EIB PAPERS

Innovative financing of infrastructure – the role of public-private partnerships:

Infrastructure, economic growth, and the economics of PPPs

European Investment Bank

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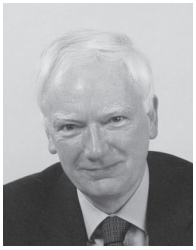

Philippe Maystadt
President

Public-private partnerships—or PPPs for short—have been around in their modern form for a decade and a half. They emerged as an innovative way to finance infrastructure in the United Kingdom in the early 1990s and have subsequently spread around Europe and, indeed, the world. While the United Kingdom remains in unrivalled lead in terms of the width and depth of its PPP experience, numerous other European countries, including some new members of the EU, are well underway developing their own national PPP programmes.

The European Investment Bank has a long-standing and, in a way, obvious interest in public-private partnerships as a way to finance and provide infrastructure. The Bank has been intimately involved in setting up and financing PPP projects throughout their existence. While the Bank has always, as a matter of policy, left it to the national authorities to decide whether to procure an investment project by means of a public-private partnership or some other way, it nevertheless has a keen interest in understanding what drives the decision in favour of a public-private partnership in general and a specific PPP model in particular. But the interest of the Bank obviously does not end here. Equally important, to further improve its contribution to the effectiveness of public-private partnerships, the Bank needs to know clearly what has worked in practice and what has not – and why.

It is against this background that the contributions to this volume of the *EIB Papers* are set. Drawing on presentations made at the *2005 EIB Conference on Economics and Finance*, the contributions address a variety of themes such as: trends in public investment and in public-private partnerships in EU countries, the link between infrastructure and economic growth, the economics of public-private partnerships (all in Volume 10, Number 1), the applicability of the PPP model across different sectors of the economy, the assessment of public-private partnerships in theory and practice, and – last but not least – the lessons learned from a portfolio of EIB-financed PPP projects (all in Volume 10, Number 2).

To sketch some of the issues addressed, it is useful to start by pointing out that the emergence and expansion of public-private partnerships has occurred against the background of long-term fiscal problems in most European countries, a downtrend in public investment, and concerns about the possible negative effects of reduced investment in infrastructure. Under such circumstances public-private partnerships have had obvious appeal to financially constrained policymakers: they offer a possibility to get infrastructure delivered while, at the same time, relieving the pressure on strained public finances. But one has to be clear about the underlying facts and figures in terms of how much public investment has indeed declined over the past two-three decades, and to what extent that decline has been offset by privately financed infrastructure investment through public-private partnerships. Moreover, to assess the consequences of those developments, one needs to have an idea about how and how much infrastructure investment affects economic performance at the aggregate level.

The fiscal dimension has undoubtedly played a major role in the spread of public-private partnerships, but there can be other, more virtuous economic benefits associated with them. A partnership between the public and the private sectors may combine the strengths of both and, consequently, deliver infrastructure—to the benefit of the whole economy—with a higher degree of efficiency—to the benefit of the private partner and the taxpayer alike. But what is the cost the economy has to pay in order to obtain these benefits? Furthermore, what are the preconditions for a successful partnership and when are they likely to be met?

As regards the costs and benefits of public-private partnerships, the obvious challenge is to identify the circumstances in which a public-private partnership appears superior to traditional public procurement of infrastructure investment, and the infrastructure sectors where these circumstances are likely to prevail. A related challenge is to design contractual arrangements that make public-private partnerships live up to their potential. Turning to the preconditions for a successful partnership and when they are likely to be met, this is pursued in the companion edition (Volume 10, Number 2). Suffice to note here that at a decade and a half, the experience with public-private partnerships is already long enough to allow their assessment from a practical perspective.

All in all, public-private partnerships have established themselves as an alternative to traditional public procurement of infrastructure investment projects. But they come with both costs and benefits, and for the EIB, which has come to play an important role as a source of not only funding but also advisory services at all stages of PPP projects, it is crucial to fully grasp these costs and benefits. Its support for public-private partnerships in the past has put the Bank in a unique position to accumulate a wealth of experience of public-private partnerships across countries and sectors. I am confident that the research findings presented in this volume of the *EIB Papers* will further enhance our understanding and I am happy we can share them with you.

Innovative financing of infrastructure – the role of public-private partnerships:

Infrastructure, economic growth, and the economics of PPPs

The *2005 EIB Conference on Economics and Finance* – held at EIB headquarters in Luxembourg on January 20 – examined the role of public-private partnerships in the provision of public infrastructure services. Presentations covered a variety of aspects, including the link between infrastructure and economic growth, the economics of public-private partnerships, and the experience of countries – and the European Investment Bank – with public-private partnerships.

Speakers include:

Jakob DE HAAN,
of the University of Groningen,
The Netherlands

Mathias DEWATRIPONT
and Patrick LEGROS,
of the Université Libre de Bruxelles,
Belgium

Paul GROUT,
of the University of Bristol, UK

Patricia LEAHY,
of the National Audit Office, UK

Rui Sousa MONTEIRO,
of Parpública SA, Portugal

Armin RIESS,
of the EIB

Campbell THOMSON,
of the EIB

Timo VÄLILÄ,
of the EIB

Christian VON HIRSCHHAUSEN,
of the Dresden University of Technology,
Germany

Editors' introduction

Mobilising private finance to fund infrastructure projects is not entirely new. On the contrary, historically, toll roads, bridges, canals, schools, railways, hospitals, and the like have often been supplied by the private sector. Notably, there has been a long tradition of concession agreements in countries like France. That said, what distinguishes public-private partnerships (PPPs) from other forms of private sector involvement in the financing and provision of infrastructure services is that they establish a long-term, interactive partnership between the public and private sectors. Such a partnership has many salient features. One is that the public sector purchases infrastructure services rather than the infrastructure asset itself. Another is the allocation of risks between public and private partners, with each partner assuming those risks it can control and manage better than the other partner.

Several factors have spurred the use of PPPs in lieu of traditional public sector procurement. Some observers see them driven largely by government budget constraints, arguing that they enable governments to provide public services without having to incur upfront high infrastructure investment cost. Others consider them part and parcel of a paradigm shift, calling for a greater role of the private sector in economic activities that used to be the domain of the government. Related, but not identical to this view is the notion that PPPs are better at delivering public services than the traditional way of supplying them. But are they?

The contributions to this volume of the *EIB Papers* (comprising two editions: Volume 10, Number 1 and Volume 10, Number 2) all evolve around this question. They cover a wide range of conceptual and practical themes, including trends in public investment and capital; the link between public capital and economic growth; the economic pros and cons of PPPs; contract design and risk transfer; the applicability of the PPP model across different economic sectors; PPP appraisal questions – notably how to find out whether they promise value for money; and PPP experience from a variety of countries.

Before introducing the contributions, a note on terminology is warranted. There is often confusion about the terms 'infrastructure investment' and 'public investment'. While it is true that the bulk of public investment is infrastructure investment—such as the construction, operation, and maintenance of roads, bridges, tunnels, schools, hospitals, prisons and the like—the reverse does not hold. That is, a whole lot of infrastructure investment is undertaken by commercial entities (public sector corporations or private sector ones) and often mistakenly taken for public investment. Examples include investment by energy companies in generation capacity; telecoms companies in networks; or rail companies in rolling stock or rail infrastructure. In all these cases the investment is financed and undertaken by commercially run enterprises and therefore recorded as private investment in national accounts statistics—regardless of the ownership structure of that enterprise. Only investment directly financed from the budget of the government—be it at the central or subnational level—qualifies as public investment.

With this clarification duly noted, here is our guided tour through Volume 10 of the *EIB Papers*.

In their paper on trends in EU infrastructure investment, **Timo Välilä**, **Tomasz Kozluk**, and **Aaron Mehrotra** assess the evolution and determinants of public infrastructure investment in EU countries – old and new – and the significance of infrastructure finance through public-private partnerships, which are often portrayed as a substitute to traditional public procurement of

infrastructure. The paper offers many interesting insights; we sketch three of them here. While public investment has been on a downtrend in many pre-enlargement EU countries, public capital stocks have continued to grow in most of them, which suggests that infrastructure assets are not being eroded. Drawn-out episodes of fiscal consolidation explain most of the decline in public investment in the pre-enlargement EU countries, but EMU membership does not, and fiscal consolidation in the new member states of Central and Eastern Europe has not led to wholesale squeeze of infrastructure investment either economy-wide, or by the public sector. Finally, while PPPs have undoubtedly brought about an important structural change qualitatively speaking, their quantitative importance remains modest. The overall conclusion then is that while public investment has been trending down in many countries and while public-private partnerships are gaining popularity, the quantitative significance of these developments should not be exaggerated.

Understanding trends in infrastructure investment and their determinants is important. But even if there were a decline in the stock of public infrastructure, would it matter? **Ward Romp** and **Jakob de Haan** address this question in their survey of the theoretical and empirical literature on the link between public capital and economic growth. Non-economists may find this a superfluous question in the first place, thinking that infrastructure is an essential factor of production and a lack of it must surely stifle economic development. Although this is correct in principle, reality is more complex, and the authors highlight at least three reasons why a positive impact of public capital on economic growth cannot be taken for granted. For a start, infrastructure investment is not sufficient on its own to generate a sustained rise in economic growth. There is evidence that the effect of public investment spending depends, among other things, on the policy and institutional environment. And then, resources devoted to infrastructure cannot be used for other, potentially more productive purposes – such as private investment, maintaining the existing public capital stock, and human capital formation. Finally, even when observing a positive link between public capital and economic growth, the direction of causality is unclear: while public capital may affect productivity and output, economic growth can also shape the demand and supply of public capital services. All in all, the authors conclude that although not all studies find a growth-enhancing effect of public capital, there is now more consensus than before that public capital furthers economic growth. They stress, however, that the impact reported by recent studies is not as big as some earlier studies suggested. What is more, the effect of public investment differs across countries, regions, and sectors.

Accepting the consensus view that public capital is indeed productive on average leads to an obvious question: is there a lack of public capital in the European Union? The contribution by **Christophe Kamps** is one of the first papers trying to answer this question for EU-15 countries. He uses two measures to gauge the size of public capital. One is the ratio of the stock of public capital to GDP; the other is the ratio of the stock of public capital to the stock of private capital. For each ratio, the author estimates the growth-maximising level and compares it to actual ratios. It turns out that most countries have a ratio above the growth-maximising level, but the deviation from the optimum is not statistically significant. The exceptions are Austria, France, and the Netherlands, which have a ratio of public capital to GDP significantly above the growth-maximising level. For the second measure, the estimates show that all countries but two have ratios of public to private capital above the growth-maximising value. That said, only in four countries (France, Greece, Ireland, and the Netherlands) is the excess of public capital statistically significant. By contrast, only Portugal appears to have too low a public to private capital ratio. To summarise, the empirical results suggest that there is currently no lack of public capital in most EU-15 countries. But Kamps takes the analysis a step further and examines whether a shortage of public capital might arise if current trends in public investment were to continue. He finds that current public investment seems adequate for the EU-15 as a whole, but Austria, Belgium, and the United Kingdom seem to grossly under-invest in public capital, while there is evidence for over-investment in Portugal.

The paper by **Timo Välilä** turns to the spotlight on public-private partnerships. It takes as a starting point two opposing views about why public-private partnerships emerged and gained popularity. Some observers claim that fiscal considerations have driven public-private partnerships as they allow governments constrained by binding fiscal deficit rules to implement infrastructure projects that would otherwise never materialise, or would only materialise with a delay. Others argue that public-private partnerships offer real benefits through higher productive efficiency at the project level. It is against this background that the paper analyses the microeconomic pros and cons of public-private partnerships by identifying the sources of both higher benefits and higher costs associated with them, as compared to traditional public investment. The broad conclusion is that public-private partnerships can offer productive efficiency gains over traditional public provision, but that such gains come with costs (in particular possibly lower allocative efficiency and higher transaction costs), which may outweigh the gains. Another key conclusion is that fiscal policy should be a non-issue in deciding how to finance and provide services. The shifting of investment between public and private sector books does not create any leeway in public finances or in the economy more broadly. In other words, there is no macroeconomic case for – or against – public-private partnerships. Taken as a whole, Välilä concludes that despite many caveats, there is an economic case for a public-private partnership if it can deliver a socially acceptable level of allocative efficiency, while delivering a higher level of productive efficiency than traditional public provision, at non-prohibitive transaction costs.

Cognisant of the potential benefits of public-private partnerships, especially their capacity to generate life-cycle cost savings through 'bundling' the construction and operation of infrastructure assets, **Mathias Dewatripont** and **Patrick Legros** critically assess the implications of contract design and risk transfer on the provision of public services under public-private partnerships. Two results stand out. First, the alleged strength of public-private partnerships in delivering infrastructure projects on budget more often than traditional public procurement could be illusory. This is because there are costs associated with trying to avoid cost overruns. There is then a trade-off between these costs and the benefits of minimising cost overruns. An intriguing implication of this insight is that cost overruns, as they often occur in traditional procurement, could reflect equilibrium phenomena rather than too costly procurement of infrastructure assets. The other result is equally gripping: the use of external (i.e., third-party) finance in public-private partnerships, while bringing discipline to project appraisal and implementation, implies that part of the return on efforts exerted by the private-sector partner accrues to outside investors; this may undo whatever beneficial effects arise from 'bundling'. In this context, the authors also argue that debt finance is less damaging than third-party equity finance, which speaks in favour of large, expert creditors when outside investors are relied on to finance public-private partnerships.

Armin Riess further delves into the microeconomic pros and cons of public-private partnerships, investigating whether the PPP model is applicable across sectors. Focussing on two key features of public-private partnerships – the 'bundling' of construction and operation of an infrastructure asset, for one, and private ownership for another – he argues that the PPP model is suitable for some public services but not for others. More specifically, public-private partnerships for roads, bridges, tunnels, water resources and supply, waste management, and accommodation services provided by schools, hospitals, prisons, city halls, and so on seem to make eminent sense. By contrast, they might do more harm than good in providing IT services and core services in education (i.e., teaching) and health (i.e., clinical services). Also, the case for public-private partnerships is doubtful when public safety is of considerable concern – railway networks being a prime example. What then makes a service unsuitable for a public-private partnership? The key issue here is the importance of public-interest objectives the service aims at and the ease (or difficulty) of specifying, measuring, and guaranteeing them. The author's main conclusion is that for public-private partnerships to work for

the general good, the incentive-oriented, performance-based mechanism – supposed to give them an edge over traditionally procured infrastructure – warrants performance measures that inform well about the attainment of public-interest objectives. When they do, public-private partnerships can work wonders, but when they do not, they might backfire precisely because of their incentive-oriented mechanism.

