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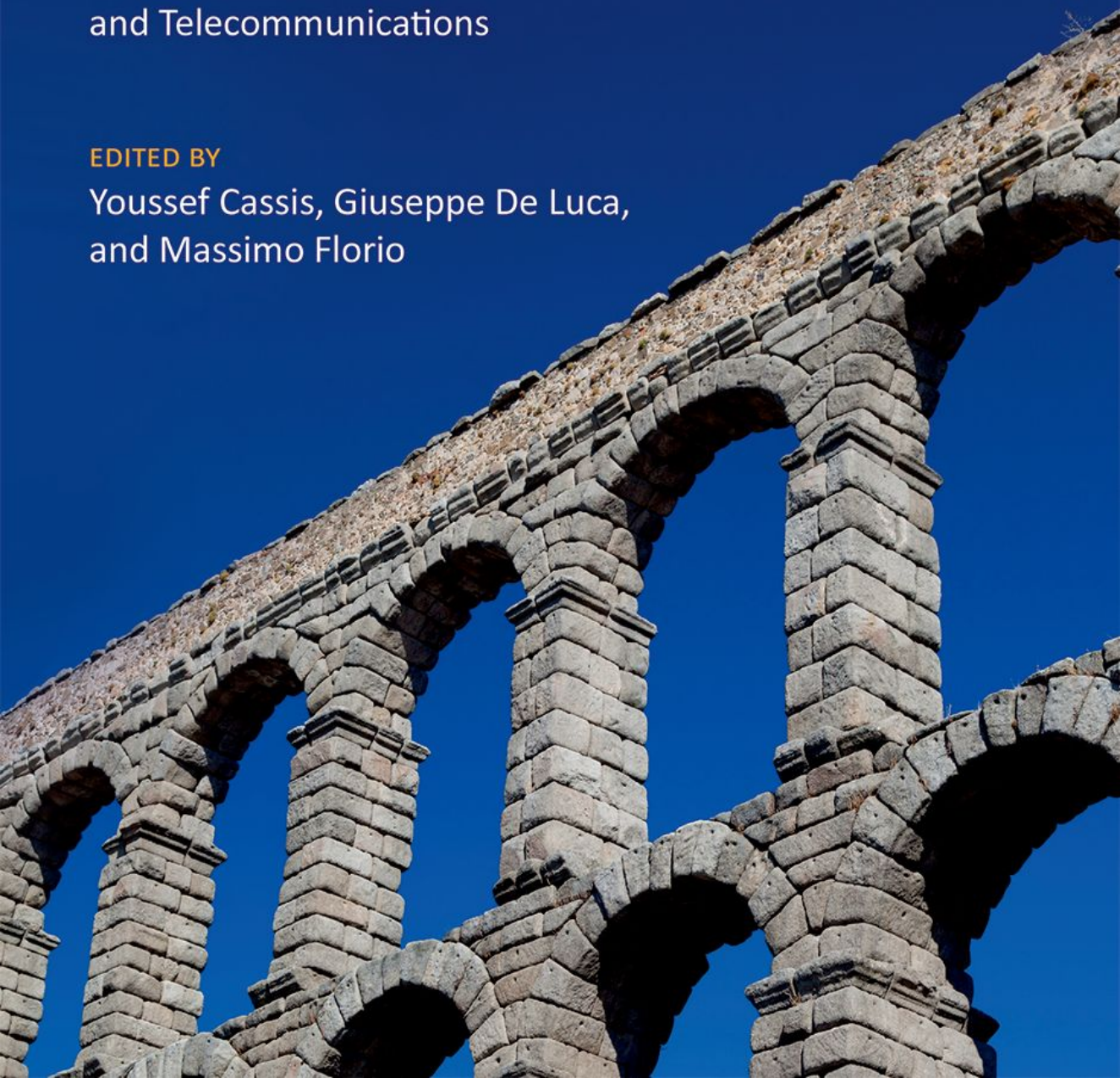
INFRASTRUCTURE FINANCE IN EUROPE

Insights into the History of Water, Transport, and Telecommunications

EDITED BY
Youssef Cassis, Giuseppe De Luca, and Massimo Florio



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Preface

Although funding infrastructure has always been a challenging issue in any country and at any time, the topic is still largely unexplored. A European history of infrastructure financing over the long term does not yet exist, and the purpose of this book is to partially fill the gap. It explores the diverse historical paths pursued in order to solve the problem of infrastructure finance in various European countries (Italy, Spain, France, Great Britain, Germany), drawing upon the findings of an international and interdisciplinary research project. Economic historians, economists, and engineers grouped together to investigate case studies showing paradigmatic examples and to unravel their specificities across the Old Continent by combining evidence from the literature and untapped sources.

Four universities were initially involved (Bauhaus-Weimar, Cantabria, LMU-Munich, University of Milan). Subsequently, other researchers joined the network, which gradually became an active laboratory exploring mostly uncharted domains. The content and structure of the book have been discussed and enriched at two events—the seminar organized by the Jean Monnet Chair on EU Industrial Policy at the University of Milan in 2012 and a session of the XVI World Economic History Congress in Stellenbosch (South Africa)—where the outline was laid down for a single work giving a comprehensive account of the financing of infrastructure across Europe.

Our view is that the tendency whereby the successful financing models of leading countries is unduly projected onto the past is widespread, yet it has proved to be a substantial failure. Studies that have considered the past in order to investigate the cause–effect relationship have attempted to understand the historical period not in its own terms, but in terms of its distance from contemporary practice. We hope that the different, more flexible, approach adopted in this book may be more helpful for understanding opportunities and constraints in infrastructure finance. This approach reveals something about the multiple possibilities at any given moment (multiple equilibria stories) and at the same time reminds us of how cogent the specificities of each context are. Moreover, the results counsel caution in explaining institutions only as efficient and beneficial responses to the needs of the economy. They conversely suggest adopting an alternative understanding by investigating how

institutions have resolved distributional conflicts. In this regard, the establishment of resilient path-dependences in infrastructure finance will also become clearer.

Hence this book is addressed not only to economic historians but also to all those who deal with infrastructure planning, such as policymakers, economists, and engineers, who have to disentangle complex problems relating to financing issues and can draw from these chapters original insights and interactions between theory and policy issues. The empirical evidence shows that one single pattern fitting all does not exist in infrastructure financing. Historical specificity suggests that the same financing system may be successful in one country while it may fail in another, or even in other parts of the same state. For instance, the toll-contracting system employed in Austria's Crown lands proved to be a disaster, while it yielded productive outcomes in Habsburg Lombardy. Likewise, joint-stock companies were failures in France while they prosperously developed and expanded in England. Most of the fragmentary current work on the history of infrastructure financing gauges the distance of previous specific financing means from an ideal unilinear model. Yet this book advises caution in considering the past to be a simple aggregate of facts to plunder in order to validate a theory. It invites consideration of history as a research laboratory in which to understand why the economic and financial dogmas of our times are challenged by past experience.

The book is structured into four sections, each comprising three chapters. After an introductory chapter by the editors, the first section offers 'horizontal' contributions that encompass the entire history of European infrastructure finance. The other three sections deal with one single sector each, namely water, transport, and telecommunications.

