

Introduction and Overview |

Over the past three decades, significant economic and social progress has been achieved in the developing world. Infant mortality rates have been halved, primary school enrollment rates have doubled, and in some countries life expectancy has increased by more than 20 years. During the 1990s alone, per capita income increased on average by 2.6 percent.

However, progress has been uneven. In some countries, the rapid spread of HIV/AIDS has literally erased many of the gains achieved in increasing life expectancy. And although the *proportion* of people in extreme poverty fell slightly as a whole over the past decade, the *absolute number* of poor people increased in almost all regions (except in East Asia), with large concentrations in South Asia (which contains the largest number of the world's poor) and in sub-Saharan Africa (which continues to have the largest proportion of its population living in poverty). Today, one in every four people, or 1.3 billion persons, lives in extreme poverty in the developing world. In the past 10 years alone, the number of poor people in sub-Saharan Africa increased by more than a third. Although access to clean water and sanitation is now recognized as a human right by the United Nations, almost 900 million people continue to lack access to safe drinking water and more than 2.6 billion do not have access to basic sanitation. Because of water- and sanitation-related diseases, each year about 1.5 million children under the age of five die and millions of school days are lost (see United Nations (2005)). Malaria, by itself, claims the lives of 1 million children under the age of five every year. Through various channels, the global financial crisis triggered by the collapse of the subprime mortgage market in the United States has set some countries back by more than a decade.

The persistence of poverty and lack of progress in human development has led policymakers to put renewed emphasis on policies aimed at promoting economic efficiency and improving the productivity of the poor, generating income-earning capabilities and creating opportunities for using them productively, through education and health (which affect productivity), increasing opportunities to invest in small- and medium-size enterprises (which depend in part on access to credit), and improving housing and basic infrastructure services.

Much of the current international debate on how these policies should be sequenced has centered on the need to promote a large, front-loaded, increase in public investment. Reports by the United Nations (2005), the Commission for Africa (2005), and the World Bank (2005*a*) and prominent advocates like Jeffrey Sachs (2005, 2008) have indeed recommended a “Big Push” in public infrastructure investment in poor countries, financed by generous debt relief

and a substantial increase in aid, to spur growth, reduce poverty, and improve the quality of human life in low-income developing countries. In a report on sub-Saharan Africa, for instance, the World Bank (2005a) called for a doubling of spending on infrastructure in the region, from 4.7 percent of GDP in the years prior to the report to more than 9 percent over the subsequent decade.

A common argument for a large increase in public spending on infrastructure is that infrastructure services have a strong growth-promoting effect through their impact on the productivity of private inputs and the rate of return on capital—particularly when, to begin with, stocks of infrastructure assets are relatively low. In that regard, and with the exception of cellular telecommunications, low-income countries are at a particular disadvantage. In sub-Saharan Africa, for instance, only 16 percent of roads are paved, and less than one in five Africans has access to electricity. The average waiting time for a fixed telephone connection is three and a half years. Transport costs are the highest of any region, and high freight charges continue to represent a major constraint on the expansion of exports to industrial countries. Given the scale and lumpy nature of many infrastructure projects, and the fact that prospects for public-private partnerships in infrastructure investment for the region, and low-income countries in general, remain limited (if not nonexistent, in some cases), closing the infrastructure gap will indeed require a substantial increase in *public* investment.

At the same time, recent analytical and empirical research has highlighted the fact that, beyond its effects on the productivity of private inputs and the rate of return on private capital, public infrastructure may spur growth through a variety of other channels. For instance, it has been argued that good public infrastructure (such as a reliable power grid or well-maintained roads), by reducing the need for the private sector to spend on maintenance of its own stock of physical capital, may raise the rate of capital formation. A large body of evidence, based on microeconomic studies, suggests also that infrastructure may have a significant impact on health and education outcomes. Accounting for the externalities associated with infrastructure may thus be essential in designing and quantifying growth and human development strategies.

This book focuses precisely on these externalities and their implications for growth and human welfare—that is, the well-being of individuals, as opposed to social welfare or the well-being of the community as a whole—in low-income developing countries. Its purpose is threefold. First, it provides a systematic overview of the recent evidence on the different channels, beyond those deemed conventional, through which infrastructure may affect growth. Second, it takes a resolutely analytical approach by developing an integrated series of formal models for understanding how these channels operate. Possible extensions of these models are also indicated. Third, policy implications, with respect to formulating growth and human development strategies, are drawn.