With public-private partnerships, a government has now more options than before to ensure the provision of public services. When projects were traditionally delivered solely by the public sector, the government's main decision was whether to undertake the project or not. Now the government also has to decide whether to choose the traditional mode of delivery or whether to opt for a public-private partnership. In the latter case, it also has to decide between alternative private sector suppliers.

But how should governments assess alternative service delivery options? This is the question pursued by **Paul Grout** in his paper on value-for-money measurement in public-private partnerships. He considers alternative value-for-money tests, discusses their main conceptual problems, and looks at their use in the United Kingdom. The focus is on three broad tests: a full cost-benefit analysis of alternative procurement options, an assessment of the cost to the government budget of alternative procurement options (which rests on a comparison of private PPP bids with a so-called public sector comparator), and – much simpler – a comparison of private PPP bids. The author shows that under reasonable assumptions the second test yields the same ranking of procurement alternatives as the first one, putting the second test ahead of the first given it is less costly to carry out. But this does not mean these tests correctly guide decision-makers. On the contrary, as Grout argues, they come with major problems. One is that when comparing the cost of a public sector comparator to the budgetary cost of a public-private partnership, adjustments need to be made for differences in the underlying cost and benefit streams, where these differences should be assessed at social values rather than market prices. This gives rise to huge scope for error. Moreover, Grout reasons that the correct discount rate for evaluating the budgetary cost of a public-private partnership is likely to be higher than the discount rate for the public sector comparator. It follows that if the same discount rate is used for both types of cost – as is often done in practice – there is a built-in bias against public-private partnerships. This leaves the simple tests of comparing private PPP bids. Obviously, the scope for error just discussed does not fully disappear, but it is likely to become much smaller. In sum, the paper argues that value-for-money tests centred on comparisons between private sector alternatives are well focussed, less prone to measurement error than other tests, and more likely to deliver the best candidate from the group it considers. It also stresses that competition for public-private partnerships is key for getting value for money – not only in terms of obtaining a good price but also in generating a sound understanding of the project – and that with sufficient competition, public sector comparators play a secondary role.

The lessons **Patricia Leahy** draws from the UK Private Finance Initiative (PFI) – launched in 1992 – echo some of Paul Grout's findings. For one thing, there is the importance of competition in the bidding for public-private partnerships and the prerequisites for effective competition. For another, there is the need for a value-for-money appraisal framework conducive to choosing PFI when it is most likely to deliver value for money. To this end, the UK appraisal framework has been changed in recent years, including a reduced emphasis on the public sector comparator. But there are other lessons that go beyond the procurement phase of PFI projects. For a start, while the experience with the operational performance of PFI remains limited to-date, work carried out by the National Audit Office points to several factors affecting the performance of PFI projects. Such factors relate, most notably, to the management and evaluation of the contract, with any contractual changes calling for an in-depth analysis of their costs and benefits, and the monitoring

and sanctioning of the private partner's performance, including a credible threat to terminate the contract. Another lesson is that excessive risk transfer to the private sector should be avoided, as it would only create problems for the public sector further down the road. A final lesson worth highlighting is that financing arrangements can affect value for money. In conclusion, the UK Private Finance Initiative – covering a much wider range of sectors than similar initiatives in other countries to-date – offers lessons that, if learned, promise better value for money.

This takes us to the paper by **Rui Sousa Monteiro**, who reviews the PPP lessons from Portugal, the only other country next to the UK where public-private partnerships are significant in terms of both the number of projects undertaken and their size relative to public investment. In fact, the importance of public-private partnerships relative to overall investment, sectoral investment, and – in particular – to GDP has been considerably higher in Portugal than in other EU countries. Related to this is the fact that compared to countries with a higher per capita income – such as the UK – public-private partnerships in Portugal have often implied a major extension of infrastructure assets rather than small additions to the existing infrastructure. A key message transpiring from Monteiro's analysis is that one must not confuse the effectiveness of public-private partnerships in rapidly developing infrastructure and in improving the quality of public services, for which Portugal provides considerable evidence, with the ultimate goal of enhancing the efficiency of using and allocating scarce resources. The author observes that on this count, Portugal's PPP projects may not have scored as high as they could have. Against this background, Monteiro discusses recent changes to Portugal's institutional framework for public-private partnerships (especially a more rigorous appraisal of public-private partnerships, their long-term budgetary implications, and of the contractual arrangements supporting them) that aim at ensuring efficiency in the provision of infrastructure services and, thus, value for money. A key lesson is that one needs to thoroughly analyse the long-term budgetary impact of future public-private partnerships, as payment obligations the government has taken on under previous PPP deals have given rise to considerable fiscal pressures. To illustrate the scope of the challenge, shadow toll payments to PPP concessionaires are projected to soon reach an amount equal to the current central government public investment budget for the road sector (around 0.5 percent of GDP). Another aspect worth noting is that Portugal's PPP appraisal framework now calls for public sector comparators to guide the decision for or against public-private partnerships. In this sense, Portugal – as well as other countries – seems to be swimming against the UK tide and the recommendation of Paul Grout, which – of course – does not mean that Portugal is on the wrong track.

Given the urgency of expanding and modernising public infrastructure in countries moving from plan to market, it would not be unreasonable to expect an important role for public-private partnerships in countries of Central and Eastern Europe (CEE). That this has not been the case is a key message emerging from the paper by **Andreas Brenck**, **Christian von Hirschhausen**, **Thorsten Beckers**, and **Maria Heinrich.** Although the authors focus on the highway sector in selected CEE countries, their findings explain more generally why public-private partnerships have not lived up to their potential and, by extension, what needs to be done so that they will in future. Institutional shortcomings top the list of explanations. Looking forward, the authors stress the need for a systematic assessment of procurement options, a more transparent and clearly defined contract awarding process, a credible commitment by the government not to interfere and/or backtrack on agreements, and a rational framework for renegotiating contracts. Improvements in these areas should lead to better-prepared PPP tenders, more competition for public-private partnerships, fewer delays in project implementation, and lower transactions costs. Other factors explaining why public-private partnerships have underperformed include the 'usual suspects' known from countries such as Portugal and the UK: too narrow design specifications, which discourage contractors to choose innovative solutions, and far too optimistic demand projections. Factors specifically

applying to highway PPPs include too optimistic an assessment of users' willingness to accept tolls and failure to properly take into account network effects – notably the diversion of traffic to toll-free roads. In sum, the complex structure of public-private partnerships has been a formidable challenge for transition countries and, in fact, may have exceeded their institutional capabilities. That said, the authors note substantial progress towards a more stable, focused, and transparent institutional framework. This bodes well for the future, promising that PPP projects will be more successful, result in higher efficiency, and be chosen because they offer value for money and not because governments perceive them as a means to circumvent budget constraints.

The contributions outlined so far look at public-private partnerships from a variety of angles: trends in public investment, the quantitative importance of public-private partnerships in EU economies, the impact of public investment on economic growth, the economics of public-private partnerships, and the PPP experience of several countries. An obvious question that remains is: and what about the public-private partnerships supported by the European Investment Bank?

Campbell Thomson sheds light on this question. Summarising the findings of an evaluation carried out by Operations Evaluation of the Bank, his paper suggests that projects were largely completed on time, on budget, and to specification. There is also evidence on some projects that the standard of the works was higher than would have been found in a public procurement project. But he also reports evidence that optimistic demand forecasts may compromise the efficiency and financial sustainability of some projects. The key impact of the PPP mechanism was, however, that the projects were implemented at all. For all the projects evaluated, public sector budget constraints meant that the alternative to a PPP project was no project, or at least no project within the foreseeable future, rather than a public procurement project. The paper observes that in such cases the use of a public sector comparator to examine whether a public-private partnership offers better value than public procurement might be questioned and, indeed, a public sector comparator was carried out only for a minority of the projects evaluated. As to the prerequisites for prime performance of public-private partnerships, Thomson concludes that projects should have clear boundaries and output specifications, the underlying project must be economically and financially sustainable, competition must be maintained to minimise costs, and the private sector partners need to carry risk. That said, the paper also emphasises that public-private partnerships are not a panacea for public expenditure. They create new challenges for promoters, private sector partners, and financiers. But in the right circumstances, they can make public infrastructure available earlier, more effectively, and more efficiently than traditional public procurement. The challenge is to match their use to the circumstances.

Taken together, the contributions to this volume of the *EIB Papers* identify a few prerequisites for meeting this challenge. Perhaps most importantly, both theoretical considerations and practical experience suggest that the seeds of success or failure are sown early on in the procurement phase. The soundness of the framework for appraising value for money; the transparency and competitiveness of the bidding process; the importance of getting the contractual relationship, especially risk transfer right; and the need to keep in check the additional transaction costs of setting up and following through a PPP receive ample attention across contributions. Get these prerequisites right, and a PPP is an attractive route to follow. Get them wrong, and the public sector is in for an expensive ride.

Armin Riess and Timo Välilä

ABSTRACT

This paper describes long-term trends in public investment and analyses their causes and consequences. *This has been undertaken separately for the EU-15 and the new member countries in Central and Eastern Europe. In addition, it assesses the significance of infrastructure finance through public-private partnerships, which are often portrayed as a substitute for traditional public procurement of infrastructure. The conclusion that emerges is that while public investment has been trending down in non-cohesion countries and while public-private partnerships are gaining popularity, the quantitative significance of these developments should not be exaggerated.*

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Roads on a downhill? Trends in EU infrastructure investment

"I see gr-reat changes takin' place ivry day, but no change at all ivry fifty years."
Finley Peter Dunne

1. Introduction

Timo Välilä

Tomasz Kozluk

Aaron Mehrotra

Public investment in most old member countries of the EU has been on a trend decline for the past three decades, at least if measured in relation to GDP. In the new member states, the transition-induced need for additional infrastructure spending has coincided with a protracted need for fiscal consolidation, leaving its mark on infrastructure investment. Are European roads on a downhill, figuratively speaking? To what extent is that downhill being flattened by new, innovative ways to finance infrastructure, such as public-private partnerships?

The aim of this paper is to assess the evolution and determinants of public infrastructure investment in EU countries. In particular, we wish to go beyond the accepted wisdom that public investment in the old member countries has been on a downtrend by studying country-by-country the exact extent of the slide; its implications for public capital stocks; and the factors that have been responsible for the slide. Furthermore, we examine the evolution of infrastructure investment in general and public investment in particular in the new member countries so as to precisely verify what impact fiscal consolidation has had. Finally, we assess the quantitative significance of public-private partnerships, thereby evaluating whether or not there has been a major structural shift in the infrastructure sectors away from public and toward private financing and provision.

By addressing this array of issues, this paper sets the stage for the other contributions to this volume. To put the analysis of public-private partnerships in a proper perspective, it seems opportune to set the facts and figures straight and to analyse what has been driving their trends and bumps. In other words, this paper wishes to assess the quantitative evidence underlying the qualitative observation that the financing of infrastructure is undergoing structural changes.

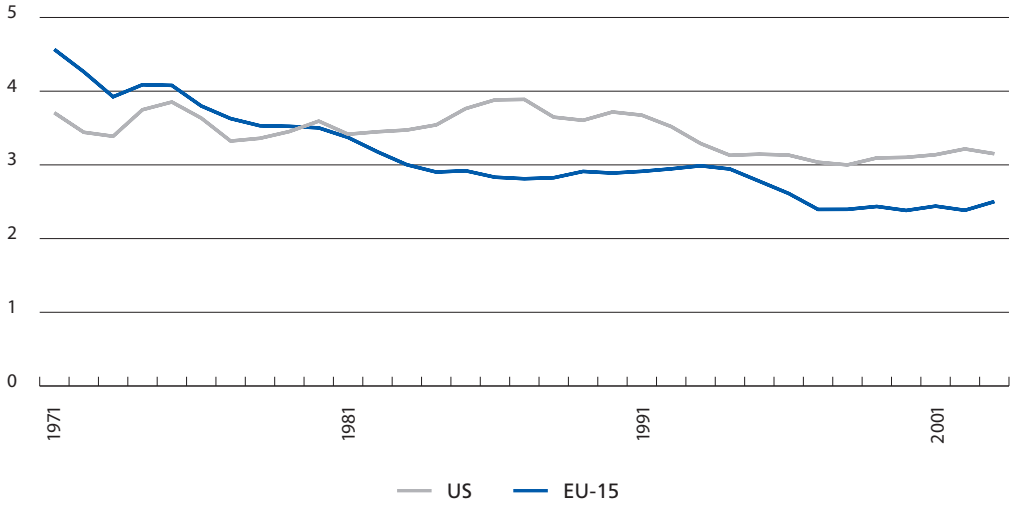
Before entering the analysis, a note on terminology is warranted. There is often confusion about the terms 'infrastructure investment' and 'public investment'. While it is true that the bulk of public investment is infrastructure investment—such as the construction, operation, and maintenance of roads, bridges, tunnels, schools, hospitals, prisons and the like—the reverse does not hold. That is, a whole lot of infrastructure investment is undertaken by commercial entities (public sector corporations or private sector ones) and often mistakenly taken for public investment. Examples include investment by energy companies in generation capacity; telecoms companies in networks; or rail companies in rolling stock or rail infrastructure. In all these cases the investment is financed and undertaken by commercially run enterprises and therefore recorded as private investment in national accounts statistics—regardless of the ownership structure of that enterprise. Only investment directly financed from the budget of the government—be it at the central or subnational level—qualifies as public investment.

2. Public investment and capital stocks in old member states

It is accepted wisdom by now that public investment has been on a trend decline in most industrial countries since the 1970s. Indeed, gross fixed capital formation by the general

government in the 15 countries constituting the pre-enlargement EU has halved from well over 4 percent of GDP in the early years of the 1970s to just over 2 percent of GDP in recent years.[1] In the United States (US) the decline has been less pronounced from 3.5 percent of GDP in the early 1970s to 3 percent of GDP now.

Figure 1. Gross fixed capital formation by the general government in the EU-15 and the US (in % of GDP), 1971-2003.



Source: OECD.

This section aims to examine the evolution of public investment in the pre-enlargement EU, with a special focus on the causes and consequences of the downtrend in public investment flows. The observation that public investment, as a share of GDP, has been declining is not very informative *per se* and therefore requires further investigation in several respects. First, has the downtrend been a common phenomenon in more or less all old EU member countries, or does the aggregate figure hide significant differences across countries? Second, has the downtrend in public investment been so steep as to ignite an erosion of public capital stocks, or are the current levels of investment still sufficient to cover at least the depreciation of public capital assets? Third, what are the factors explaining the downtrend? These questions are addressed in turn below.