The opening section, Part I, covers the long-term narrative of the diverse financial means established from the early Middle Ages until the modern era. Chapter 1, by Giuseppe De Luca, starts by outlining how some of the most magnificent public works, built in the Roman age and still in use today—for instance roads, bridges, and aqueducts—were conceived and supported. The main heritage this civilization left the Middle Ages and its heirs, as far as infrastructure is concerned, no longer seems to be an eternal, unaltered road network. First, the principle of distributing building and maintenance costs proportionally among abutting dwellers according to wayside landholding and, second, the pay-as-you-use method. Then, between the twelfth and the fifteenth century, new funding solutions arose on and beyond these 'Roman ways', counting on ever less rudimentary and ever more organized financial systems, with which they entered into a relationship of mutual interplay. This brought about specific financial innovations, such as earmarked taxes and public debt, that even today make up the pillars of infrastructure financing.

Chapter 2, by Marcella Lorenzini, focuses on the three centuries between the end of the Middle Ages and the Early Modern age. In that period, transport and travel systems in particular attracted new interest from the great monarchies, which saw an extensive and well-connected transport network as a pre-condition for unifying and controlling the country. In terms of infrastructure financing, two main patterns took shape in the eighteenth century: on the continent state-led funding became prevalent, whilst in England a private-oriented system progressively emerged.

The concluding Chapter 3 in the narrative part of the book, by Youssef Cassis, addresses some questions regarding factors which have shaped the modern financial world—from the railways adventure to the 'new banks' of the mid nineteenth century, from the Euromarkets in the mid twentieth century to derivatives and structured products at the turn of the twenty-first century. There is little doubt that infrastructure finance had a crucial role in the origins of financial innovation. The financing of major infrastructure projects has often given rise to complex financial arrangements, sometimes highly innovative ones, with broader implications for the development of the financial system and the economy as a whole.

Part II, devoted to water infrastructure financing, begins with Chapter 4, a case study on Rû Courtaud by Massimo Florio. This 25-km canal in the Alps, built in the 1400s for irrigation purposes, conveyed water from the glacier of Ventina in the Ayas Valley to villages in the countryside of Saint-Vincent. The distinctive interest of this story concerns the way in which the investment and maintenance costs were afforded by the project's promoters. After an initial payment of 80 golden florins to the *Seigneur* of Challant, who held the water rights, the households promoting the infrastructure furnished a very well-tuned supply of labour in the form of *corvées*. These were established under a voluntary contract binding the promoters and their heirs. This was indeed a long-term venture since—given the harsh local conditions—construction of the Rû took fifty years. The returns, however, were satisfactory, and the Rû Courtaud, still in operation after six centuries, is a non-profit consortium. The opportunity to substitute money finance for labour 'finance' is analysed, and the arrangement is found to be efficient in terms of minimizing ownership-related costs. Several other water infrastructures in the Alps were created through similar schemes. This is an interesting example of a 'bottom up' mechanism for the provision of public investment. The conditions for its success are discussed, with potential lessons for infrastructure policy in less-developed contexts.

The following Chapter 5, by Olivier Crespi Reghizzi, examines the case of financing the water system in contemporary Paris (1807–1925). A variety of financing schemes and institutional solutions (municipal budget–fiscal resources, concessions, municipal bonds, and land added-value capture

schemes) are identified and described. The OECD's '3T' framework is adopted to analyse the long-term cost allocation. Tariff revenues were insufficient to meet the full costs, which were partially covered also by taxes. Long-term debt, inflation, and land added-value capture mechanisms played key roles in absorbing part of the investment costs.

The closing Chapter 6 of this section, by Hugh Goldsmith and Dan Carter, moves from the continent to England and examines the evolution of water supply as a private, for-profit business from its origins in sixteenth-century London to its return to public ownership at the beginning of the twentieth century. From 1582 onwards, the success of the London Bridge Waterworks encouraged other start-ups. A total of twenty-nine different private companies operated water services in the area that became Greater London, but by 1850 they had been consolidated into eight local monopolies operating within mutually agreed boundaries. The initial success and survival of private services depended on a mix of economic, institutional, and political factors. Start-up subsidies as grants or public equity to complete the first major projects were crucial for success. Financial sustainability was achieved through a pricing policy that fixed the basic charge for a household connection at £1 and kept this constant in nominal terms for two and a half centuries. Technological progress, efficiency, new knowledge about public health, continuous investment, and ever tighter regulation drove change. All private companies struggled financially during their early years, but eventually became highly profitable. In the long run, users paid for services, with wealthier households providing a cross-subsidy to poorer ones over time. The policy implication is that early public-sector financial support in the form of grants, soft loans, or 'patient equity' may be necessary to launch private-sector solutions for water services, but also that quality and price regulation is needed to drive standards and cap excessive profits from a natural monopoly providing an essential public service.

Part III on transport begins with Enrico Berbenni's Chapter 7 on the origin of the Italian motorway system in the 1920s. The initiation of this infrastructure dates back to the beginning of the century. The first proposals for special roads for cars were made in the first decade of the twentieth century, but it was only after the First World War that these projects were regarded with greater interest in several European countries. The construction of the first motorways between the two wars was made possible by direct state intervention or through concessionaries still widely supported by the public authority, according to a scheme that would be substantially replicated in the second half of the century. The Italian experience between the two wars is of particular interest given the precocity of Italy's motorways and the close partnership between public and private capital.

Financing railways is the subject of Chapter 8 by Pedro Pablo Ortúñez Goicolea, who investigates the case of Spain (1855–1941). He adopts both

agency theory and the theory of regulation of natural monopolies as theoretical backgrounds. The state's incorrect response to financial problems caused the economic and railway crisis of the 1860s and implied a steep increase in corporate financial gearing. This worrying financial background forced the state to take the lead, especially after the First World War. The railway companies continued to grow but, owing to difficulties of raising money from capital markets and the state's control on fares, the growth was financed with public subsidies. Thus, the state became both regulator and fund provider until the sector's nationalization in 1941. As the recent financial meltdown has shown, all these facts warn against the expansion of corporations based on excessive corporate gearing.

The following Chapter 9, by Björn Wündsch, delves into the growth of a transnational European railway system in the nineteenth century. This chapter investigates the development of railway networks from local industry-based lines to small trans-regional systems initiated by the private sector. The importance of railway networks on the political agenda changed over time and had an impact on the systems of railway financing.

Part IV of the book is devoted to the telecommunications sector over the past two centuries. Chapter 10, by Damir Agic and Nico Grove, concentrates on the role of the state in the financing of telecommunications infrastructure in Europe from a cross-temporal perspective. To explore this, Agic and Grove conduct a cross-country analysis by comparing different market, financing, and institutional patterns across the European Union. By investigating telecommunications infrastructure projects across time periods, they identify different industrial structures that emerged within the telecommunications industry at the end of the nineteenth century and the beginning of the twentieth.

