. Côte d'Ivoire was held up as the growth model for Africa through the 1970s. From 1960 to 1978, real income per person grew at an average annual rate of 3.6 percent. But since then, its average income has not increased at all, and it is now lower relative to that of the United States than it was in 1960. To take another example, average growth in Mexico was very high in the 1950s, 1960s, and 1970s, negative in most of the 1980s, and moderate—with a brief but severe interruption in the mid-1990s—since then.

Over the whole of the modern era, cross-country income differences have widened on average. The fact that average incomes in the richest countries at the beginning of the Industrial Revolution were not far above subsistence means that the overall dispersion of average incomes across different parts of

[2] Comparisons of real incomes across countries are far from straightforward, but are much easier than comparisons over extended periods of time. The basic source for cross-country data on real income is the Penn World Tables. Documentation of these data and the most recent figures are available at www.rug.nl/ggdc/productivity/pwt.

the world must have been much smaller than it is today (Pritchett, 1997). Over the past few decades, however, there has been no strong tendency either toward continued divergence or toward convergence.

The implications of the vast differences in standards of living over time and across countries for human welfare are enormous. The differences are associated with large differences in nutrition, literacy, infant mortality, life expectancy, and other direct measures of well-being. And the welfare consequences of long-run growth swamp any possible effects of the short-run fluctuations that macroeconomics traditionally focuses on. During an average recession in the United States, for example, real income per person falls by a few percent relative to its usual path. In contrast, the slowdown in productivity growth since the early 1970s has reduced real income per person in the United States by about 35 percent relative to what it otherwise would have been. Other examples are even more startling. If real income per person in Kenya continues to grow at its average rate for the period 1960–2014 of 1 percent per year, it will take four centuries for it to reach the current U.S. level. If it achieves 3 percent growth, the time will be reduced to 100 years. And if it achieves 5 percent growth, as the NICs have done, the process will take only 60 years. To quote Robert Lucas (1988), "Once one starts to think about [economic growth], it is hard to think about anything else."

The first four chapters of this book are therefore devoted to economic growth. We will investigate several models of growth. Although we will examine the models' mechanics in considerable detail, our goal is to learn what insights they offer concerning worldwide growth and income differences across countries. Indeed, the ultimate objective of research on economic growth is to determine whether there are possibilities for raising overall growth or bringing standards of living in poor countries closer to those in the world leaders.

This chapter focuses on a relatively simple, transparent model that is an excellent starting point for studying these issues, the Solow growth model.[3] Even models that depart fundamentally from Solow's are often best understood through comparison with the Solow model. Thus understanding the model is essential to understanding theories of growth.

The principal conclusion of the Solow model is that the accumulation of physical capital cannot account for either the vast growth over time in output per person or the vast geographic differences in output per person. Specifically, suppose that capital accumulation affects output through the conventional channel that capital makes a direct contribution to production, for which it is paid its marginal product. Then the Solow model implies that the differences in real incomes that we are trying to understand are far too large to be accounted for by differences in capital inputs. The model treats

[3] The Solow model (which is sometimes known as the Solow–Swan model) was developed by Robert Solow (Solow, 1956) and T. W. Swan (Swan, 1956).

other potential sources of differences in real incomes as either exogenous and thus not explained by the model (in the case of technological progress, for example) or absent altogether (in the case of positive externalities from capital, for example). Thus to address the central questions of growth theory, we must move beyond the Solow model.

Chapters 2 through 4 therefore extend and modify the Solow model. Chapter 2 investigates the determinants of saving and investment. The Solow model has no optimization in it; it takes the saving rate as exogenous and constant. Chapter 2 presents two models that make saving endogenous and potentially time-varying. In the first, saving and consumption decisions are made by a fixed set of infinitely lived households; in the second, the decisions are made by overlapping generations of households with finite horizons.

Relaxing the Solow model's assumption of a constant saving rate has three advantages. First, and most important for studying growth, it demonstrates that the Solow model's conclusions about the central questions of growth theory do not hinge on its assumption of a fixed saving rate. Second, it allows us to consider welfare issues. A model that directly specifies relations among aggregate variables provides no way of judging whether some outcomes are better or worse than others: without individuals in the model, we cannot say whether different outcomes make individuals better or worse off. The infinite-horizon and overlapping-generations models are built up from the behavior of individuals, and can therefore be used to discuss welfare issues. Third, infinite-horizon and overlapping-generations models are used to study many issues in economics other than economic growth; thus they are valuable tools.

Chapters 3 and 4 investigate more fundamental departures from the Solow model. Their models, in contrast to Chapter 2's, provide different answers than the Solow model to the central questions of growth theory. Chapter 3 departs from the Solow model's treatment of technological progress as exogenous; it assumes instead that it is the result of the allocation of resources to the creation of new technologies. We will investigate the implications of such *endogenous technological progress* for economic growth and the determinants of the allocation of resources to innovative activities.

The main conclusion of this analysis is that endogenous technological progress is almost surely central to worldwide growth but probably has little to do with cross-country income differences. Chapter 4 therefore focuses specifically on those differences. We will find that understanding them requires considering two new factors: variation in human as well as physical capital, and variation in productivity not stemming from variation in technology. Chapter 4 explores both how those factors can help us understand the enormous differences in average incomes across countries and potential sources of variation in those factors.

We now turn to the Solow model.

1.2 Assumptions

Inputs and Output

The Solow model focuses on four variables: output (Y), capital (K), labor (L), and "knowledge" or the "effectiveness of labor" (A). At any time, the economy has some amounts of capital, labor, and knowledge, and these are combined to produce output. The production function takes the form

$$Y(t) = F(K(t), A(t)L(t)), \tag{1.1}$$

where t denotes time.

Notice that time does not enter the production function directly, but only through K, L, and A. That is, output changes over time only if the inputs to production change. In particular, the amount of output obtained from given quantities of capital and labor rises over time—there is technological progress—only if the effectiveness of labor increases.

Notice also that A and L enter multiplicatively. AL is referred to as *effective labor*, and technological progress that enters in this fashion is known as *labor-augmenting* or *Harrod-neutral*.[4] This way of specifying how A enters, together with the other assumptions of the model, will imply that the ratio of capital to output, K/Y, eventually settles down. In practice, capital-output ratios do not show any clear upward or downward trend over extended periods. In addition, building the model so that the ratio is eventually constant makes the analysis much simpler. Assuming that A multiplies L is therefore very convenient.

The central assumptions of the Solow model concern the properties of the production function and the evolution of the three inputs into production (capital, labor, and the effectiveness of labor) over time. We discuss each in turn.

Assumptions Concerning the Production Function

The model's critical assumption concerning the production function is that it has constant returns to scale in its two arguments, capital and effective labor. That is, doubling the quantities of capital and effective labor (for example, by doubling K and L with A held fixed) doubles the amount produced. More generally, multiplying both arguments by any nonnegative constant c causes output to change by the same factor:

$$F(cK, cAL) = cF(K, AL) \qquad \text{for all } c \geq 0. \tag{1.2}$$

[4] If A enters in the form $Y = F(AK, L)$, technological progress is *capital-augmenting*. If it enters in the form $Y = AF(K, L)$, technological progress is *Hicks-neutral*.