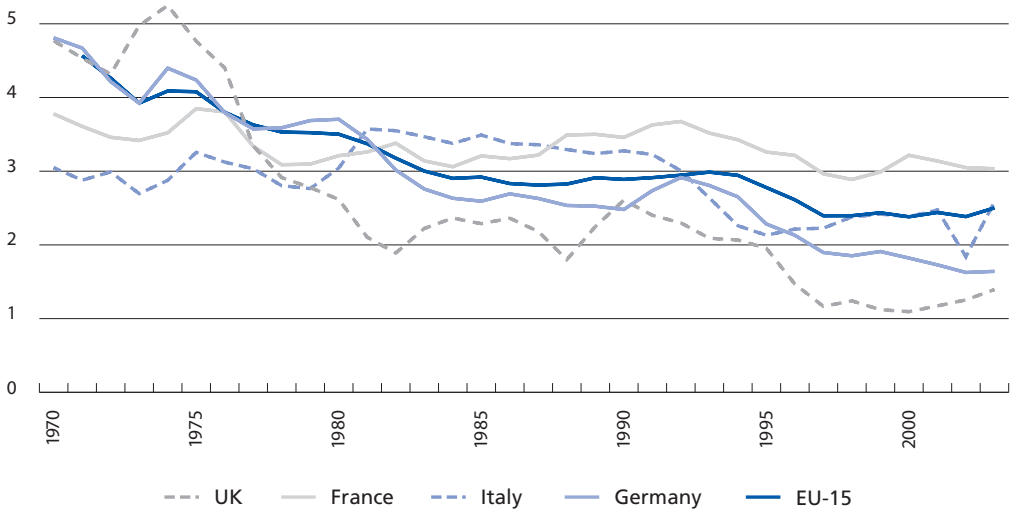
2.1 Evolution of public investment flows

Among the large EU countries, public investment has declined most in the UK.

While the general trend in public investment, as a share of GDP, has indeed pointed down in the pre-enlargement EU, there has been considerable variation across individual countries, as illustrated by the figures below. In the group of large countries (France, Germany, Italy, and the United Kingdom (UK)) public investment fell from an average of 4 percent of GDP in the early 1970s to 2.2 percent of GDP in recent years. The fall has been particularly pronounced in the UK, where public investment peaked at 5 percent of GDP in the early 1970s; fell to some 2 percent of GDP by the early 1980s where it hovered for a decade, only to continue sliding thereafter toward 1 percent of GDP.

1 Luxembourg is only included starting 1990.

Figure 2. Gross fixed capital formation by the general government in large EU countries (in % of GDP), 1970—2003.

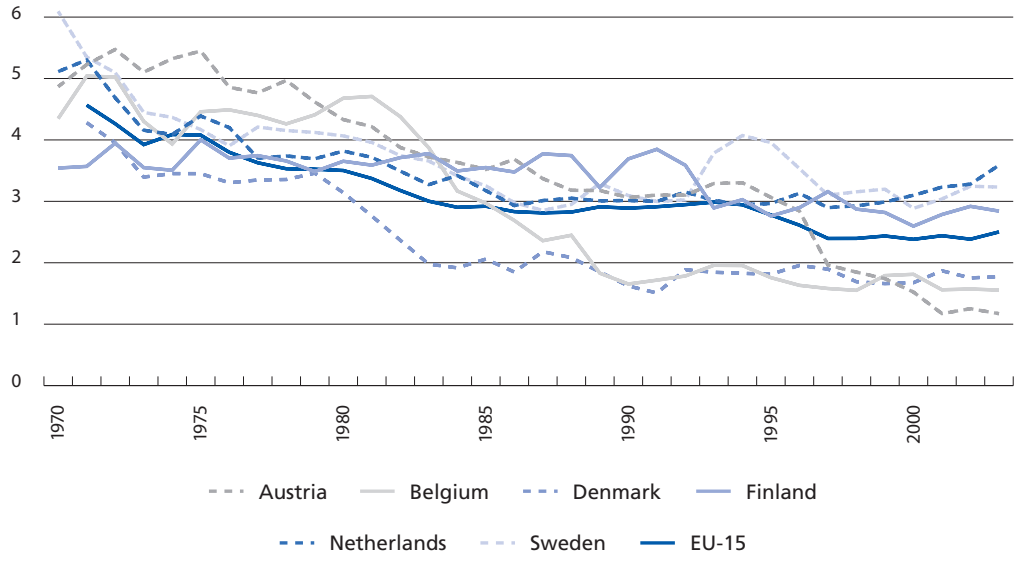


Source: OECD.

The fall in public investment was also quite pronounced in the group of smaller non-cohesion countries (Austria, Belgium, Denmark, Finland, the Netherlands, and Sweden), where average public investment more than halved from almost 5 to 2.4 percent of GDP. Austria, Belgium, and Denmark experienced the biggest declines, from 4-5 percent of GDP in early 1970s to just over 1 percent of GDP in recent years. In contrast, Finland's public investment has declined by less than one percentage point of GDP during the past three decades.

Austria, Belgium, and Denmark have had the steepest declines among smaller non-cohesion countries.

Figure 3. Gross fixed capital formation by the general government in smaller non-cohesion countries (in % of GDP), 1970—2003.

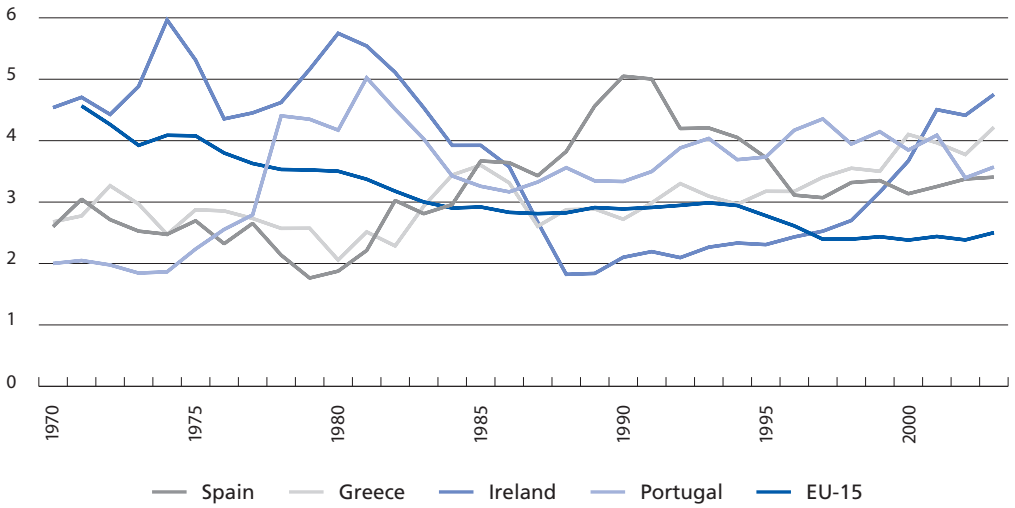


Source: OECD.

In cohesion countries, public investment has trended up rather than down.

The cohesion countries (Greece, Ireland, Portugal, and Spain) have been less homogenous as a group; nevertheless, there has been a tendency for public investment to trend up rather than down within that group, the average increasing from 3 to 4 percent of GDP. Ireland,as an extreme, has seen public investment drop from the peak of 6 percent of GDP in the 1970s to below 2 percent of GDP in the late 1980s, with a subsequent increase to nearly 5 percent of GDP more recently.

Figure 4. Gross fixed capital formation by the general government in cohesion countries (in % of GDP), 1970—2003.



Source: OECD.

2.2 Evolution of public capital stocks

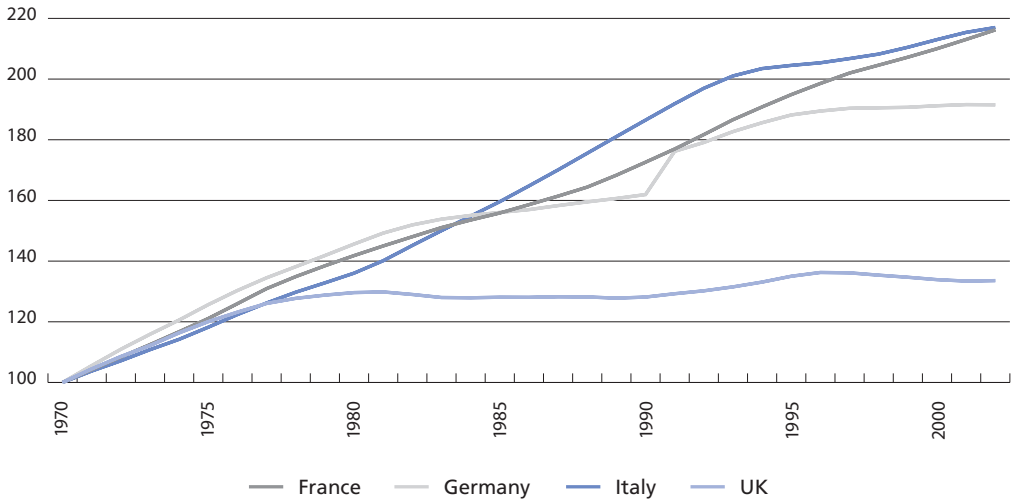
Having depicted the evolution of public investment flows above, it is of interest to examine how public capital stocks have evolved as a result of a general drop in flows—at least if measured in relation to GDP. Notably, the aim here is only to describe the evolution of public capital stocks, without any analysis or *a priori* view about their optimal size and evolution over time.

A new set of estimates on public capital stocks in 22 OECD countries has been prepared by Kamps (2004). The estimates for the pre-enlargement EU member states are presented below in relation to the size of the public capital stock in 1970 in each country and also in a cross-country comparison.[2]

Figure 5 below suggests that public capital stocks have roughly doubled since 1970 in all large EU countries except in the UK, where the cumulative growth has been below 40 percent. Moreover, the public capital stock in the UK has remained rather flat since the late 1970s.

2 The estimates for the public capital stocks depicted below are calculated using the so-called perpetual inventory method. The capital stock in any given period is calculated as the sum of the stock in the previous period plus gross investment flow in the current period less depreciation. The initial capital stock is estimated assuming that the capital stock in year 1860 equalled zero, and that gross investment grew during 1860-1960 at a constant rate of 4 percent, to reach the actually observed level in 1960. The rate of depreciation is assumed constant for any given year but variable across years during 1960-2001. It is assumed to have been constant at 2.5 percent during 1860-1960, while increasing gradually from 2.5 percent in 1960 to 4 percent in 2001. The constant depreciation rate implies that capital put in place in any given year will never be fully depreciated, it just converges towards zero over a very long time.

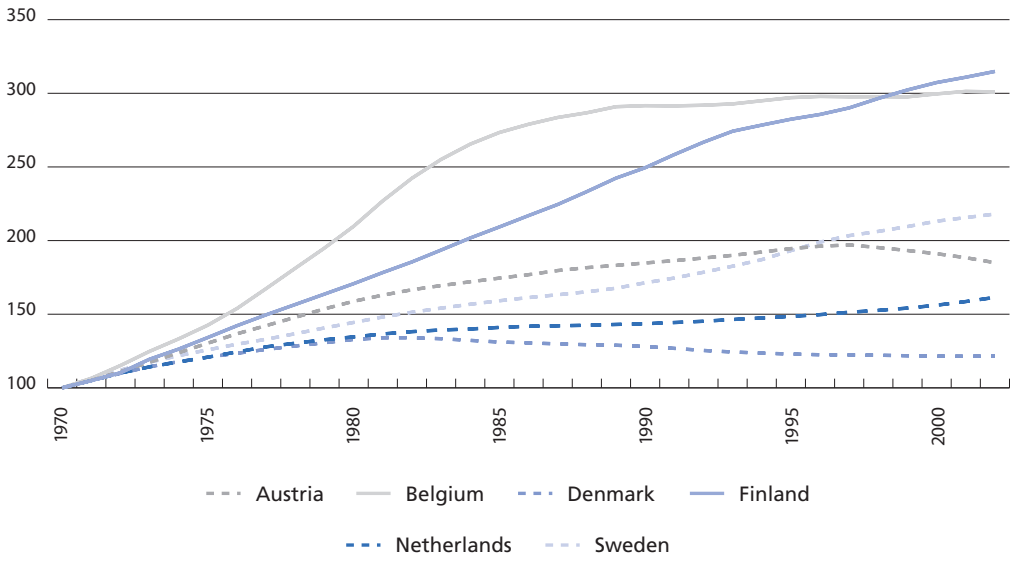
Figure 5. Public capital stock in large EU countries (1970 = 100), 1970—2003.



Source: Kamps (2004).

Among smaller non-cohesion countries public capital stocks have trebled in Belgium and Finland, doubled in Austria and Sweden, while growing more modestly in the Netherlands and Denmark. The growth took place as early as the 1970s in Austria, Belgium, and Denmark; since the 1980s, these countries' public capital stocks have been almost unchanged.

Figure 6. Public capital stock in smaller non-cohesion countries (1970 = 100), 1970—2003.

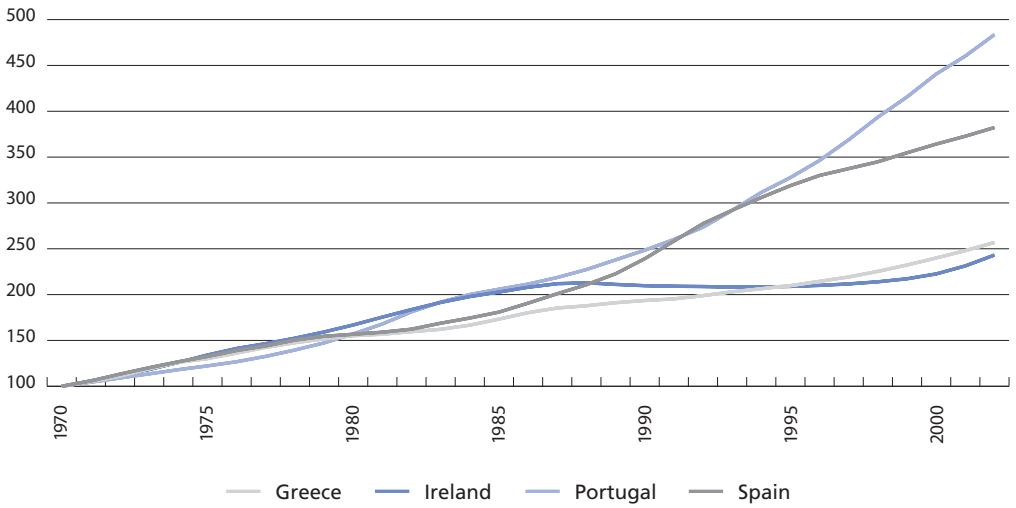


Source: Kamps (2004).