The next Chapter 11, by Simone Fari, examines the financial instruments employed to finance telegraphy in nineteenth-century England. In the late 1830s the first electric telegraph models were patented both in Europe and the United States, but it was only in the following decade that the first distance telegraph transmissions actually took place, mainly as a support for the railway system. Two kinds of telegraphy were to develop: land and submarine. On land, the telegraph infrastructures were cheap and easy to build and therefore state-managed in all European countries except Great Britain, at least until nationalization in 1869. Conversely, submarine cables were difficult to lay and consequently very expensive. Important problems had to be solved: the construction of well-insulated cables, the transport of cables by ship, laying the cables on the sea-bed, and long-distance communication. Only Great Britain had the technology with which to carry out such operations. Given the different levels of undertaking and investment, two kinds of telegraph financing came to exist in the second half of the century: (1) the state directly financed the development of the land telegraph; (2) businessmen acted

as stock-holders and invested in submarine telegraph companies, which had high market risk but big returns. After the case study on Great Britain—the only country to experience both the private and public management of the service—the chapter goes on to describe who invested in telegraph infrastructures in that period, why, and how.

The concluding Chapter 12 of this last part of the book is devoted to a highly technical and innovative sector, that of satellites. Matteo Landoni shows how in the last decades of the twentieth century the expansion of telecommunications urged the development of a satellite network infrastructure. A satellite network, like every network technology, has public-good features alongside high costs and technological risks. The design of the Italian satellite telecommunication system is a distinctive case of public private partnership. Landoni compares the SIRIO and Italsat satellites in order to highlight the differences in the partnerships between the public buyer and the firms involved in the two different projects. In the latter case, the partnership between private companies and a public agency took the form of an agreement to purchase a service with specific requirements at a specific time in the future, creating incentives for innovation and on-time and on-budget implementation.

The rich and varied evidence collected in these twelve essays, and in some previous literature, is critically reviewed in the following Introduction by the three editors of the book. This historical perspective is combined with our own interpretation of contemporary infrastructure finance research and policy issues.

Acknowledgements

The editors and the authors are grateful to the European Investment Bank Institute (<http://institute.eib.org/>) for its support for the 'History of European Infrastructure Finance' project under its EIBURS programme.[1] In particular, they want to express their sincere gratitude to Hugh Goldsmith (EIB), who has been the contact point in the EIBURS frame, has effectively steered the process over three years, and has contributed to the project with helpful advice and with insights based on both research and practical experience.

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List of Contributors

Damir Agic, as of June 2011, has been a PhD researcher at the Bauhaus University Weimar at the Chair for Infrastructure Economics and Management, held by Prof. Dr Nico Grove. His research focus lies primarily on issues related to regulation, financing, and economics of network-based infrastructure sectors—particularly in the field of telecommunications (network neutrality) and energy industries. Before joining the Bauhaus University of Weimar, Damir held an internship at the Konrad-Adenauer-Foundation e.V., Office in Serbia and the National Bank of Serbia, where he was entrusted with overseeing a project on de-euroization in Serbia. Damir holds a Master's (honours) degree in Economics, Political Science, and Psychology from the Friedrich-Alexander-Universität Erlangen-Nürnberg.

Enrico Berbenni graduated in Economics at the Bocconi University of Milan, with a thesis on the expected effects of the Euro on the labour markets of Eastern European countries. He gained his PhD in Economic History from the University of Milan, with a study of the investments of Italian universal banks on the real estate market between the two world wars. He is currently Research Fellow at the Catholic University of Milan and his primary research interests are banking and financial history. His current research focuses on financial relations between Italy and Switzerland in the nineteenth and twentieth centuries.

Youssef Cassis is Professor of Economic History at the European University Institute, Florence. His work mainly focuses on banking and financial history, as well as business history more generally. His numerous publications on the subject include *City Bankers, 1890–1914* (Cambridge University Press, 1994), *Big Business. The European Experience in the Twentieth Century* (Oxford University Press, 1997), *Capitals of Capital. A History of International Financial Centres, 1780–2005* (Cambridge University Press, 2006), and *Crises and Opportunities. The Shaping of Modern Finance* (Oxford University Press, 2011). He was the co-founder, in 1994, of *Financial History Review* (Cambridge University Press) and is a past President (2005–07) of the European Business History Association.

Dan Carter teaches history at the University of Cambridge. He recently completed his PhD at the Centre of Latin American Studies on the politics of land reform in the 1960s and 1970s. Other research interests include the transition to democracy in Spain, with a particular focus on municipal politics, and the history of public service reforms.

Olivier Crespi Reghizzi is an analyst at Eau de Paris and PhD candidate in Economics at the Centre International de Recherche sur l'Environnement et le Développement (CIRED)—AgroParisTech and at the Centro di Economia Regionale, dei Trasporti e del

Turismo (CERTET)—Bocconi University. His research interests focus on public finance, particularly on infrastructure financing issues in urban water and sanitation services in Europe. He spent more than two years in Dakar, Senegal, as a project officer for the Agence Française de Developpement and as a consultant for the World Bank. Olivier holds an MSc in Civil Engineering from Politecnico di Milano and from Ecole Centrale de Nantes.

Giuseppe De Luca is Professor of Economic History at the University of Milan. He has been a visiting scholar at the Complutense University of Madrid and at several Iberian institutions. His research interests encompass the theoretical groundings of credit and the interplay between finance and economic growth, with a focus on preindustrial Italy. He is co-editor of *Growing in the Shadow of an Empire. How Spanish Colonialism Affected Economic Development in Europe and in the World (16th–18th cc.)*, Milan, 2012 (with G. Sabatini), and has recently published *Milanese Finance, 1348–1700*, in G. Caprio (ed.), *Handbook of Key Global Financial Markets, Institutions, and Infrastructure*, London, Elsevier, 2013.

Simone Fari is Assistant Professor of Economic History at the University of Granada. He has been both a Post-Doc Assistant at the University of Lugano (Switzerland) and a Research Fellow at the London Science Museum. He started his research on telecommunications history during his PhD at University of Bari. He has also investigated finance history over a Post-Doc fellowship at the University of Torino. He has published *A Penisola in Comunicazione* (Cacucci, 2008) and articles in international reviews.

Massimo Florio is Professor of Public Economics and the Jean Monnet Chair 'ad personam' of EU Industrial Policy at the University of Milan, where he has also been head of the Department of Economics, Business, and Statistics. He has been a visiting scholar at the London School of Economics and at other British universities, where he started his research on privatization, leading to his books *The Great Divestiture* (MIT Press, 2004) and more recently *Network Industries and Social Welfare* (OUP, 2013). For more than twenty years, Professor Florio has advised the European Commission and other international organizations on social cost–benefit analysis of infrastructure projects in the context of EU regional policy.

Hugh Goldsmith is Economic Advisor at the European Investment Bank (EIB) in Luxembourg. With an engineering and economics background, he has been involved in the design, appraisal, and monitoring of global infrastructure investment projects for over thirty years. At EIB, he specialized in project finance and public private partnerships (PPP), including providing policy advice to the European Commission and IMF. He headed the Bank's Water & Wastewater Management Division. Hugh has been a visiting lecturer at UCL and other universities in the UK and Portugal. His publications include papers on water, PPPs, and the history of infrastructure.

Nico Grove is heading the Institute for Infrastructure Economics and Management, Munich. In addition, he is Assistant Professor at BUW, lectures at Regensburg University and the Ludwig-Maximilians-Universität München, where he received his PhD. He was Visiting Professor at the CIS, Stanford Law School, Stanford University 2011–12. Additionally, he is a serial active entrepreneur and supports (new) companies in high scalable growth. Previously he worked in strategy consultancy at Accenture and

A.T. Kearney and in media production companies for TV broadcasters. He holds a Masters in Business Administration (Dipl.-Kfm) and a Masters of Business Research (MBR) degree from the Munich School of Management, Ludwig-Maximilians-Universität München, as well as a Masters in Economics (MEc) from the Macquarie University Sydney.