Reflecting this multiplicity of purpose, chapters 1 to 6 all begin with a background section, which reviews the evidence on the issue at stake, and

then present a rigorous analysis of a particular channel. Chapter 7 outlines a comprehensive research agenda, and the conclusion of the book draws together the main policy lessons of the analysis. Of course, given that throughout the book only small analytical models, rather than applied, country-specific models, are developed, only broad policy lessons can be drawn; nevertheless, there are good reasons to believe that these lessons provide a solid foundation for more operational analysis and country-specific policy advice.

By its very nature, the book can also be used as a single reference for a short, specialized course on economic growth or development economics, or as a supplement to more general advanced courses in those areas. It is largely self-contained and the step-by-step solution of all models (provided in either the text itself or chapter appendices) makes it relatively easy to follow. Students who have no prior exposure to this area will find the literature review on each topic covered in the book to be fairly comprehensive and will welcome the research perspectives provided in the last chapter. At the same time, this book is not a comprehensive textbook; as such, it assumes familiarity with basic concepts in microeconomics (such as utility and profit maximization) and macroeconomics (such as aggregate production functions), as well as core elements of modern growth theory. Although some key concepts are defined when appropriate, this is done in a rather succinct manner. Readers familiar with the basic chapters in Barro and Sala-i-Martin (2003) or Acemoglu (2008), for instance, would be well equipped to tackle the issues discussed here.

Throughout, the analysis is based on the Allais-Samuelson Overlapping Generations (OLG) model.¹ OLG models have proved to be a powerful analytical tool to address development issues in general; this book shows that they are particularly well suited to address the links among infrastructure, growth, and human welfare. Given its analytical focus, the book is most suited for professional economists and graduate students specializing in either macroeconomics or development economics, who also firmly believe (as I do, hence the subtitle) in the role of economic theory in providing analytical foundations for public policy.

Throughout the book, the terms “public infrastructure” and “public capital” are used interchangeably, in line with the literature in the field. Of course, public capital is a broader concept—it also includes school buildings, hospitals, public libraries, and all other physical assets owned by the state. However, there is no risk of confusion because references to these other components of public capital will be made only sparingly—if at all. Moreover, the focus

¹ See Allais (1947), Samuelson (1958), and the extension by Diamond (1965) to include physical capital. P. Weil (2008) offers a brief history of the OLG model and some of its recent applications, whereas De la Croix and Michel (2002) provide a comprehensive analytical treatment. The baseline OLG model is discussed in many textbooks on economic growth, including Acemoglu (2008).

will be on “core” public capital, which includes transport, water supply and sanitation, information and communications technology, and energy.

To facilitate the task of the reader, and references across chapters, common notations for both variables and parameters are used as much as possible throughout the book. The main symbols are summarized at the end of this introduction.

The book is organized as follows. Chapter 1 begins by focusing on “conventional” channels through which public capital is deemed to affect growth, namely, productivity, complementarity, and crowding-out effects. It presents a basic two-period OLG model, which is extended in subsequent chapters to address a host of other issues. At the core of this model is a production function in which, following the seminal contribution of Arrow and Kurz (1970), public capital is complementary to private capital. In addition, the production of new public capital depends not only on the flow of investment in infrastructure but also on the existing stock of public capital. The latter assumption is shown to be critical in generating dynamics in the public-private capital ratio.

Several extensions of the basic model are then considered, including indirect taxation, a complementarity effect operating through the efficiency of private investment, an effect of public capital on household utility, and maintenance expenditure. The allocation of government spending between maintenance and new investment in infrastructure, possible trade-offs that may arise between these two components of public outlays, and the possibility that public spending on maintenance may also affect directly the durability of private physical assets are discussed as well.

The chapter also provides a discussion of optimal fiscal policy, which is studied from the perspective of growth maximization by a benevolent government, rather than in terms of *social* welfare maximization. A key reason for doing so is the fact that the purpose of this book, in line with the practical concerns of policymakers today, is how public capital can promote growth; and sustained economic growth is critical to achieving progress in reducing poverty and improving standards of living across the board. There are other reasons as well, related in particular to the coexistence of several generations at any given moment in time and the difficulty of defining a social welfare function in such conditions. It should be pointed out, nevertheless, that the book does examine the implications of public capital for *human* welfare, in addition to growth, to the extent that it considers education and health outcomes.

Chapters 2 to 6 are devoted to the various externalities that public capital may generate. Chapter 2 focuses on the links among public capital, knowledge accumulation, and economic growth. It is common to argue that knowledge spillovers are a key determinant of economic growth (see for instance Jones and P. Romer (2010)). In this chapter, the view that is emphasized, in line with the empirical evidence, is that knowledge accumulation itself may depend critically on access to public capital. It also considers the possibility of a

trade-off between public spending on education and investment in infrastructure. The point is that even though these expenditure components may be strongly complementary at the microeconomic or sectoral level, they may be substitutes at the macroeconomic level due to a financing constraint. The question that arises, then, is how to allocate optimally (limited) resources among alternative uses. It is addressed by assuming, as discussed earlier, that the government's goal is to maximize growth.