As regards the cohesion countries, the public capital stock has grown almost fivefold in Portugal, fourfold in Spain, and more than doubled in Greece and Ireland.

Public capital stocks have grown fastest in the cohesion countries.

Figure 7. Public capital stock in cohesion countries (1970 = 100), 1970—2003.



Source: Kamps (2004).

While the increases in public capital stocks reported above seem large at the outset, one needs to recognise that they have occurred over more than three decades. Over such a long period of time average annual growth rate of no more than 2.3 percent is sufficient to double the initial stock.

The downtrend in public investment has not eroded public capital stocks.

Nevertheless, the important observation above is that public capital stocks have been growing considerably in real terms since the beginning of the 1980s in all but three sample countries (Denmark, the Netherlands, and the UK). This implies that the downtrend in the ratio of public investment to GDP has not been so steep as to cause public investment to fall below the level of depreciation; on the contrary, in most old EU member countries public investment continues to cover depreciation and allow for a further expansion of public capital stocks. The downtrend in investment flows has, however, led to a slowdown in the rate of growth of public capital stocks, but it has not reversed that growth.

Let us then compare the size of public capital stocks across countries. This is shown in Figure 8, converting the estimates in national currency units for the year 2000 into US dollars at purchasing power parity. Moreover, the stocks are expressed in per capita terms to abstract from the differences in country sizes.

Among the old EU member states, Austria has the largest public capital stock (USD 15,000 per capita). This is less than half of Japan and some 10 percent less than the US. At USD 6,600 per capita, Portugal's public capital stock is the smallest in the sample.

The size of public capital stocks varies strikingly between non-cohesion countries. Consider Austria, Belgium, Denmark, and the UK, all of which have had virtually flat public capital stocks since the mid-1980s. The Austrian public capital stock per capita is more than 50 percent larger than that in Belgium and the UK, with Denmark in the middle.

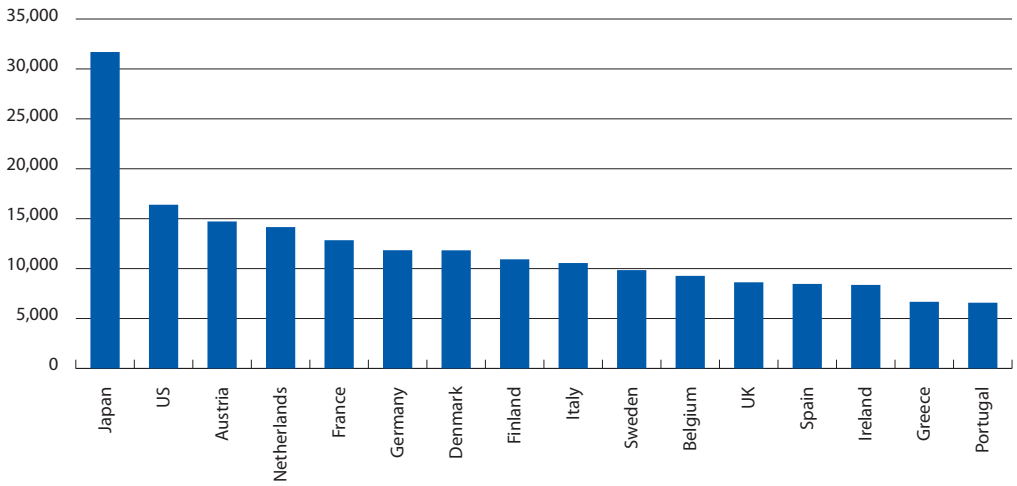
Some of the dispersion is likely to reflect statistical differences related to the institutional set-up for providing infrastructure and public services.[3] Furthermore, geography and demography can explain

3 An infrastructure or public service may be financed and provided by a public corporation in one country (thus showing up as private investment in national accounts statistics), while in another country it is financed directly from local budgets, for instance (thus showing up as public investment).

away some of the differences: it is more expensive to construct roads in mountains than in lowlands, and it is more expensive to provide public services in countries with relatively old populations.

The size of public capital stock varies a lot across countries.

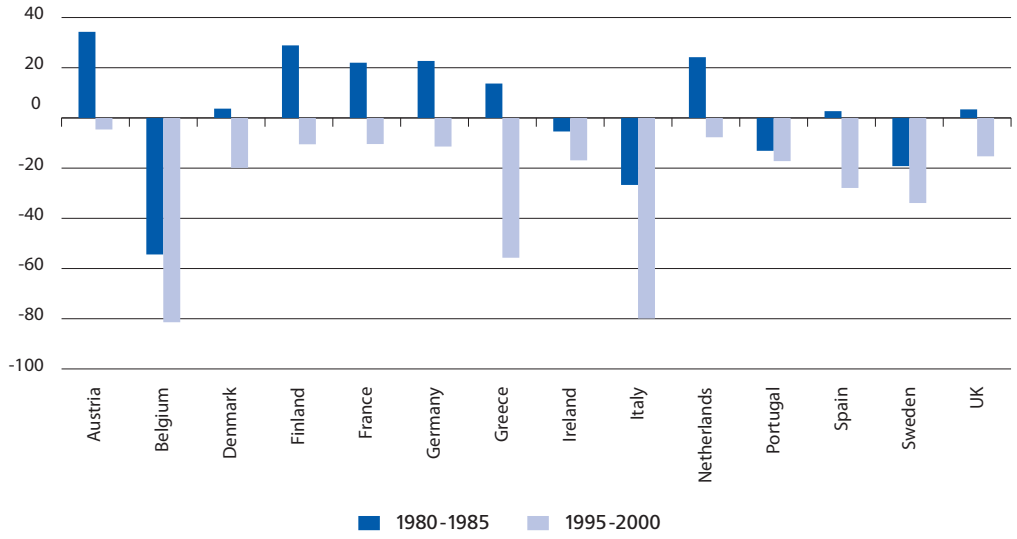
Figure 8. Public capital stock per capita at purchasing power parity in 2000 USD



Source: Kamps (2004).

Finally, the estimates for public capital stocks can be compared with the amount of public debt, thus providing a very rough measure of governments' net worth. This is done in Figure 9 below, with the following caveats. First, the ratio of public capital to GDP is expressed in real terms, so it is fully comparable with the debt-to-GDP ratio only under the assumption that the GDP deflator can also be used to deflate public investment. Second, public debt is measured in terms of gross outstanding debt, thus excluding any contingent liabilities.

Figure 9. Public capital less public debt (in % of GDP)



Sources: Kamps (2004), OECD.

Governments' net worth has deteriorated significantly.

With the caveats in mind, our narrow measure of net worth would seem to have deteriorated significantly in all pre-enlargement EU countries by the mid-1990s. Two decades ago, public debt was more than fully backed by public capital in the majority of countries. However, in the second half of the 1990s it was no longer the case in any single country, and the gap reached over 15 percentage points of GDP in 9 out of the 14 countries.

2.3 Determinants of public investment

The above description of the evolution of public investment flows and capital stocks raises three kinds of analytical questions. First, what created the patterns observed above, especially the dominant long-term downtrend in public investment? Second, what are the consequences of the observed public investment behaviour, especially in terms of economic growth? Third, in view of the significant cross-country differences in the size of public capital stocks, what is the economically optimal amount of public capital in a country and, similarly, do EU countries have too much or too little public capital? The second and third questions will be addressed in detail in Romp and de Haan as well as Kamps, respectively (this volume), so let us focus here on the underlying factors of the observed developments in public investment and capital stocks.

Several hypotheses have been put forward to explain the downtrend in public investment. They include, most notably, extensive privatisation and the drive toward a smaller economic role for the state in the past two to three decades; the emergence of alternative ways to finance infrastructure investment, such as public-private partnerships; the impact of EMU's fiscal rules; and a decreasing need for additional infrastructure.

Some of these hypotheses can be refuted up-front. Privatisation, for one, has not affected public investment—let alone accounted for its long-term downtrend—as any investment undertaken and financed by public enterprises is recorded in national accounts statistics as private investment. Only investment directly financed from the budget of the national or a subnational government qualifies as public. Consequently, privatisation *per se* would not affect public investment at all.[4] Furthermore, it is unlikely that any political drive toward a smaller economic role for the state has been very important; after all, if measured in terms of tax revenue to GDP ratios, it would seem that governments have not become smaller in recent decades. Finally, public-private partnerships remain a recent phenomenon and account for a visible share of infrastructure investment in only a few countries, as discussed in detail in Section 4.

Little rigorous analysis has been devoted to the testing of other hypotheses. De Haan *et al*. (1996) and Sturm (1998) focus on politico-economic factors affecting public investment, and they conclude that episodes of 'fiscal stringency' and frequent changes of government tend to be associated with lower public investment. In a more recent study Galí and Perotti (2003) focus on whether or not EMU has changed the cyclical behaviour of public investment, finding that the 'mildly procyclical' behaviour of public investment has not been significantly altered by EMU. Finally, European Commission (2003) and Turrini (2004) assess the role of a range of general economic and fiscal variables in determining public investment, finding among other things that EMU has had a positive direct impact on the level of public investment, but a negative indirect impact through a reduction in fiscal deficits and public debt.

While these studies cast some light on the determinants of public investment in Europe, they do not offer comprehensive and conclusive evidence of why public investment has trended down for so

4 However, privatisation may well affect other items in the budget, such as capital transfers.

long. Also, none of them addresses the hypothesis that public investment has been falling because of the decreasing need for additional public capital. While this hypothesis is intimately related to the question of optimal size of public capital stocks, it can be assessed alongside the other hypotheses even without first estimating the optimal size of public capital stocks.

Our analyses[5] (see Box 1 for details) aim to establish the macroeconomic determinants of public investment, with a special focus on its long-term trend, and to assess whether the level of public investment is influenced by the size of public capital stock. The statistically significant determinants of public investment include the level of national income, the budgetary situation, and fiscal sustainability considerations. Higher levels of GDP tend to be associated with higher public investment; episodes of discretionary fiscal consolidation depress public investment, as do high levels of public debt. Neither financing costs nor EMU have played a statistically significant role. As regards EMU, we cannot find any statistically significant impact on public investment either directly or indirectly through its fiscal rules on fiscal deficits and public debt. The only exception is possibly Finland, where there is some evidence that EMU may have had a negative impact on the level of public investment, albeit of minuscule magnitude. These findings appear consistent with the fact that fiscal consolidation efforts were initiated in many countries long before the Maastricht Treaty entered into force.

As regards the long-term downtrend in public investment, we find that drawn-out episodes of fiscal consolidation, ultimately aimed at addressing fiscal sustainability concerns, are the key factor in most sample countries. In other words, public investment is one of many fiscal policy tools used to curtail budgetary deficits and the accumulation of public debt. Notably, the use of public investment for such purposes appears unrelated to the fiscal rules embodied in EMU.

Finally, we find no evidence in support of the hypothesis that the level of public investment would depend on the size of the public capital stock. That is, we reject the view that public investment has slowed down due to a saturation of the demand for public capital (infrastructure). This result, in turn, appears consistent with the earlier observation that there is no relationship between the evolution of the public capital stock (i.e., the steepness of the downtrend in public investment) and its size.

In sum, our analyses suggest that none of the reviewed hypotheses about the decline in public investment, measured in relation to GDP, seems valid. Specifically, we find no evidence that the fiscal rules embodied in EMU would have accounted for the downtrend, nor do we find evidence that the demand for public capital would be saturated. Instead, drawn-out periods of fiscal consolidation, undertaken independently of the EMU fiscal rules, are the main reason why public investment has declined in non-cohesion countries. Whether this decline has had a detrimental impact on economic growth at the aggregate level will be examined in Romp and de Haan (this volume).

The long-term downtrend in public investment is related to drawn-out episodes of fiscal consolidation, unrelated to EMU.

5 The detailed results are reported in Välilä and Mehrotra (2005).

Box 1. Econometric analyses of the determinants of public investment

To test the hypotheses according to which EMU or the saturation of infrastructure demand has accounted for the long-term behaviour of public investment and, more broadly, to establish the macroeconomic determinants of public investment, the following econometric analyses were conducted.

Determinants: panel data analysis

To establish the macroeconomic determinants of public investment without distinguishing their short-term (cyclical) and long-term (trend) components, a panel data analysis was conducted estimating a model with real GDP; real long-term interest rates; public debt (in relation to trend GDP); net lending (or surplus) of the general government (in relation to trend GDP); and an EMU dummy as explanatory variables for public investment (in relation to trend GDP). The estimation was conducted separately for non-cohesion countries and cohesion countries. Also, single-equation estimation was performed for each non-cohesion country individually. The results of the panel data analysis suggest that GDP, public debt, and the fiscal position are significant determinants of public investment, with neither financing costs nor EMU playing a significant role. In addition to the EMU dummy, its interaction terms with the public debt and net lending variables were both statistically insignificant. The results do not differ significantly between cohesion and non-cohesion countries.

Long-term trend: cointegration analysis

To account for the long-term trend behaviour of public investment, a cointegration analysis was conducted for public investment, public debt, and net lending (all variables in real terms). GDP could not be included due to trend-stationarity. The cointegration analysis was conducted for eight non-cohesion countries with sufficient data (Austria, Finland, France, Germany, Italy, the Netherlands, Sweden, and the UK). No cointegrating relationship was found for Sweden. The results for the other countries suggest that drawn-out episodes of fiscal consolidation are the main factor associated with long-term trends in public investment. While the ultimate purpose of long-term fiscal consolidation is obviously to address debt sustainability concerns, a direct link between public debt and public investment was present only in Germany and the Netherlands.

Testing the saturation hypothesis: cross-section analysis

Cross-section analyses were conducted to test whether cross-country differences in the level of public investment are explained by cross-country differences in the level of GDP per capita; public debt, and the size of public capital stock. The analysis comprised all non-cohesion countries, and the years studied included 1980, 1990, and 2000. The results of this cross-section analysis reject the saturation hypothesis. In none of the years analysed was the level of public investment determined by the size of the public capital stock, regardless how the latter was measured (in relation to GDP or per capita). In 1980 and 1990, cross-country differences in both GDP and public debt were significant factors in explaining cross-country differences in the level of public investment; however, in 2000, such links could no longer be established.

3. Infrastructure in new member states

Turning to the new EU member states—notably the eight countries in Central and Eastern Europe (CEE)[6] —it is of interest to examine the implications of their economic transition and the associated fiscal consolidation on investment in infrastructure and public services. This is addressed in two steps below. First, we examine the evolution of public investment, especially with a view to the conflicting needs for additional infrastructure spending and fiscal consolidation to support macroeconomic stabilisation efforts. Second, we describe how total investment (public and private) in the transportation (including communication), health, and education sectors has evolved in the CEE countries during the past decade or so, and we contrast the findings to developments in the old member states (EU-15).