Matteo Landoni is a Research Assistant in management and strategy at the Department of Business Studies of the Catholic University of the Sacred Heart in Milan. He earned a PhD in Business History and Management from the Graduate School of Social, Economics, and Political Sciences of the University of Milan in 2013. Before his graduation he had been visiting scholar at the Department of Management and Global Business and fellow of the Center for Urban Entrepreneurship & Economic Development at Rutgers Business School in Newark, NJ. Since 2010 he has been a teaching assistant in Business History at the Catholic University of the Sacred Heart in Milan. He represented the University of Milan at LERU (League of European Research Universities) in 2010 and 2012.

Marcella Lorenzini received her PhD in Business History from the University of Milan and is presently a researcher in Economic History at the University of Trento. Her main research interests focus on the dynamics of informal credit markets in Early Modern Europe. She is currently working on a project concerning the role of nonbank financial intermediaries in the Republic of Venice and the Habsburg Empire during the seventeenth and eighteenth centuries.

Pedro Pablo Ortúñez Goicolea (PhD, University of Valladolid, 1999) is Senior Lecturer in Economic History at the University of Valladolid (Spain). His research interests include the Spanish railway system and the public sector before nationalization of the railway; regulation and business history. He has published his research in books and specialized journals, and has participated in conferences in these fields. He has undertaken research in several stays at the London School of Economics and at the École des Hautes Etudes en Sciences Sociales (Paris).

Björn Wündsch, during his postgraduate studies, worked for a consulting company with a focus on structuring public private partnerships. After his graduation he worked full-time in the field of real estate asset management in an international investment bank. He gained professional knowledge in international property valuation and real estate asset management. Before joining Bauhaus-Universität as research associate he also worked as junior fund manager for product development as well as for the fund advisory of a real estate private equity (REPE) fund of funds. He also developed and implemented a portfolio management tool for indirect REPE investments as project manager.

Introduction: The History of European Infrastructure Finance

An Analytical Framework

Youssef Cassis, Giuseppe De Luca, and Massimo Florio

I.1 Introduction

Our perspective in structuring an inquiry into the history of infrastructure finance is to acknowledge a wide variability of arrangements across time and space and to try to discern some recurrent themes. In effect, we exploit the variability of circumstances to qualitatively analyse a core of three fundamental drivers of infrastructure investment decisions in the long term: technological and organizational change, political and economic priorities of various elite groups as well as emerging social needs, and internationalization of the economy versus domestic factors. Against this broad frame, we understand finance as a set of mechanisms conveying resources to support both investment and running costs over the long term.

We do not claim, however, that causality is in one direction only. In some cases finance has shaped infrastructure opportunities, in other cases the need to build infrastructure has changed finance itself (see De Luca Chapter 1 and Cassis Chapter 3), and there have been feedbacks and mutual interplays. This makes the topic challenging and fascinating.

The scope of the analysis covered in this book is wide, but admittedly most of the research has focused on the Western world, from the Roman *res publica* to contemporary Europe. Enlarging the span to the evolution of our themes in the Eastern world, including the ancient civilizations of the Middle and Far East, was unfortunately largely beyond the evidence we were able to collect. Nevertheless, the ways ancient China, Egypt, or the Mesopotamic civilizations structured their economies around the construction and operation of infrastructures suggest that such a more global historical perspective would be

important. An example is the debate on Wittfogel's hypothesis on the Asiatic mode of production,[1] focused on the role of hydraulic works, how the society had to pay for them, and what consequences they had on economic, social, and institutional development.

More recently, the Californian School has singled out the over-commitment in hydraulic works on the part of China, in order to face the increasing population's rice need, as one of the first reasons of the Great Divergence between Eastern economic evolution and Western development (Pomeranz, 2000).These examples suggest that the study of infrastructure finance from an historical perspective may have wider implications for social sciences. Nonetheless, we need to be more modest.

The set of case studies presented in this book is part of a tradition of inquiry that is interested in a research question that is generic, but also relatively narrow in terms of its scope: How can socio-economic resources be mobilized to pay for works that offer benefits only in the future, often in the distant future? This is indeed a difficult question that has elicited very different responses. Thus, even if the countries and periods of time we consider are only a relatively small sample of a global history of infrastructure finance, and we do not explore the broader social implications of infrastructure provision, we have tried to have in mind some general issues that we discuss below. Thus, each case study is a piece of evidence of our research on the ways a fundamental inter-temporal mismatch between social costs and benefits has been addressed in different times and nations. We look at finance within this broad meaning.

In this introductory chapter we present the core ingredients of our analytical framework. In Section I.2 we discuss what we understand by infrastructure, a term that can have different meanings/semantic contents, and whose definition issues reveal some recurrent conceptual problems. Section 1.3 introduces the way we look at finance, which—as mentioned—is here understood in the very broad sense of a set of mechanisms bringing to investment, and future benefits, the resources needed in advance to pay for it. Section I.4 offers a brief discussion of technological and organizational change, as several of our case studies and other literature that we cite show that investment and finance decisions are deeply interwoven with knowledge, management, and technical progress. Section I.5 is about government involvement on both sides of our

[1] Wittfogel (1957) proposed a general interpretation of the Asiatic mode of production based on a 'hydraulic-bureaucratic state'. In that interpretation public works related to large-scale irrigation and the public administration machinery necessary were at the origin of bureaucratic despotism. While this is still an interesting and controversial research hypothesis (Sofri, 1973), the geographical scope of most of our analysis is such that we cannot discuss its implications for our research. For a different view, see Diamond (1997).

theme: investment and financing decisions, but also on the wider issue of service provision in the context of emerging widespread social needs.

In fact, the social demand for infrastructures often manifests itself as only mediated by governments or a small group of players, while the services offered by the infrastructure have subsequently created general interest, sometimes unexpectedly. In Section I.6 we mention the tension between the national and the international dimensions. This tension is closely related to all the previous issues, but has also a specificity, which was more evident in ancient empires, in colonial times, and in contemporary globalized economies, with recurrent periods of a more domestic focus, however. Section I.7 suggests a taxonomy of the macrotypes of infrastructure financing we have identified, and sums up their spread and evolution over the long term. Section I.8 concludes with some remarks for future research.

I.2 What We Mean by 'Infrastructure'

The wide literature on the economics of infrastructure does not provide a unique definition that we can use from the perspective of economic history.

Some ingredients of the contemporary debate are reviewed by, for example, Gramlich (1994), Torrisi (2009), Florio (2013), and Picot et al. (2015). We depart from some of this literature because of its exclusive focus on contemporary issues in market economies, while the object of our analysis spans from Roman roads to Big Science research infrastructures. In particular, we do not want necessarily to focus on the economic role of infrastructure investment in the context of developed capitalist economies, even if many of our examples are indeed related to such an environment. In our broader perspective, we shall identify infrastructures as investment with three key features:

a) The objective of providing a service perceived to be of major, even critical, importance by the national or (more recently) international decision-makers or stake-holders: in many cases just small groups of individuals with their long-term vision of priorities. We shall refer to them as the 'infrastructure élites', a general label for those who have influence on infrastructure decisions.
b) The high capital intensity of the investment needed to support the provision of infrastructure services, adopting a very wide definition of capital that includes the social opportunity cost of works relative to operations.
c) The long time needed to build the tangible or intangible facilities, the long useful life, the long time needed to 'pay back' the investment, and the consequent risk and uncertainty related to the forecasts of such returns.