Chapter 3 examines interactions among public capital, health, and economic growth, using both two- and three-period OLG models. The first model dwells on the large body of evidence that suggests that access to infrastructure may be critical to improving health outcomes. The second accounts, in addition, for the fact that there is persistence in health outcomes between childhood and adulthood, the first two stages of life. This creates the possibility that public capital may affect health in ways that are different than commonly thought: if, for instance, greater access to infrastructure services allows parents to devote more time to child rearing, and if children's health depends positively on parental time, their productivity and earnings in adulthood will also be affected. In effect, what this analysis shows is that time allocated to child rearing, which is often considered as unproductive in growth models, may turn out to be a critical channel through which public capital affects growth. The chapter concludes by noting that interactions between health and education, which are well documented, may serve to magnify the effect of public capital on growth and human welfare.²

Chapter 4 focuses on the links among public capital, innovation and the diffusion of new products, and economic growth. Potential trade-offs associated with the provision of infrastructure and government support for innovation (as well as education, as in chapter 2) are discussed once again: if governments have access to limited resources to cover their expenditure, different types of government interventions entail dynamic trade-offs at the macroeconomic level—even though at the microeconomic or sectoral level these interventions are largely complementary. In addition, different types of government intervention may generate spillover effects on other sectors, which may have an indirect impact on innovation capacity. In particular, there is much evidence to suggest that access to telecommunications and highly skilled labor are important determinants of innovation capacity. Thus, if lack of infrastructure and low quality of tertiary education are key constraints on research and development activities, increasing spending on infrastructure or universities may ultimately prove to be more efficient to stimulate innovation than, say,

² A critical point that also emerges from the models presented in Chapters 2 and 3 (albeit unrelated to public capital *per se*) is that when thinking about human capital, and in contrast to commonly held views, it is essential to distinguish between health and knowledge; while the latter can be accumulated without bounds, the former cannot. This distinction has important analytical and policy implications.

subsidies for research activities in the private sector. Trade-offs involved in the allocation of public expenditure between infrastructure investment and support for R&D activities are illustrated through both an intuitive discussion and numerical experiments. The last part of the chapter discusses the role of public capital in the transition from *imitation* activities (copying or adapting foreign products or technologies to local markets) to *true innovation* (which involves the creation of new products, at the cutting edge of technology). It argues that this transition may necessitate not only a more qualified workforce in a range of areas but also a different *type* of public capital: whereas imitation may require only access to “basic” infrastructure (roads, basic telecommunications services, electricity, and so on), to switch to true innovation may require a more “advanced” type of physical assets, which exhibit a greater degree of complementarity with skilled labor. Recent research provides robust evidence to suggest that access to broadband infrastructure, in particular, is critical for the rapid generation and distribution of decentralized information and ideas, which in turn are important steps to promote innovation. Without the provision of this type of capital there is a risk of being caught in an “imitation trap,” a situation in which economic growth is positive—both in absolute and per capita terms—but moderate, lengthening therefore the process of convergence to high-income status.

Chapter 5 presents a gender-based model to analyze the links among public capital, gender, and economic growth, taking into account women’s time allocation among market work, home production, child rearing, and their own health care. Women are assumed to bear the brunt of domestic tasks (processing food crops, providing water and firewood, caring for children, and so on), in line with the evidence for developing countries. As in chapter 3, health status in adulthood (which affects productivity and wages) is taken to depend on health status in childhood as well as time allocated to own health care. Thus, health persistence and time allocated by mothers to child rearing become again key factors in the growth process. The implications of the analysis for the debate on the relationship between women’s labor supply and the level of development as well as various extensions (including intrahousehold bargaining) are also discussed. Although the analysis focuses on the impact of infrastructure on women’s time allocation, the model can be used to study a variety of gender-based policies; the chapter may therefore prove to be of independent interest to those working on gender and growth issues.