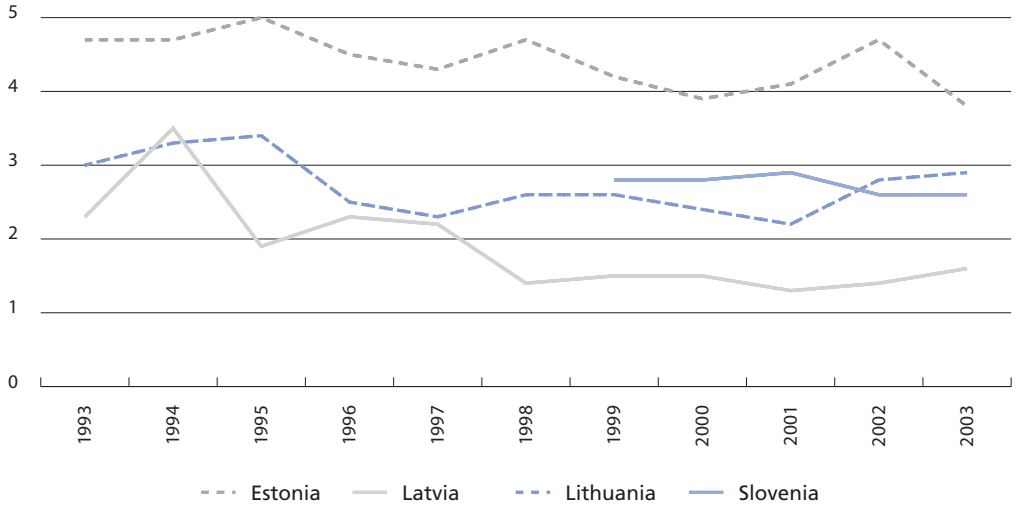
3.1 Public investment

Alongside other transition economies, the eight new EU member states were characterised by significant macroeconomic imbalances at the outset of their transition. Subsequent macroeconomic stabilisation efforts required prolonged periods of fiscal consolidation in many cases. How did the fiscal consolidation affect public investment in these countries?

Public investment in new member countries has remained stable in relation to GDP.

Measured in relation to their GDP, few CEE countries have experienced a steep decline in public investment, as shown in Figures 10 and 11. Only Latvia and perhaps the Slovak Republic have had a clear downtrend, while all other countries' public investment lacks an unambiguous trend one way or the other. However, there is a clear difference in terms of the volatility of the public investment-to-GDP ratio between the Czech Republic, Hungary and the Slovak Republic on the one hand, and the other five countries on the other hand, with the former group of three countries displaying significantly more ups and downs.

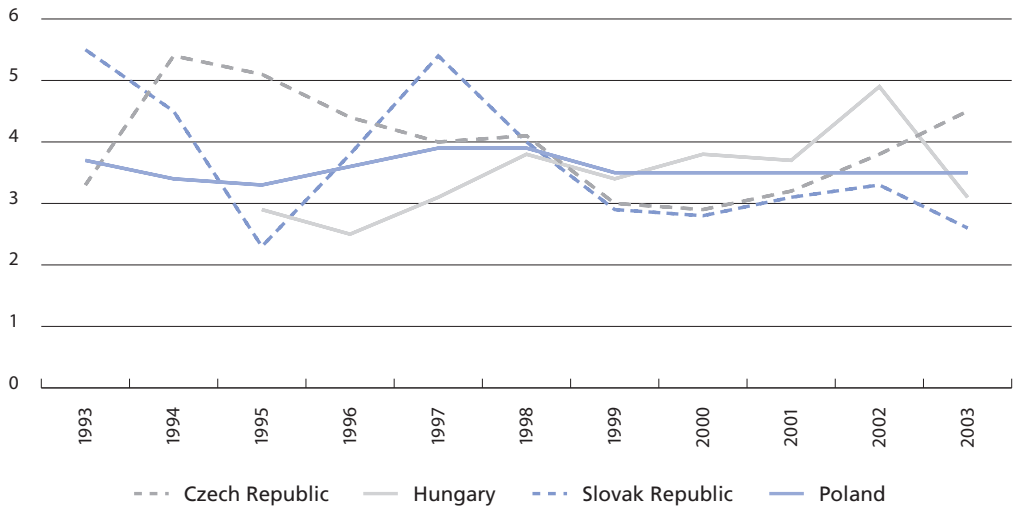
Figure 10. Gross fixed capital formation of the general government (in % of GDP).



Source: New Cronos.

6 These countries include the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, the Slovak republic, and Slovenia. The other two new member countries, Cyprus and Malta, are left outside this analysis both because their economies are structurally different from the eight listed above and also because data availability is inadequate for them.

Figure 11. Gross fixed capital formation of the general government (in % of GDP).

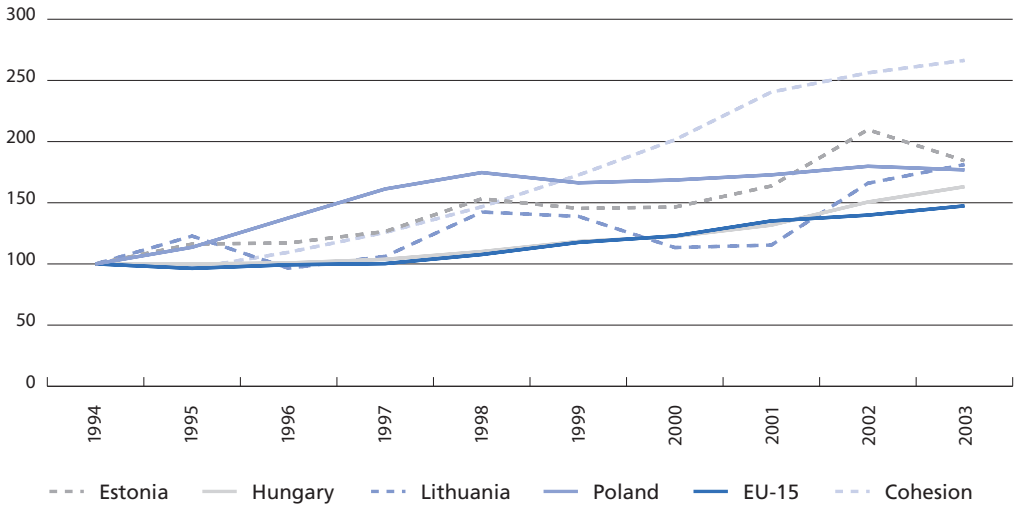


Source: New Cronos.

Deflated by PPI, public investment has grown in most CEE countries.

The figures depicted above also reflect volatility in GDP—which in the case of the CEE countries has been significant—so let us also consider the evolution of public investment using the index of producer prices as a deflator and, moreover, using 1994 as the base year. The results are shown in figures 12 and 13 below, and are also contrasted with the EU-15 and the cohesion countries. Taking the EU-15 average (unweighted) as a benchmark, real growth in public investment exceeded this benchmark in the cohesion countries as well as in Estonia, Lithuania, Poland, and Hungary. Public investment growth has been slower than the EU-15 average in Latvia, the Czech Republic and the Slovak Republic. In 2003, Latvia's public investment was at the same level as in 1994 in real terms; in the Czech Republic, it was 30 percent higher, and in the Slovak Republic some 20 percent lower.

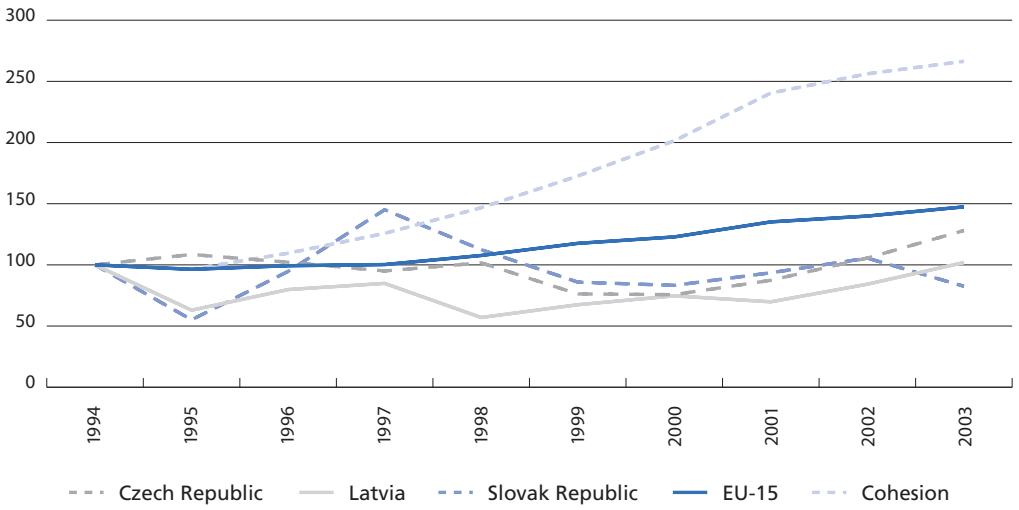
Figure 12. Real gross fixed capital formation of the general government (1994 = 100).



Source: New Cronos.

Note: Gross fixed capital formation of the general government deflated by the Producer Price Index.

Figure 13. Real gross fixed capital formation of the general government (1994 = 100).



Source: New Cronos.

Note: Gross fixed capital formation of the general government deflated by the Producer Price Index.

All in all, there has been no clear across-the-board decline in public investment in the new member countries. Measured in relation to GDP, public investment has not displayed any significant trends. In real terms, it has been growing in most new member countries at rates close to or above the EU-15. Exceptions include especially Latvia and the Slovak Republic, where public investment remains at or below its 1994 level.

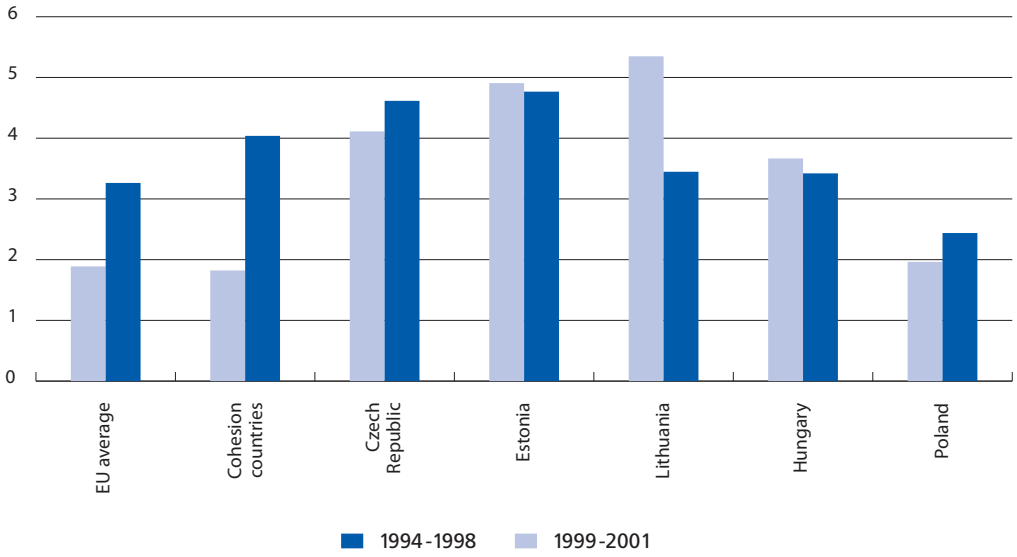
3.2 Sectoral investment

Figures 14-16 below depict total economy investment (public and private) in the transportation, health, and education sectors, respectively, for those CEE countries for which such data are available and also for the EU-15 (unweighted average) and the cohesion countries (unweighted average). The figures compare the time periods before and after 1999 in order to gauge differences, if any, between 'initial' and 'subsequent' transition—both concepts and time periods being naturally *ad hoc* in character. The time periods covered are short, so one should obviously avoid too far-reaching conclusions. Furthermore, it is important to recognise that the discussion concerns investment flows, telling us nothing about the size of capital stocks, as estimates for capital stocks are not available for the CEE countries.

Transportation sector investment has converged between old and new member countries.

As regards investment in the transportation sector (also including storage and communication in the absence of a further breakdown), Figure 14 suggests there has been some convergence between the five CEE countries and the EU-15. Apart from Poland, the sampled CEE countries had transportation investment levels around the mid-1990s twice as high as those in the EU-15 and cohesion countries. The significant increase in transportation investment in the EU-15—especially in the cohesion countries—combined with small increases or drops in the CEE countries, bridged the gap between investment levels; with the EU-15 average reaching 3.3 percent of GDP and the CEE sample average falling to 3.7 percent of GDP.

Figure 14. Gross fixed capital formation in transportation, storage, and communication (total economy), in % of GDP.

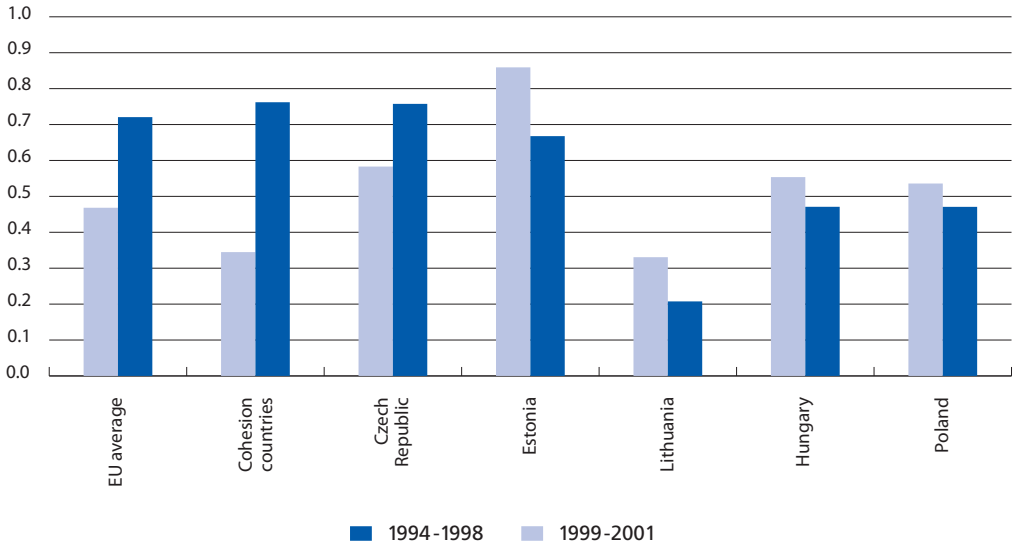


Source: New Cronos.

Health and education investment, too, has converged between old and new member countries.