We briefly elaborate on each item of this ample definition. We consider it unique, in the sense that the lack of any of the three features would make it difficult to analyse the investment in terms of what we here regard as infrastructure.

I.2.1 *The Elistist Nature of Infrastructure Decision-Making*

First of all, we are not exclusively stressing the *economic* services provided by the infrastructures. This role has been and is still of paramount importance, and modern finance has been particularly stimulated by the prospect of offering means to support ventures of direct economic significance. As several of the case studies collected in this book show, it would be misleading to conclude that all infrastructures have been motivated by economic opportunities and calculation of financial returns. Our definition includes major military works, cultural and religious buildings, and even Big Science projects, all being perceived as a priority by some influential élites.

The defence (or imperialistic) dimension of many such projects cannot be exaggerated. Main roads in Rome (see De Luca Chapter 1; or in the Inca civilization, Metraux 1970; Von Hagen, 1976), railways in France, telegraph in the UK (see Fari Chapter 11) just to offer some examples, were considered by political ruling groups of their times to be of paramount importance for military reasons in the first place, and initially of negligible importance by the large majority of the population. It is hard to believe that the poor rural households in the Gallia, or even in late nineteenth-century France and the UK, were really perceiving as urgent priorities investment in long-distance transport, or the quick exchange of information between distant places. Robert Millward (2005) has provided convincing evidence that the initial momentum for government involvement in twentieth-century network industries such as energy, transport, and telecommunications was enhanced by nation-building and defence considerations of governments. It is doubtful whether the Kennedy Space Center, with more than one million visitors per year, and all the huge NASA infrastructure (Florio & Sirtori, 2014), would have ever taken off without the background of the Cold War, when the control of space was conceived as the ultimate frontier of defence (see Landoni Chapter 12).

Cathedrals in the Middle Ages until the seventeenth century (and beyond) in Europe or Spanish colonies in South America did not provide economic services in their time,[2] but they played an important function in terms of

[2] They, however, were stimulating economic activities during their construction. Today the important buildings of Christianity in Europe are also a non-negligible economic factor, as they are also visited by tens of millions of tourists every year, as expressions of the cultural heritage of

building identities for local and later national and supranational communities. They were investment with a long-term cultural return.

Having said this, the economic importance of infrastructures has obviously been a constant feature of development across centuries and space. A considerable part of the trade of the Roman Empire or of Athens was not by roads, but through navigation in the Mediterranean Sea. Ports such as Piraeus or Ostia were infrastructures that were supportive of market developments from their early beginnings, in combination with their respective roles for the fleets of Athens and Rome. Building a telegraph network was perceived by the military as crucial to ensure communication of strategic importance, but in Victorian London, the capital of a global empire based on overseas trade, it was mainly perceived as serving commerce as it gave investors immediate access to news on prices and availability of goods in distant colonial markets. If French generals wanted railways to quickly deploy troops against the border with Germany if needed (Millward, 2013), subsequently the advantage for business to move quickly to Paris by train instead of road was realized and explains the radial structure of the network. Satellite networks were initially the result of the post-Sputnik era, largely a matter of political and strategic competition between the USA and USSR, but their then role as communication infrastructure was attracting substantial investment and they are now part of global everyday communication. Nowhere can the germane economic and military role of infrastructures perhaps be perceived better than in the arsenal of Venice, where for five centuries the fleet of the Republic was built and mantained for trading, but when needed, a large additional number of military vessels could be launched in a matter of weeks thanks to the wide spare capacity and perfect division of labour among specialized handicrafts (Davis, 2007).

Our insistence that (major) infrastructures answer needs as perceived/realized by influential groups in the first place has some importance for the later discussion of the emergence of a larger social demand, as this has often been mediated or anticipated by the leading groups themselves (or occasionally widely misunderstood). Hence, the demand for infrastructure in our perspective is different from the standard micro-economics textbook narrative, where typically atomistic agents, that is households or firms, demand goods for which they have a set of coherent preferences. Only small groups demand and take decisions on infrastructure, sometimes later discovering that they have changed the lives of millions.

Thus, the culture of infrastructure élites plays a crucial role in establishing what is important for society in terms of large-scale, long-term capital

Europe. Some of these buildings are currently visited by more tourists, many of them coming from non-Christian countries, than by believers to attend religious services. This is another case of the changing role of infrastructure over time.

investment. The fact that in the nineteenth and twentieth centuries, and of course in contemporary economies, private investors, visionary entrepreneurs, venture capitalists, and other individuals have played a considerable role in the development of infrastructures, should not blur the message. While economic (i.e.) profit motivation would have been a powerful driver of early champions of the electricity industry or of the Internet economy, a careful analysis of their role shows that they were not responding to an existing demand. In effect, they were often *creating* such a demand. This fact is reflected in the persisting uncertainty often surrounding the measurement of the growth impact of new technologies.[3]

Hence, in a fundamental sense, the service provided by the infrastructures becomes of general interest only after (with some lag) a decision made by relatively small groups of sponsors who are in the right place at the right time and are able to force decisions about which investment is important for the society at large.

I.2.2 *Capital Intensity*

Turning to investment itself, the second ingredient of our definition is high capital intensity. We need to use the term 'capital' here in a way that is abstract, because the scope of analysis includes times and countries outside the strict notion of capital in the usual sense (which itself is not without its problems). Thus, we need to elaborate on our definition.

We do not refer here to a monetary concept of capital, and in fact even in the next section, on funding mechanisms, we shall propose a broad definition of finance. Here what we mean is simply that the social cost of investment is high relative to the social cost of operation. Thus, for example, the social cost of building roads under the feudal corvées system in France in principle can be exactly measured even if no money transaction occurred at all: it is the cumulative value of labour deployed in building such roads, and in turn such value is properly measured by its opportunity cost in terms of displaced agricultural production. What is typical of infrastructures is that such opportunity cost of capital investment is much greater than the cost of operation and ordinary maintenance. Thus, several tens of thousands of working days are needed to build a canal over some years, and only a small fraction of such an amount is needed to monitor and properly maintain it over decades.

The importance of this abstract notion of capital, in terms of social opportunity cost, becomes clear when we look at the consequences of high capital

[3] See, for example, for the ICT compared with the industrial revolution, Freeman and Louca (2001); for a survey, Draka et al. (2007); for recent estimates in the EU regions, Del Bo et al. (2013); and for a critical discussion of general purpose technologies, Nuvolari (2014). See also the discussion by Pellegrin and Sirtori (2012).

intensity in the abovementioned meaning. The issue of scale economies, so typical of infrastructures, is a mere reflection of capital intensity in this sense, and natural monopoly a necessary consequence, with vertical integration a widespread tendency. This is true for any sort of infrastructures. There were indeed not many competing Coliseums in Rome at the time of Titus. Parallel rival railroads proved a secure recipe for economic disaster; and the persisting oligopolistic nature of contemporary telecoms, where every effort has been made by regulators to force competition, are telling us something about the resilience of natural monopoly when fixed costs are so much greater than operating costs (Florio, 2013).