Chapter 6 focuses on the network effects of public capital and considers how a Big Push in public investment may help a poor country escape from a poverty trap, that is, an equilibrium characterized by low or zero growth in income. Network effects typically imply nonlinearities or threshold effects, often resulting in the degree of efficiency of infrastructure being nonlinearly related to the existing stock of public capital itself. Specifically, the marginal

benefits of public capital, in terms of its own efficiency, may be highly positive at first, once a core network is completed; but beyond that, these marginal benefits, while they remain positive, may increase at a decreasing rate. The analysis shows that, depending on how strong nonlinearities are, multiple equilibria may emerge. Provided that the quality of governance is adequate enough to ensure a sufficient degree of efficiency of public investment, a large increase in the share of spending on infrastructure may shift the economy from a low-growth equilibrium to a high-growth steady state. The chapter also studies how the choice of production technology is affected by access to public capital, in a setting where the critical value of that variable (that is, the point at which a switch in technology occurs) is endogenously determined through a rate-of-return arbitrage condition. Similar conclusions on the impact of public investment are obtained. The analysis provides therefore a conceptual underpinning to the Big Push idea, with the important proviso that for this policy to work, the quality of governance may need to be improved at the same time. The practical implications of these results for the ongoing debate on “scaling up” public investment in poor countries cannot be overemphasized.

Chapter 7 outlines a research agenda for improving further our understanding of how public capital, economic growth, and human welfare interact. It addresses issues such as heterogeneous infrastructure assets, the political economy of government spending allocation, excludable public goods, interactions between government debt and public capital accumulation in the presence of fiscal rules, spatial and regional dimensions of public capital, public-private partnerships, the impact of public capital on income distribution, negative externalities associated with infrastructure, and empirical tests of the impact of public capital on growth. The view that underlies this book is that the scale of infrastructure projects and the lack of access to private capital markets by the poorest countries hamper their ability to invest in this area. However, even though public investment will continue to be needed to address a range of needs (such as new road capacity in sparsely populated areas), the issue of private sector provision of infrastructure services will become increasingly important in the coming years. Some low-income countries have also started to leverage their natural resources. Understanding what the best long-term arrangements with the private sector are in a context where promoting growth is a key objective remains therefore an important area of investigation. The discussion points out as well that most existing studies, based on linear, single-equation regressions, seriously underestimate the true impact of public capital on output. To a significant extent, this is the consequence of the fact that many of these studies did not attempt to account for some of the externalities associated with infrastructure, as discussed in this book.

Even though the last chapter suggests that there is still a lot to understand in the relationship among public capital, economic growth, and welfare, my hope is that this book makes it clear that there has been much progress toward that

endeavor—both conceptually and empirically. Its key message is that, beyond the conventional productivity and cost effects, as well as complementarity and crowding-out effects that economists tend to emphasize, there is a wide range of externalities associated with public capital—and these should be accounted for in analytical models and introduced in policy debates. It is not a gross exaggeration to argue that investing in infrastructure may be as much about promoting markets as it may be about achieving health and education targets, fostering a culture of innovation, and empowering women. What this means, paradoxically, is that in some circumstances the best way to improve, say, education or health outcomes could be to spend less on schooling and health facilities and instead spend more on infrastructure. This does not mean of course that intrinsic challenges in those sectors should be ignored; in the education sector, for instance, there are serious quality issues in low-income countries that need to be addressed. The point, however, is that lack of access to public capital may be an equally important, if not more important, constraint in some cases. This also has implications for the selection, monitoring, and evaluation of infrastructure projects; in addition to conventional methods for project assessment (often based solely on internal rates of return), it is essential to account for the benefits that these projects may provide in terms of human welfare. The fact that measuring these benefits can be difficult in practice should not be used as an excuse for ignoring them.

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This book is the product of the research that I have conducted for the past few years at the University of Manchester and the Centre for Growth and Business Cycle Research on public capital, economic growth, poverty reduction, and welfare. The university has provided me with a superb environment and unique conditions for developing this agenda, and for that I am most grateful.

In conducting this work, I have benefited from collaborative projects and interactions with several colleagues and students at Manchester, including Keith Blackburn, Kyriakos Neanidis, and Devrim Yilmaz. Many of the practical insights upon which this book dwells emerged from the research agenda on growth and poverty reduction that I initiated during my time at the World Bank, and more recently through a collaborative project on women's time allocation and growth. Economists from the bank with whom this collaboration has been most fruitful include Otaviano Canuto, Karim El Aynaoui, Emmanuel Pinto Moreira, and Luiz Pereira da Silva. Last but not least, I am grateful to my daughter Madina, a doctoral student at the Harvard School for Public Health at the time of this writing, for getting me to think harder and more creatively about women's health and gender issues in general—issues, unfortunately, that remain foreign territory for too many macroeconomists. I am thankful to all for their contributions, although I retain sole responsibility for the opinions expressed herein.

In preparing this book, I have used material from several of my papers published in professional journals. I thank *Economica*, the *Journal of Development Economics*, the *Journal of Economic Dynamics and Control*, the *Journal of Macroeconomics*, *Oxford Economic Papers*, and the *Journal of Public Economic Theory* for permission to dwell on these contributions.