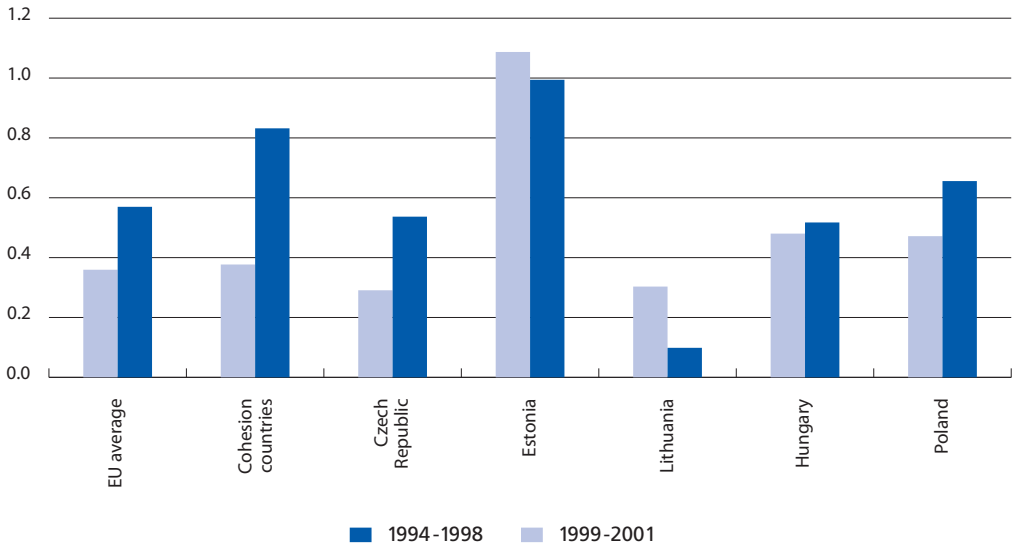
There has been convergence between the EU-15 and CEE countries also in the health (and social services) as well as education sectors, as shown in Figures 15 and 16. Total economy health sector investment in the CEE sample has fallen from 0.6 to 0.5 percent of GDP on average, while the EU-15 average has increased from 0.5 to 0.7 percent of GDP. Education sector investment, in turn, has increased in both groups, reaching 0.6 percent of GDP in the later sample period.

Figure 15. Gross fixed capital formation in health and social services (total economy), in % of GDP.



Source: New Cronos.

Figure 16. Gross fixed capital formation in education (total economy), in % of GDP.



Source: New Cronos.

Consequently, total economy investment in the sectors considered has converged between the CEE sample and the EU-15. Investment in all these sectors was significantly higher in the CEE countries around mid-1990s than in the EU-15 and cohesion countries. However, investment in these sectors increased significantly in the EU-15 in general and in the cohesion countries in particular, which – combined with a drop or only modest increase in the CEE countries –resulted in the convergence of investment levels in the two groups of countries.

The convergence of investment levels, however, tells us nothing about the relative sizes of infrastructure assets. In the absence of estimates for capital stocks, one can only observe that if differences in terms of assets' age and quality exist between the old and new EU member countries—as is commonly perceived to be the case—the new member countries would need higher flow investment than the EU-15 to close those gaps. Converging investment flows would only serve to sustain the gaps at their current levels.

The convergence of sectoral investment serves to sustain gaps in stocks of infrastructure assets between old and new member countries.

4. Significance of public-private partnerships

Section 2 above suggested that public investment has undergone a structural change in the old member states, where the downtrend in the ratio of public investment to GDP has slowed down or even brought the growth of public capital stocks to a halt. Another structural change—at least qualitatively speaking—in the financing of infrastructure and public services is the emergence of private finance through public-private partnerships (PPPs). The aim of this section is to examine their quantitative significance across countries, and to thereby assess to what extent they may or may not have offset the decline in public infrastructure finance.

Before embarking on the analysis, a caveat concerning data is required. PPPs are a relatively recent phenomenon, and only in the UK have they existed for more than a decade. This relative novelty is reflected in the data available on PPPs. Until early 2004, there were no European-wide guidelines regarding the treatment of PPPs in national accounts statistics (see Box 2). Consequently, countries have treated them in various ways, and apart from the UK where data on flow investment through PPPs are available, it has been difficult to assess their macroeconomic impact.

Box 2. Statistical treatment of public-private partnerships

National accounts statistics are based on the principle that any economic unit, including a PPP, can only be recorded in national accounts statistics in one institutional sector. That is, a PPP can only be a public sector entity or a private sector entity. Even when a PPP is a joint venture with shared equity participation by the public and private sector partners, it cannot be split between the institutional sectors.

Whether a PPP is included in the public or private sector affects the measured fiscal position. If the partnership is part of the public sector (general government), the financing and acquisition of the underlying assets appear on the public sector's balance sheet, directly affecting the measured fiscal deficit and public debt. If, on the other hand, the partnership is recorded as a private sector entity, it has only a limited short-term impact on the fiscal accounts. The financing and acquisition of the underlying assets appears on the private sector's balance sheet, with the public sector only incurring current expenditure for paying for the service itself once its supply starts.

To harmonise the varying recording practices across countries, Eurostat (2004) issued a decision on the treatment of public-private partnerships in the national accounts. It is based on an assessment of the distribution of risks between the partners, and it stipulates that a partnership should be recorded off the public sector's balance sheet if the private partner carries the construction risk and either the availability or the demand risk for the project in question. In other words, the private partner is to carry at least one of the major long-term risks, in addition to the shorter-term construction risk, for the partnership to be recorded as a private entity and thereby outside the public sector's deficit and debt calculation. Otherwise, the partnership is recorded on the public sector's balance sheet.

To get around this problem, the analysis below is based on micro-level data on individual projects structured as PPPs. The data come from the ProjectWare database (for non-UK countries) and other additional sources. This approach allows us to get an aggregate picture of the extent of PPPs, even in the absence of macro-level data. However, the project-level data generally only indicate the total value of each project (a stock variable), but gives no indication of the annual investment flows envisaged during the lifespan of the project.[7] This makes it difficult to assess exactly how much a particular project has contributed to aggregate investment, demand, and growth each year.

A comparison of PPPs and public investment ...

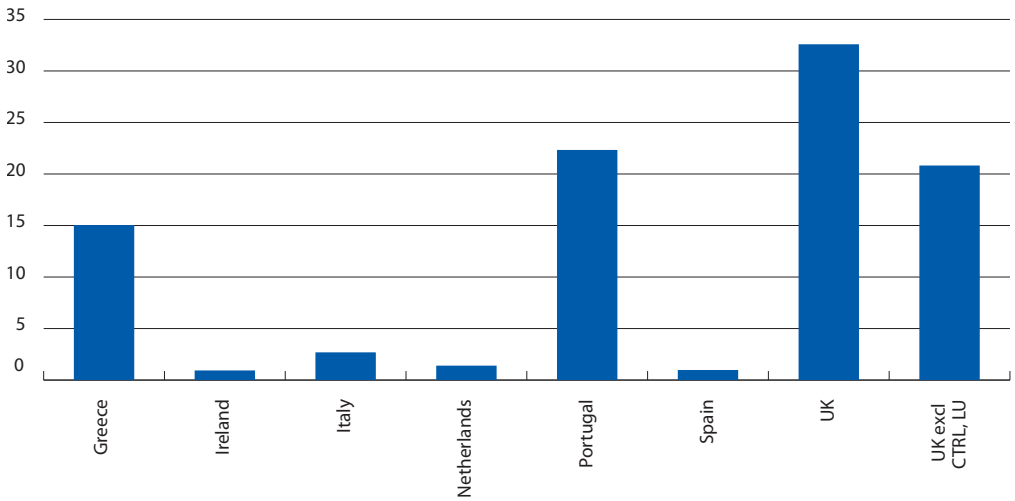
With these caveats in mind, let us turn to the assessment of the quantitative significance of PPPs. Figure 17 shows the value of signed PPP contracts (a stock variable) in relation to public investment (a flow variable) in those EU member countries where the ratio has been significant. PPPs are compared to public investment, rather than to another macroeconomic aggregate such as GDP, in order to highlight the role of PPPs as an alternative to public investment.

The only countries where PPPs appear to have some persistent systemic importance are Portugal and the UK.[8] In all other countries even the stock value of signed public-private partnership contracts is small compared to annual public investment flows, or they represent a small number of projects. The latter is notably the case in Greece (three projects).

7 In other words, the data only reports the financial commitment at project signature, which may differ significantly from actual investment flows that materialise over the life cycle of the project. This being the case, the analysis should be interpreted as telling us something about the upper bound of the size of PPPs.

8 The UK figures for 2002-03 include the London Underground project, which alone accounts for more than 70 percent of the total signed value of PPP projects in those years.

Figure 17. Signed value of PPP contracts, in % of public investment (average 1995-2003).

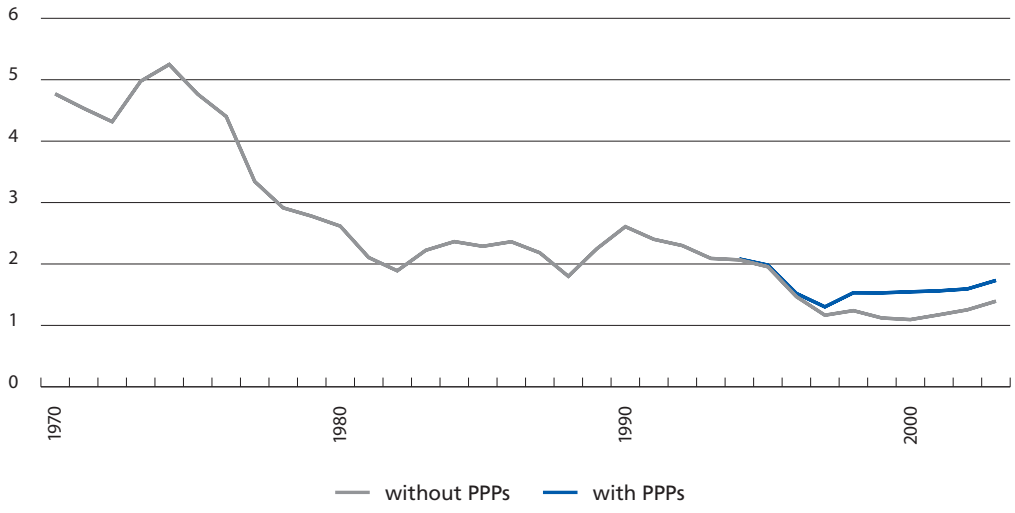


Sources: ProjectWare; HM Treasury; New Cronos; European PPP Report 2004; European Investment Fund.

... suggests that PPPs have systemic importance only in Portugal and the UK.

In the UK, investment through PPPs has equalled 15—25 percent of total public investment in the past five years (including the London Underground and Channel Tunnel Rail Link projects), as shown in Figure 18. While corresponding flow-to-flow comparison is not available for Portugal, one can use the stock figures depicted above to estimate their investment flow implications. Assuming that investment related to a project starts the year it is signed, and assuming that investment flows are equally distributed over four years, one can estimate that investment through PPPs in Portugal equalled 15—35 percent of total public investment during 1999-2003.[9]

Figure 18. Public investment with and without PPPs in the UK, in % of GDP



Sources: OECD, HM Treasury.

9 To the extent that PPP projects are recorded on the public sector's balance sheet in Portugal, the public investment figures already include investment through such PPPs. This being the case, the estimated ratios of investment through PPPs to public investment would belittle the relative importance of PPPs.

PPPs are, indeed, geographically concentrated in the UK and Portugal, even if measured in pure value terms. The UK alone accounts for almost 70 percent of the signed value of all PPP contracts within the EU. Of those 70 percent, 25 percentage points are accounted for by the London Underground project alone. Portugal, in turn, accounts for almost 10 percent of the signed value of all PPP contracts, leaving only 20 percent for the other countries.

The difference in sectoral distribution of PPPs in the UK and other countries (see the contribution by Riess for details) has led to a difference in the distribution of contract size between the UK and other countries. In the UK, the median contract is small, in the range of £10—50 million. Outside the UK, the median contract ranges within €100—500 million, as transportation sector projects in general and road projects in particular tend to be large in value. Put differently, in the UK as many as 80 percent of all PPP contracts are worth less than £50 million, while outside the UK, 70 percent are worth more than €100 million.

To sum up the findings about PPPs in financing infrastructure and public services, we have seen above that they have systemic significance from a quantitative perspective in the UK and Portugal, where annual investment through them corresponds to some 15—30 percent of public investment. In all other EU countries PPPs are few in number and relatively small in value.

5. Summary and conclusions

European infrastructure finance would seem to have changed fundamentally.

Taken at face value, it would seem that major structural changes have taken place in the financing and provision of infrastructure services in Europe. In most old EU member countries, public investment, measured in relation to GDP, has been on a trend decline since the 1970s. At the same time, the last 10 to 15 years have seen the emergence of privately financed and produced infrastructure services, starting in the UK in the early 1990s and spreading subsequently to continental Europe. In the new EU member countries in Central and Eastern Europe, the need for upgrading infrastructure assets in the context of their economic transition has coincided with the need for fiscal stringency, which could in principle have caused a detrimental squeeze on infrastructure investment.

While all of these developments are undoubtedly important qualitatively speaking, this paper has focussed on assessing their quantitative significance. In particular, we have studied the implications of falling public investment flows on the size of public capital stocks in the old EU member countries; the reasons behind the downtrend in public investment; the evolution of public and private infrastructure investment in the new member countries; and the extent to which public-private partnerships have replaced public investment in old and new EU member countries alike.

As regards public investment in the old member states of the EU, the stock of public capital has continued to grow in all but a few non-cohesion countries, despite the downtrend in public investment. In other words, the downtrend simply reflects the fact that public investment has been growing more slowly than GDP, but it has still grown. In most countries, this growth has been sufficiently high to cover depreciation and a further build-up of public capital stocks, albeit at a rate that has been slowing down.

While the downtrend in the public investment-to-GDP ratio should therefore not give rise to overblown concerns about the erosion of infrastructure, it is nevertheless important to know what caused that downtrend so as to grasp its economic consequences. Some of the most commonly expressed hypotheses in this regard have included privatisation and the drive toward a smaller economic role for the state; the emergence of alternative ways to finance infrastructure investment, such as PPPs; the impact of EMU's fiscal rules; and a decreasing need for additional infrastructure.

We refuted all of these hypotheses. A series of empirical analyses of the determinants of public investment in the pre-enlargement EU countries during 1970—2003 suggested that the level of national income and fiscal considerations, including budget deficits and public debt, are the key macroeconomic determinants of public investment. Neither the fiscal rules of EMU nor financing costs, nor the size of the public capital stock are significant factors explaining the behaviour of public investment. In explaining the long-term trend behaviour of public investment, drawn-out episodes of fiscal consolidation play the dominant role.