The standard discussion in public economics textbooks in terms of market failure associated with natural monopoly captures only one aspect of the story, that related to social inefficiency of monopoly pricing or alternatively to the social efficiency of marginal cost-pricing, with the implication of the need for subsidies to cover losses of the infrastucture-based service. But the issue of the implications of high capital intensity pre-exist any pricing mechanism for the services provided. We do not want to insist on this point here, because the financing issues involved in the topic will be discussed later. But the point we want to make is simply that in general infrastructures are unique because it would be too costly to have more than one (in a specific place), and this simple fact poses a very special issue in terms of finance because each operation has to be 'customized'. This also has wide consequences for the way financial risk is perceived and mitigated, leading in many cases to suppression of risk through the use of slave labour, corvées, or taxation. We turn to this role of coercion against modern finance in the next section.

I.2.3 *Timing*

The challenge posed by the inter-temporal dimension is our third key feature. The uniqueness of infrastructure is compounded as a risk factor by the critical theme of the uncertainty of predictions because of the fairly long times required for building, much longer times of operation, and hence the usually slow pace of recovering in some way the social value of investment.

Again, we want to be general, and we stress below non-economic services from this perspective. Military infrastructure in many times and countries often took decades or even centuries to be built. The Great Wall of China (in fact a series of different fortifications) is reported (Rojas, 2010) to have been started around the seventh century BC and culminated around AD 1600. In comparison to the time taken to build it, its actual usage was limited to a relatively small number of episodes (while the effectiveness of the containment effects on invasions is highly disputed). Consequently, the military 'social returns' of the investment (including the cost of perhaps one million

causalties during construction) are dubious in retrospect, despite the cultural value and mythology surrounding it (Waldron, 1988). Jumping to a contemporary research infrastructure, the LHC particle accelerator at CERN took around twenty years to be assembled (and this only because it used the existing underground 27-km tunnel of the pre-existing LEP), but will be operated for perhaps another twenty years. Obviously its discovery potential looking back in the early 1990s and even today is widely unpredictable (Giudice, 2010).

The risks connected to more conventional infrastructures are not negligible either. Another tunnel, the Eurotunnel, slightly less than half the length of the LHC and moving trains instead of protons, was the realization of ideas going back to the beginning of the nineteenth century and of many subsequent projects. Eventually it took only eight years to build (1986–94). However, cost overruns were nearly double the initial planned investment, traffic was widely over-estimated (it was less than one-half of predictions in initial years), and the whole venture came close to bankruptcy and had to be rescued by the British and French governments through several mechanisms, including an extension of the concession until 2086 to give time for the investors to recoup their considerable losses (Gourvish, 2006).

Cost overrides and optimism bias in forecasting demand are more the norm than the exception in major infrastructures, and one may even conclude that they are needed to force consensus around high-risk projects. In fact, Albert Hirschman (1967), in his ex post study of eleven World Bank funded projects, concluded that a beneficial 'hiding hand' is at work to ex ante obfuscate the difficulties that would otherwise discourage promoters and investors.

How in this context is it possible to find the resources needed to support such long-term and uncertain benefits?

This is the core question of our research, dealt with in the next section and in Section I.7.

I.3 Finance as Time Machine

Building on the abovementioned three generic features of infrastructure projects (elitist decision-making, high capital intensity, distant and uncertain returns) we can try to answer the previous question about funding as the main problem for promoters. First, as mentioned, this promoter is typically an influential individual or small group. It is not a wide social group that can take a decision, for example based on the imitation of regular patterns, such as independent farmers considering investment in their plot in a wide irrigated area, or manufacturers in a Marshallian industrial district. Any infrastructure decision is a breakthrough, a unique act of willingness.

We shall devote most of this chapter to discussing the technological, managerial, and institutional conditions that make such an act possible, but here we want to emphasize that a necessary prerequisite is the ability of the promoter to mobilize considerable external resources for sufficient time to finance 'now' something that will build benefits in future, even in a distant or totally unknown future.

By external resources, we understand here the common fact that given the high capital intensity of the project, the promoter often does not possess sufficient resources to pay with their own funds for the investment in the first place. Any funding decision of an infrastructure needs to build a support coalition.

Hence, there are basically three mechanisms that historically have been deployed to solve this problem, and we briefly discuss them below (each of them is then illustrated by detailed case studies in the rest of the book).

I.3.1 *Coercion and Taxation*

When the project promoter has the power, coercion[4] may be an efficient solution for the problem of mobilizing sufficient resources for infrastructure. The technological features of some of the public works in ancient empires and in the Middle Ages were sufficiently simple, or in any case well understood, when basically the core input needed for public works was an unskilled labour force with some monitoring. In economies where slavery was widespread, the cost of conveying slaves to the appropriate places, organizing their work, policing it, and providing a minimum of food or shelter was the least costly solution for large-scale construction activities.[5]

Taxation to fund infrastructure has taken different forms: earmarked monetary taxation, general taxation, but also in-kind taxation—which was largely dominant until relatively recent times. The substitution of slavery or corvées, that is direct coercion of labour, with collection of taxes, may be a more efficient way to finance infrastructure under several circumstances: when slaves are relatively scarce; when the opportunity cost of distracting labour from agriculture is relatively high (which is in turn related to progress in farming techniques); when the cost of recruitment and monitoring of the labour force under coercion is high; when the skills required are less than abundant; and eventually when labour is no longer the only or main input of

[4] There is an excellent discussion about the understanding of the importance of coercion in the entry of the *Stanford Encyclopaedia of Philosophy* (Anderson, 2014). Differently from most of the debate reviewed there, from Aquinas to Nozick and beyond, we do not make any claim about the moral status of coercion as a way to finance infrastructure. We simply suggest that coercion in this domain is about threats, while the rest of the mechanisms are based on offers.

[5] A contemporary version of this mechanism could have been observed in the USSR, where a workforce in Gulag was regularly employed for public works on a large scale, with some continuity with the Czarist mobilization of a captive workforce for infrastructure construction (Pipes, 1974).

construction, and fixed capital is needed in the form of special tools, intermediate products, equipment and machinery, and more recently software and other intangibles.

We do not claim, however, that coercion and taxation were always efficient ways to support infrastructure investment; in some cases they probably long survived the decline of their role because of path dependency. We have scarce documents on the social opportunity cost of using coercion in ancient economies, but we have large evidence that a huge waste of resources was often associated with using forced or compulsory labour from detention camps in the USSR for public works between the 1930s and 1940s (Pipes, 1974; Lewin, 1985; Applebaum, 2003) or in the British Empire throughout most of the nineteenth century (Ferguson, 2004) (in a variety of forms, including 'coolie' labour in India, indentured contracts in Virginia, convicted criminal workforce in Australia, etc.).

From this perspective, taxation, either in cash or in kind, is a relatively recent and progressive arrangement. A cursory examination of the public finance records of the states until well into the twentieth century does not suggest that taxes were able to finance most of the infrastructure needed for the development of modern market economies. As a matter of fact, governments until the Great Slump had a relatively small fiscal basis, entirely absorbed by law and order, military expenditure including servicing of the debt incurred because of past wars, general administration, and other minor items, with limited room for supporting considerable capital investment, which was mostly left to other financing mechanisms (some data and literature is reviewed by Florio and Colautti, 2005).