Turning to the new member countries of the EU, notably the eight CEE countries, the conclusion is that there has been no wholesale squeeze of infrastructure investment either economy-wide, or by the public sector. While total economy (public plus private) investment in the transportation, storage, and communication sectors has fallen somewhat in the five sampled CEE countries (in relation to GDP), it still remains above the average for the EU-15. Total economy investment in health and education has hardly changed, staying at approximately the same level as in EU-15. However, the stability of investment flows is rather uninformative per se, and in the absence of hard data on capital stocks it is hazardous to draw too far-reaching conclusions about their size and evolution.

Despite the protracted need for fiscal stringency in the course of transition, public investment, too, has escaped a downtrend. It has been volatile in a few CEE countries and has known episodes of fiscal contraction that have relied on cuts in public investment spending, but apart from Latvia and the Slovak Republic there has been no clear downtrend in public investment. This, in combination with the developments in selected infrastructure and public service sectors reported above, suggests that fiscal consolidation in the CEE countries has not led to any disproportionate squeeze on infrastructure investment. To accelerate their economic transition, it might have been desirable for infrastructure investment to grow faster in these countries, but at least it has not collapsed.

The change in the European infrastructure finance has been qualitatively more important than quantitatively.

Against the background of the slowdown in public capital accumulation in the old EU member countries and the stable though not necessarily optimal level of public investment in the new member countries, how much difference has private financing and provision of infrastructure services made? While the emergence of PPPs has undoubtedly brought about an important structural change qualitatively speaking, their quantitative importance remains modest. Only in the UK have PPPs sufficient depth and breadth to make a systemic difference. Portugal is the other country where PPPs are significant for the macroeconomy, but even there their application has been limited almost exclusively to the road sector. In all other EU countries, both old and new, private financing and provision of infrastructure remains limited in terms of value, number of projects, and sectoral distribution.

In conclusion, European roads are not on a steep downhill. While public investment, as a share of GDP, has been on a downtrend in the old EU member countries, and while PPPs have not become a significant source of infrastructure provision outside the UK and Portugal, infrastructure assets are nevertheless not being eroded, as evidenced by the continued growth of public capital stocks in most countries. Similarly in the new member countries: even though infrastructure investment could have grown faster, it has at least not collapsed.

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ABSTRACT

This paper provides an overview of both theoretical and empirical literature on the link between public investment (capital) and economic growth (national income). *We first survey the channels through which public capital can conceivably affect growth. We then turn to reviewing the existing empirical literature, and we conclude that although not all studies find a growth-enhancing effect of public capital, there is now more consensus than in the past that public capital furthers economic growth. However, the impact reported by recent studies is not as big as some earlier studies suggested. We conclude with an overview of what is known about the optimality of public capital stocks.*

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Public capital and economic growth: a critical survey

1. Introduction

Ward Romp

Jakob de Haan

Public capital, and especially infrastructure, is central to the activities of households and firms. According to the World Bank (1994), public capital represents the 'wheels' – if not the engine – of economic activity. Input-output tables show, for example, that telecommunications, electricity, and water are used in the production process of nearly every sector, while transport is an input for every commodity. However, the World Bank (1994, p. 19) also concludes that "infrastructure investment is not sufficient on its own to generate sustained increases in economic growth".

In recent years, a substantial research effort focused on estimating the contribution of public capital to the productivity of private factors of production and to economic growth. This research was motivated by two factors (Aschauer 2000). First, for many years the ratio of public capital investment to gross domestic product (GDP) declined in the OECD area. Figure 1 shows average government investment spending as a percentage of GDP for 22 OECD countries over the period 1963-2001 (left-hand side scale) and its standard deviation (right-hand side scale). The data relate to consolidated general government and are based on the Standardised National Accounts compiled and published by the OECD. Figure 1 shows that public capital spending as a share of GDP declined between 1971 and 1990 and slightly recovered afterwards.[1] Another conclusion that can be drawn from Figure 1 is that government investment spending varies considerably across countries. As Table A1 in the Annex shows, in 2000-01, government capital spending ranged between 1.6 percent of GDP in the United Kingdom and 6.9 percent in Japan.

Second, various authors claim that the decline in public non-military capital spending in the United States contributed to the productivity slowdown of the 1970s and 1980s. The early empirical work in this area, conducted largely at the national level, reported a significant and large impact of public capital on productivity. For instance, using a production-function approach for the US between 1949 and 1985, Aschauer (1989) found that a 10-percent rise in the public capital stock would raise multifactor productivity by almost 4 percent. Other studies using aggregate data also reported large effects of public capital spending. At a time when the slowdown in productivity growth was a widespread concern, these findings suggested that a decline in the rate of public capital accumulation was "a potential new culprit" (Munnell 1990a, p. 3).

However, several economists questioned the estimates of Aschauer on the grounds that they were implausibly high (see, for instance, Gramlich 1994). Furthermore, the early studies were fraught with methodological and econometric difficulties. Issues ranking high on the list of potential problems include reverse causation from productivity to public capital and a spurious correlation due to non-stationarity of the data.

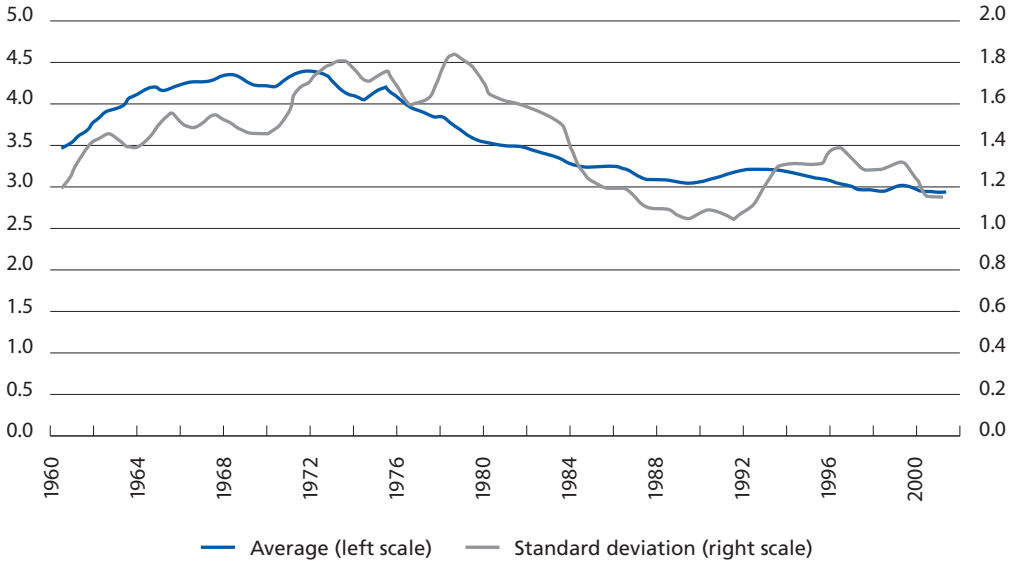
Perhaps the most important concern is the direction of causality between public capital and aggregate output: while public capital may affect productivity and output, economic growth can also shape the demand and supply of public capital services, which is likely to cause an upward bias

1 According to Oxley and Martin (1991, p. 161) the decline of government investment reflected "the political reality that it is easier to cut back or postpone investment spending than it is to cut current expenditures." De Haan *et al.* (1996) report evidence that in times of large fiscal contractions, government capital spending is indeed reduced more than other categories of government spending.

in the estimated returns to public capital if endogeneity is not addressed.[2] The recent literature on the economic growth effects of public capital suggests various ways of solving this problem.

Some of the earlier studies have also been criticised for not taking the stationarity of the data properly into account (see, for instance, Sturm and de Haan 1995). Unit root tests often suggest that output and public capital contain a unit root. However, it is well known that unit root tests have low power to discriminate between unit root and near unit root processes. This problem is especially pronounced for small samples. One way to alleviate the small-sample problem that has become popular in recent research is to make use of the cross-sectional dimension of the data and to apply panel data techniques.

Figure 1. Government investment in 22 OECD countries, 1961-2001, average (% GDP) and standard deviation



Source: Kamps (2004).

Early estimates for the impact of public capital on economic growth cover a wide range - making them almost useless from a policy perspective.

In some of the earlier studies unit roots in GDP and capital stock were removed by taking first differences. But this may ignore evidence of a long-run relationship in the data if the series are cointegrated (Munnell 1992). Indeed, various recent studies report evidence for such a cointegrating relationship between public capital (or infrastructure) and output. By exploiting this cointegrating relationship, these studies estimate the long-run effect of public capital (or infrastructure) on GDP per capita. However, the existence of a cointegrating relationship in itself does not necessarily imply that causality runs from infrastructure to long-run growth (Canning and Pedroni 1999).

In their survey of the earlier literature, Sturm *et al.* (1998) show that the literature contained a relatively wide range of estimates, with a marginal product of public capital that is much higher than that of private capital (e.g., Aschauer 1989), roughly equal to that of private capital (e.g., Munnell 1990b),

2 The problem not only occurs in studies like that of Aschauer (1989), but also in studies based on panel data, like Munnell (1990b), who found positive elasticities of output to public capital using panel data at the US state level. According to Holtz-Eakin (1994, p. 13), "[b]ecause more prosperous states are likely to spend more on public capital, there will be a positive correlation between the state-specific effects and public sector capital. This should not be confused, however, with the notion that greater public capital leads a state to be more productive".

well below that of private capital (e.g., Eberts 1986) and, in some cases, even negative (e.g., Hulten and Schwab 1991). The wide range of estimates makes the results of these older studies almost useless from a policy perspective.

However, more recent studies generally suggest that public capital may, under specific circumstances, raise income per capita. The purpose of this paper is to review this literature, thereby providing an update of the survey of Sturm *et al.* (1998). We focus on two important questions. First, does an increase in public capital spur economic growth? Second, to what extent do conclusions on the effect of more infrastructure change once it is taken into account that infrastructure construction diverts resources from other uses?

The remainder of the paper is organised as follows. Before we start reviewing the literature in some detail, Section 2 zooms in on our central questions and some other general considerations. Section 3 reviews studies belonging to the production-function approach in which the public capital stock is considered as an additional input factor in a production function. The next sections review three other approaches that have been applied to assess the impact of public capital on economic growth: the cost-function approach (Section 4), vector autoregressions (Section 5), and cross-country models (Section 6). In Section 7, we discuss the issue of the optimal capital stock. Section 8 offers some concluding comments.

2. Key questions concerning the link between public capital and economic growth

2.1 What do we want to know?

Empirical research on the relationship between public capital and growth should provide answers to two important questions. First, does an increase in the public capital stock foster economic growth?[3] Second, the policy relevant question for infrastructure investment is not what is the effect of extra infrastructure, holding everything else constant, but what is the net effect of more infrastructure given that infrastructure construction diverts resources from other uses (Canning and Pedroni 1999). In other words, is the existing stock of capital optimal?

In analysing the impact of infrastructure on income, different growth models have been used.

Of course, the possibility of a long-run impact of infrastructure on income very much depends on whether the data are generated by a neoclassical exogenous growth model or an endogenous growth model. In the exogenous growth model, in which technical progress drives long-run growth, shocks to the infrastructure stock can only have transitory effects. In an endogenous growth model, shocks to infrastructure can raise the steady-state income per capita. For instance, in the endogenous growth model with constant returns to aggregate capital of Canning and Pedroni (1999), positive shocks to infrastructure stocks raise long-run income per capita when the economy is below the efficient infrastructure level.

Apart from the growth model selected, the existing capital stock matters for the marginal productivity of public capital. This is clear from a network perspective: a new network may yield a one-time increase in productivity rather than a continuing path to prosperity (Fernald 1999). Furthermore, according to the law of diminishing returns, an increment to the public capital

3 The impact of public investment on economic growth is also relevant from a regional policy perspective. Governments can influence the rate at which regions accumulate various productive factors, particularly infrastructure. If these factors affect productivity and the location of mobile private production factors, there will be room for supply-side policies to influence the regional dispersion of income (de la Fuente and Vives 1995).

stock would have a small (large) output effect if the capital stock in the previous period was large (small). There is evidence that countries with a small public capital stock have the highest marginal productivity of public capital (Demetriades and Mamuneas 2000). Many empirical studies focus on the average, as opposed to the marginal, productivity of public capital and can therefore not be used to assess whether the existing capital stock is optimal. Kamps (this volume) adopts the methodology proposed by Aschauer (2000) in order to investigate whether there is a lack of public capital in European Union countries.

The impact of infrastructure on income is likely to depend on how additional public investment is financed.

In addressing the second question, it comes natural to take a government budget perspective and to look at how additional public investment is financed. The effect of public investment on growth is likely to depend on how the increased spending is financed. Increases in taxes are widely considered to reduce the rate of economic growth. An increase in public capital stimulates economic growth only if the productivity impact of public capital exceeds the adverse impact of higher taxes. If cutting other government spending finances an increase in capital spending, there is still no guarantee that growth will be enhanced. Hulten (1996) argues, for instance, that new infrastructure construction may have a perverse effect if it draws scarce government resources away from maintenance and operation of the existing capital stock.

Sections 3 to 6 will focus on the growth-enhancing effects of public capital spending while Section 7 will turn to the issue of the optimality of the public capital stock. But first we review why public capital may affect growth and how the stock of public capital can be measured.

2.2 Why does public capital matter for economic growth?

How does public capital affect economic growth? This issue has received only scant attention in the literature on the relationship between public capital spending and economic growth. As Holz-Eakin and Lovely (1996, p.106) note, "A somewhat surprising feature of this literature is the noticeable absence of formal economic models of the productivity effects of infrastructure".

In the earlier literature it is generally assumed that public capital forms an element in the aggregate production function. The stock of public capital (G_t) may enter the production function in two ways. First, it may enter the production function directly, as a third input. Second, it may influence multifactor productivity (A):

$$(1) \qquad Q_t = A(G_t)\, f\,(K_t, L_t, G_t)$$

where Q_t is real aggregate output of the private sector, L_t is (aggregate hours worked by) the labour force, and K_t is the aggregate non-residential stock of private fixed capital.

Although is it pretty common to model the growth effects on government capital by adding a third factor in the production function, on second thoughts it is questionable whether it makes much sense. After all, government roads as such do not produce anything. Implicitly, it is assumed that the services of public capital are a pure, non-rival public good, with services proportional to the stock of capital. However, as pointed out by the World Bank (1994), many infrastructure services are almost (although not perfectly) private goods. Private goods can be defined as both rival (i.e., consumption by one user reduces available supply to others) and excludable (i.e., a user can be prevented from consuming them).