The under-development of general taxation or of earmarked taxation in comparison to other mechanisms to support infrastructure investment should thus be traced back to the fiscal history of states particularly in the Western world. After the fall of the Roman Empire, central governments were in general simply too weak to collect taxes for funding anything that was not perceived as an urgent matter for the survival of the state itself or of the élites. The long-term returns of infrastructure, the uncertainty and risk surrounding them, the state of war or of the epidemics that plagued Europe for centuries de facto made it impossible until the last century for European governments to replicate the large-scale planning approach of the Roman Empire for roads, aqueducts, and ports. These plans were supported by an effective mix of coercion, taxation, and concessions, which for centuries was unavailable.

I.3.2 *Voluntary Schemes and Pricing*

As kings, feudal landlords, or the governing élites were so often unable to extract enough saving from the economy to support infrastructure projects,

the alternative to coercion (before recurring to debt and to equity-based finance) was to return to the voluntary contribution of potential beneficiaries. In the Roman Empire, many roads, bridges, and aqueducts were directly financed by affluent citizens either for charity or for euergetism (i.e. the system, widely spread in the Hellenist and Roman world, of delivering a gift to the community in order to win favour or to increase personal prestige, see De Luca Chapter 1). In addition, if Greek temples or Catholic cathedrals are considered infrastructures providing services to believers, then the fact that they were widely supported by donations should be considered a form of voluntary finance. The perception that a benefit will accrue, even beyond life, because of the donation, is a form of investment, an exchange between a tangible cost today against an intangible benefit in the future. Cathedrals of Christendom were not the only examples of donation (and bequest) finance. Others include hospital buildings, such as the Ca' Granda that now hosts the Rector's offices of the University of Milan (Cosmacini, 1999); or the Bodleian Library in Oxford, and hundreds of other cultural or charitable institutions. Obviously it was easier to collect donations for such institutions than for military or transport infrastructures, but the importance of donation finance in the European Middle Ages, or the Islamic world,[6] and in the United States (encouraged by generous tax expenditure mechanisms) cannot be exaggerated.

There is also some evidence that cooperative schemes were successful in supporting rural electrification in the US: Hansmann (2000) discusses at length why such arrangement based on user-owned enterprises in this context was more efficient than investor-owned organization. This is not the only case. We report in this book an example of how local communities in the Alps have initiated irrigation channels in challenging environmental conditions since the fourteenth century (see Florio Chapter 4).[7]

To put into a contemporary perspective such cooperative experiences, the notion of co-production initially proposed by Ostrom et al. (1978) and recently reviewed and restated by Alford (2013) seems helpful. While the involvement of citizen–users in construction–production and financing of services delivered by infrastructures has played a minor role in the countries we consider, it is nevertheless interesting to study the conditions that have

[6] Because of the limitation of our geographical scope we are unable to deal with Islamic finance and its role in supporting infrastructure development in some countries, see Visser and Visser (2009), or with participatory frameworks in the Global South (Mc Donald, 2014).

[7] Consortia of farmers in the plains of North America were also responsible for the construction of works of collective importance for the local communities. Even today storage of cheese and wine in Italy is often based on cooperative facilities (which meet our criterion because of their visionary early promoters, relatively high capital intensity, the long time needed to achieve the desired stage of maturation, and the uncertainty of future prices, see e.g. the history of the Consorzio Agrario di Parma, founded 1893 <http://www.consorzioagrarioparma.net//>. The founding fathers were a professor and a member of the parliament. The consortium has currently around 3,000 participants (agricultural firms).

made co-production possible in certain circumstances (Ostrom, 1996). A variety of financing schemes were invented by promoters of these cooperative infrastructures. It was common to request from users a contribution, often in kind, in proportion to their use of the shared facilities.

User fees and service pricing were widespread as a financing arrangement for canals and roads in England, and still are for modern highways (see Berbenni Chapter 7) or airports (landing fees and similar taxes). There are two problems with such mechanisms. The most obvious one is that they can start to collect resources only when the infrastructure already exists, thus the fees can more easily cover operation and maintenance costs than investment. This is not, however, an absolute constraint if the investors own a portfolio of infrastructures of different vintages, such that the cash flows of the older ones can support the new projects.

Another, and potentially more serious, problem was discovered by Jules Dupuit (1853) of the Écoles des Ponts et Chaussées in Paris, in his seminal work on what we now label consumer surplus. Dupuit explained why in general it is socially inefficient to collect users' fees when marginal costs are low or negligible relative to fixed costs, for example for a bridge, and that general taxation is a better financing mechanism than tolls in terms of social welfare.

A related issue is the recurrence of externalities in infrastructure intensive services. The fact that in many circumstances it is impossible or too costly for developers of such projects to fully capture their economic returns lies at the heart of the potential divergence between the financial and the social rates of return (Florio, 2014a), and is the reason why social cost–benefit analysis is needed to make explicit the welfare impact of infrastructures and to take decisions on the allocation of public capital expenditures (European Commission, 2014).

1.3.3 *Returns to Capital*

Beyond coercion and voluntary schemes, the two main solutions over the centuries to financing infrastructures has been to attract capital to support investment either through loans or in the form of equity, or often combining these instruments. As this is the main content of our case studies in the rest of the book, we can be brief here.

The common feature of both forms of finance is simple: those who have control of capital and are available to invest it in a third-party venture need to be adequately remunerated, by interest in the case of loans, or by dividends and capital gains in the case of holders of equity. Our research shows how different the contractual arrangements can be over time and across countries in order to meet the objective of convincing holders of capital to join infrastructure

projects. This variability of financial schemes does not lend itself to suggesting generic considerations of which was more efficient and why.

However, some aspects are recurrent in the case studies. The uniqueness of infrastructure projects often makes them difficult clients for banking activities designed for 'business as usual'. Financing inventories in manufacturing, anticipating the cost of seeds and fertilizers in agriculture, and most of credit for trade, is about financing working capital. This has the advantage—from the perspective of both the banker and the client—of building knowledge on a wide array of similar contracts. Replicability of loan operations is not the preserve of financing working capital only. Industrial districts in Europe have had, among others, the advantage that long-term loans for machinery and factories can to a certain extent draw from a large informative base of similar stories. While each entrepreneur is different in terms of personal traits, including managerial skills, ability to innovate, and social capital, in many industries they produce goods that are similar to those of competing firms, to serve well-known markets, with a cost structure largely determined by circumstances that are common to tens or hundreds of other firms.

The contrast with loans required to finance a specific infrastructure project cannot be greater. While a bank specializing in railway finance can acquire systematic information on certain aspects of the business, connections from point A to point B may still be very peculiar in terms of construction cost and of capacity to attract passengers or freight traffic. Information from a banker on circumstances of another line connecting C, D, E . . . may or may not be relevant. The abovementioned huge forecasting errors for the Eurotunnel, despite all the sophisticated knowledge available to the City of London, suggests that the information basis was limited for any large-scale investment project of the past, and probably of the future. In the words of Keynes ([1936] 1973, pp. 149–50):

> Our knowledge of the factors which will govern the yield of an investment some year hence is usually very slight and often negligible. If we speak frankly, we have to admit that our basis of knowledge for estimating the yield ten years hence of a railway, a copper mine, a textile factory, the goodwill of a patent medicine, an Atlantic liner, a building in the City of London amounts to little and sometimes nothing.

Thus, it is not surprising that short-term loans, but also long-term loans based on standard banking approaches, often play a limited role in the case studies we present. The alternative solutions, apart from equity finance which we mention below, were often in two opposite directions: the creation of large project portfolios on one side, or customized loans. Government debt is an example of the first type of solution, which found a formalization in the theory of risk neutrality of the public sector by Arrow and Lind (1970). Under such a theory, the government is able to pool a large set of risky projects

in its portfolio and, because risks are not synchronous, the larger the portfolio is, the more the state is ultimately able to insure itself and therefore should not be risk adverse. The argument is a good one, obviously, mainly for large countries, while it is much more doubtful for the public finance of small economies over centuries. Keynes himself concluded his chapter on 'The state of long term expectations' in *General Theory* with a note of optimism about the ability of government to plan long-term investment (and of pessimism about monetary policy):

> For my own I am now somewhat sceptical of a merely monetary policy directed towards influencing the rate of interest. I expect to see the State, which is in the position to calculate the marginal efficiency of capital-goods on long views and on the basis of general social advantage, taking an ever greater responsibility for directly organising investment . . . (Keynes, [1936]1973, p. 163)

For governments that adopted this view after the Great Depression, public debt was more important than general taxation to support investment. Perhaps something of this view is currently echoed in the 'golden rule' for public finance, where debt should match investment, and tax revenues current expenditures, for an accounting argument (H.M. Treasury, 2001).

Beyond national states, a different way to create a large investment portfolio, and take advantage of risk-pooling, is to create financial institutions specializing in the screening of individual projects, and raising funds building on their expertise and their prominent status in the infrastructure arena. The contemporary version of this alternative mechanism was a supranational project, embodied in the World Bank, and later in other IFIs such as the European Investment Bank, the European Bank for Reconstruction and Development, the Inter-American Development Bank, the Asian Development Bank, the African Development Bank, and others.[8] There are, however, several national experiences, and probably more than 100 national development banks, mainly financing public infrastructures in the public sector at the domestic level, such as the KFW in Germany, Caisse des Dépôts et Consignations in France, Cassa Depositi e Prestiti in Italy, China Development Bank, Development Bank of Japan, Brazilian Development Bank, and so on (De Luna-Martinez & Vicente, 2012). The scale of such lending activity is huge, countercyclical, and is backed by the ability to issue bonds with a modest risk premium. These risk-pooling mechanisms have cumulated large project portfolios and tend to equalize risks among them (Clifton et al., 2014).

The opposite path direction was taken by customized finance, of which contemporary project finance offers abundant examples, but undeniably

[8] The process is far from declining, see for example the recently established New Global Infrastructure Facility of the World Bank and the Asian Infrastructure Investment Bank sponsored by China.

such a path was of paramount importance in the nineteenth and early twentieth centuries (before the Great Depression), and it had much earlier examples in banks specializing in loans to European monarchs.

The advantage of such operations lies, paradoxically, exactly in the fact that financing operation and channelling of savings are tailored to the specific need of one infrastructure project that can be analysed and advertised in detail. Thus the idiosyncratic risk is supposed to be managed and mitigated by the customization of the lending operations by the issuer of project bonds (or by the banker coordinating the supporting loans of third parties). In fact, however, (bond) finance in this form, in spite of its supposed transparency, may contain a speculative element as the subscriber of debts is exposed to specific shocks affecting the owner of the infrastructure, particularly when the collaterals or the insurance mechanisms are inadequate.

Equity finance is certainly the crucial innovation in the long process of managing the risk associated with infrastructure finance, thus we can refer the reader to the discussion in other chapters of this book on the different circumstances that have led to the modern listed company. In retrospect, probably the most important innovation was the dilution of risk among a large number of shareholders, in such a way that instead of building a large portfolio of projects it was possible to build diversified and flexible portfolios of shares (see Cassis Chapter 3).

The history of the bond/loans versus equity/shareholding finance is best appreciated by looking at specific industries, such as the railways, water, or telecommunications, and in fact our research offers several examples of both ways to channel private savings towards large-scale investment.

This story is also best acknowledged in relation to innovation in the organization and management of firms, a topic that we discuss in the next section.

I.4 Innovation of Technology, Management, and Organization

The interplay of technical progress, finance, and organization is a central theme of our research. The establishment of the modern electrical utility is an illustration of this interplay. While others may have invented the incandescent electric light, Edison should be credited with having the intuition that, unlike arc lights, it required a network:

> Edison approached the problem of the incandescent light as a piece of a larger plan to develop a new utility to replace the gas-lighting utility – one that would provide lighting in residences, commercial establishments, workshops, and factories. This required an electrical infrastructure very different from that used by arc-lighting utilities and one closer to that of the gas-lighting industry (Hausman et al., 2011, p. 12).

Thus, just changing the final device, the modest lamp, had huge upstream implications for electricity generation, transmission, and distribution. Arc lights were designed to be controlled by the utilities, not by the customers, and this fact tended to be linked to local systems. The idea of an entirely decentralized management of the lamps, connected in parallel rather than in series, supported the concept of large networks, and in turn the latter was giving way to economies of scale in generation.

The larger the networks, the larger the generation plants, the better. The core infrastructure of modern times, the electrical industry, was then the result of a seemingly modest shift from one type of lamp to another. But this idea could not have been conceived if Edison had not had the backing of a group of financiers, notably J. Pierpont Morgan (Josephson, 1959; Israel, 1998).[9]

The three ingredients that we have identified in our generic definition of infrastructure are all present: electricity generation and networks were highly capital intensive projects (the capital/output ratio between 1895 and 1930 was higher than for railways and telephone (Hausman et al., 2011, Fig. 1.4)); they were supported by a small group of entrepreneurs and financiers; the timescale required to build the new system and to earn returns was long compared to manufacturing or trade.

Each infrastructure-based industry has followed its own specific path, and the relationship between innovation, organization, and finance is accordingly variable. Our research offers several examples, and this is not the place to summarize them. But we want to emphasize that even ostensibly humble innovations may have generated a path leading to sizeable infrastructure investment, and this is not a feature of contemporary history alone. For example, a large part of merchant traffic towards Rome was about importing wine (and oil). This would have been impossible without the large-scale standardized production of robust ceramic or terracotta containers, the *amphorae* and *pithos*. These standardized containers made it convenient to build bigger vessels (*naves onerariae*) that in turn required a port infrastructure. A typical ship was 19 m long, and with a draft around 3 m. Each amphora was 45–50 kg, and 3,000 of them was a typical load. The *muriophorai* ships were able to transport up to 10,000 amphorae. Peacock and Williams (1986) document how the perfection of the mass production of amphorae in Rome ultimately had a chain effect on trade, shipbuilding, and eventually on the establishment of Ostia and later of Portus, that is the harbour infrastructure needed to manage such traffic. The investment included canals and major roads (Via Ostiense, Via Portuense) and these were directly financed by the Roman state given their importance for the supply of staples to the capital. Thus innovation in the

[9] See also the relationship with finance of Giacinto Motta in the Italian context (Segreto, 2005).