Furthermore, public capital is treated symmetric to labour and private capital. According to Dugall *et al.* (1999), this goes against standard marginal productivity theory in assuming that a

market determined per unit cost of infrastructure is known to the individual firms and can be used in calculating total cost. However, since public investment is financed through general tax revenues or government debt, per unit costs of public capital are not market determined. Moreover, there is no guarantee that the total cost of infrastructure to the firm is related to the amount it uses. Aaron (1990) argues that this absence of a market test, coupled with possible government pricing inefficiencies, makes it impossible to assume that public capital as a factor input would be remunerated in line with its marginal product.

An alternative would be to incorporate public capital into the production function as part of the technological constraint that determines total factor productivity (see Dugall *et al.* 1999). Rather than acting as a discretionary factor input, public investment increases total productivity by lowering production costs. By increasing the technological index, additional public capital shifts the production function upward, and thus enhances the marginal products of the factor inputs. However, as pointed out by Sturm *et al.* (1998), in a Cobb-Douglas function (estimated in log levels) it does not make any difference whether public capital is treated as a third production factor or as influencing output through the factor representing technology. Both ways of modelling the influence of public capital yield similar equations to be estimated, so that the direct and indirect impact of public capital cannot be disentangled.

A better way to model the growth effect of public capital is by focusing explicitly on the services provided by the assets. For instance, Fernald (1999) assumes that for each industry *i*, production depends, apart from L_i and K_i, on transport services (T_i) produced within that particular sector. These services, in turn, depend upon the flow of services provided by the aggregated stock of government capital (roads) *G* and the stock of vehicles in the sector V_i. Output also depends on the Hicks-neutral level of technology U_i. This yields:

There are different ways of modelling the impact of public capital on growth. One of them focuses explicitly on the services provided by infrastructure assets.

$$(2) \qquad Q_i = U_i F^i (K_i, L_i, T_i(V_i, G))$$

This way of modelling the growth effects of public capital also makes it possible to introduce the effects of congestion and network externalities. Many services provided by the stock of public capital may be subject to congestion: more vehicles on a road lower the productivity of this road. More roads will reduce congestion, and therefore, improve productivity. Above a certain threshold, however, marginal increments will no longer affect output since they no longer cause a decline in congestion (Sanchez-Robles 1998). So congestion will give rise to non-linearities in the relationship between public capital and economic growth.

Public capital, notably infrastructure, is often distinguished from other types of capital because several market imperfections make accumulating and operating those assets prone to extensive government interventions and give rise to a special role for institutional characteristics. Economies of scale due to network externalities are a widely recognised imperfection in infrastructure services (World Bank 1994). An important characteristic of modern infrastructure is the supply of services through a networked delivery system designed to serve a multitude of users. This interconnectedness means that the benefits from investment at one point in the network will generally depend on capacities at other points. The network character also has important consequences for the relationship between public capital and economic growth. Once the basic parts of a network are established, opportunities for highly productive investment diminish. In line with this argument, Fernald (1999) reports that once the highway system in the US was roughly completed, after 1973, the hypothesis that the marginal productivity of roads is zero cannot be rejected. In other words, road building gave a boost to productivity growth in the years before 1973, but post-1973 investment did not yield the same benefits at the margin.

There is broad consensus that public infrastructure investment is an important aspect of a competitive location policy.

There is broad consensus among economists and politicians that public infrastructure investment is an important aspect of a competitive location policy.[4] Often it is argued that infrastructure lowers fixed costs, attracting companies and factors of production and, thereby, raising production (see e.g., Haugwout 2002 and Egger and Falkinger 2003). This does not necessarily imply higher growth at the national level, however, since production in other regions might go down. A common result in this type of models is that, under certain assumptions, the resulting stock of capital without coordination between regions or countries is sub-optimal. Since more infrastructure in the 'home' region attracts production factors out of the 'foreign' region, there is a risk of the infrastructure being too high in both regions compared to the situation in which they coordinate their actions. That said, spillover effects of infrastructure could lead to the opposite outcome: because the investing region only gets part of the benefits, both regions end up with too little infrastructure.

The size of spillover effects will depend on the size of the country or region concerned and its openness. One simple way to model these spillovers has been suggested by Cohen and Morrison Paul (2004). Their model for a cost function of the manufacturing sectors in US states not only includes the public capital stock in the state concerned, but also the public capital stock in geographically connected states.[5] In a similar way, the public capital stock of a neighbouring state (G_j) can be included in a production function, which gives:

$$Q_i = A_i K_i^{\alpha} L_i^{\beta} G_i^{\gamma} G_j^{\eta} \tag{3}$$

A somewhat different reason why public capital may affect economic growth is suggested by the new economic geography (e.g., Krugman 1991, Holtz-Eakin and Lovely 1996, Venables 1996, Fujita *et al.* 1999), which considers transport costs a central determinant of the location and scale of economic activity and of the pattern of trade. More transport infrastructure has a profound impact on the size of the market, so producers can cluster together in one central region. This clustering of activities leads to specialisation and economies of scale. In these theoretical models it is common to model transport costs as 'iceberg costs' (Krugman 1991, Bougheas *et al.* 1999). The producer of a particular good sells a certain quantity and during transport a fraction of the shipped quantity 'melts' away. The longer the distance, the larger the fraction that melts and the higher are the transport costs. The buyer has to pay for more goods than he actually receives. This bypasses the need to model the transport sector separately. However, the concept of iceberg costs implicitly assumes that the transport sector's production function is equal to the production function of transported products, which is a rather strong assumption.

De la Fuente and Vives (1996) offer another nice and simple way of modelling transport costs. They assume that final output Q in region i depends positively on intermediate production Y_i and negatively on transport costs C_i. Transport costs rise with the land area S of the region (as a proxy for distance) and decrease with the region's public capital stock G. De la Fuente and Vives further assume that Q_i exhibits constant returns to scale with respect to Y and C and that there is perfect private capital mobility across regions (so: $Q_i = Y_i^{c} G_i^{\gamma} S_i^{1-c-\gamma}$ where $c<1<c+\gamma$ so that transport costs increase with land area). For intermediate production they assume a Cobb-Douglas production function with private capital and labour. Substitution results in:

$$Q_i = A_i K_i^{\alpha} L_i^{\beta} G_i^{\gamma} S_i^{1-\alpha-\beta-\gamma} \tag{4}$$

4 The member countries of the European Union, for example, agreed upon a benchmark method to determine the competitiveness of the EU economies in which infrastructure plays a prominent role.

5 Also Holtz-Eakin and Schwartz (1995) consider interstate spillovers.

Even though the theoretical reasoning is different, the specification of de la Fuente and Vives is remarkably similar to equation (1), suggesting observational equivalence.

Finally, the effects of government capital spending on growth will also crucially depend on the extent to which private and public capital are substitutes. The literature generally assumes that public and private capital spending are complements. However, public investment might also be a substitute for private investment. For instance, firms might build a road on their own, thereby allowing the government to withhold from this investment.

2.3 How to define public capital?

Most people probably think about roads and other infrastructure – such as electricity generating plants and water and sewage systems – when they refer to the public capital stock. However, it is important to point out that this does not fully correspond to the concept of public sector investment expenditure as defined in national accounts statistics, which are typically used to construct data on public capital stock. First, only spending by various government sectors is included. That implies that spending by the private sector (including public utility firms concerned with electricity generation, gas distribution, and water supply) is excluded. Secondly, public investment includes spending on various items (public buildings and swimming pools, for instance), which may not add anything to the productive capacity of an economy.

Defining and measuring public capital is everything but straightforward.

In calculating the stock of public capital on the basis of investment flow data, researchers typically use the sum of past investments, adjusted for depreciation. In applying the so-called perpetual inventory method, the researcher has to make certain assumptions about the assets' lifespan and depreciation. Furthermore, one needs an initial level for the capital stock. Especially with infrastructure these assumptions are far from trivial. There is a huge variation in the economic lifespan of different types of infrastructure; the lifespan of a railroad bridge cannot be compared with the lifespan of an electricity transmission line. Usually, the initial stock is calculated by assuming that the real investments were constant at the level of the first observed investment level and that the capital stock was at its steady state at the start of the observed time series. With very low depreciation rates, the rate of convergence towards the steady-state level is very low, which requires a very long time of constant investment.

To calculate the public capital stock one needs long-term time-series data on public investment. Long-term national account time-series data on government investment spending are available for most OECD countries. However, for many developing countries the availability of long-term data is more of a problem, so that the public capital stock cannot be constructed for these countries. Therefore various studies use government investment or some physical measure of infrastructure instead of the government capital stock. A drawback of the use of government investment spending (as share of GDP) as regressor – which is a fairly common approach in studies based on cross-country growth regressions and in some vector autoregression studies – is the implicit assumption that the effects of public investment are independent of the level of the corresponding capital stock. Economic theory suggests that this assumption is dubious (Kamps 2004a). Also the use of some physical measure of infrastructure, like the number of kilometres of paved roads, has certain advantages and disadvantages (see below).

Pritchett (1996) points to some serious problems with using monetary values to calculate the stock of public capital. Prices for infrastructure capital vary widely across countries. Furthermore, the level of expenditure may say little about the efficiency in implementing the investment project. Especially if the investment project is carried out by the public sector, actual and economic costs

(defined as the minimum of possible costs given available technology) may deviate. So, monetary investment in infrastructure may be a poor guide to the amount of infrastructure capital produced because government investment may be very inefficient. According to Pritchett (1996), this is probably true, in particular, in developing countries. He estimates that only slightly more than half the money invested in investment projects will have a positive impact on the public capital stock.[6] This implies that public capital stock series constructed on the basis of investment series will tend to be overvalued.

Also from a network perspective, the monetary value as obtained by the perpetual inventory method of measuring capital stock is not appropriate. In particular, the internal composition of the stock matters since the marginal productivity of one link depends on the capacity and configuration of all links in the network. Using measures of the total stock may thus allow estimating the average marginal product of, say, roads in the past, but these estimates may not be appropriate for considering the marginal product of additional roads today (Fernald 1999).

Many recent studies have employed some physical measure of infrastructure in analysing its impact on economic growth.

Given these problems, many recent studies have employed some physical measure of infrastructure in analysing its impact on economic growth. Studies have used, in particular, the number of kilometres of paved roads, kilowatts of electricity generating capacity, and the number of telephones (see, for instance, Canning and Padroni 1999, Sanchez-Robles 2001, and Esfahani and Ramírez 2003).[7] As these physical measures are available for many countries for long time spans, they are ideal for estimating panel models. An advantage of using physical measures of infrastructure is that they do not rely on the concept of public investment as employed in the national accounts. For instance, by whom electricity is generated does not matter. However, simple physical measures do not correct for quality. Furthermore, some of the measures do not necessarily refer to (the results of) government spending.

Initially research on the impact of public capital on economic growth focused on the United States. Only few of the earlier studies investigated the productivity of government capital for a group of OECD countries (see, for instance, Ford and Poret 1991 and Evans and Karras 1994). These authors drew their data from the OECD that assembled capital stock series for 12 countries over the period 1970–1996, provided directly by the national authorities. However, these data were not internationally comparable because estimation methods differed widely across countries. This was one of the reasons why the OECD suspended the publication of the capital stock series after 1997. Recently, Kamps (2004a) has provided internationally comparable annual capital stock estimates for 22 OECD countries for the period 1960–2001.

Whereas Aschauer (1989) and many subsequent studies employed national data for the United States, other studies used regional data again with mixed findings (see Sturm *et al.* 1998). For the US, data at the state level are only available after 1970. Also for some European countries (Spain, France, Germany, and Italy) regional public capital stock data are available. Using regional data increases data variation, which may make the estimates more reliable.

To summarise, this section has set out the main research questions addressed by the literature on the relationship between public capital and growth, explained the meaning of public capital and its

6 How the project is financed may affect these figures; the stronger the incentives for the government to minimise costs, the higher the contribution to the public capital stock of an investment project.

7 Canning (1998) describes an annual database of physical infrastructure stocks for 152 countries for 1950-95. The database contains six measures: kilometers of roads, kilometers of paved roads, kilometers of railway lines, number of telephones, number of telephone main lines, and kilowatts of electricity generating capacity.

link to infrastructure, and sketched theoretical insights about the role of public capital for economic growth. The following sections elaborate on alternative empirical research strategies used to learn more about the role of public capital for economic growth

3. Production-function approach

Let us start with a description of the theoretical framework underlying the empirical studies that follow the production-function approach. In this type of analysis, the production function as given in equation (1) is generally written as an aggregated Cobb-Douglas production function in which the (monetary value of) the public capital stock (or the monetary value of the stock of infrastructure), G_t, is added as an additional input factor:

$$Q_t = A_t L_t^{\alpha} K_t^{\beta} G_t^{\gamma} \tag{5}$$

Writing equation (5) in per capita terms, taking the natural logarithm, and assuming constant returns to scale across all inputs ($\alpha+\beta+\gamma=1$), gives:

$$\ln \frac{Q_t}{L_t} = \ln A_t + \beta \ln \frac{K_t}{L_t} + \gamma \ln \frac{G_t}{L_t} \tag{6}$$

The parameter γ gives the elasticity of output with respect to infrastructure. To assess γ, a straightforward procedure is to estimate the production function in log-level or, alternatively, in first-difference or growth. This is indeed a common practice in the initial attempts at measuring the role of infrastructure. Aschauer (1989) introduces a constant and a trend variable as a proxy for $\ln A_t$. The capacity utilisation rate is added to control for the influence of the business cycle. Many subsequent papers have used this or a similar specification.[8] A drawback of the estimated production functions is that labour and capital are exogenous; it is implicitly assumed that both factors are paid according to their marginal productivity. Some studies have used a translog function, which is more general than the Cobb-Douglas function (e.g., Canning and Bennathan 2000, Albala-Bertrand and Mamatzakis 2004, Everaert and Heylen 2004, and Charlot and Schmitt 1999).

A major problem in estimating a production function is the potential for reverse causality.

A major problem in estimating a production function is the potential for reverse causation. If capital investments ($I_t = \Delta K_t$) depend on income (for example, through a savings function $S_t = sY_t$) we can write:

$$\Delta K_t = sY_t - dK_t \tag{7}$$

where Y_t is total income and d is the depreciation rate. This gives the steady-state relationship:

$$K_t = \frac{sY_t}{d} \tag{8}$$

This implies a feedback from income to the capital stock, making it difficult to identify the results of regressions such as equation (6) as a production-function relationship. There is also a potential feedback from income to the demand for infrastructure. Dealing with this problem has been at the heart of the controversy over the infrastructure–growth relationship.

8 Various authors have taken issue with the specification of Aschauer's model. Tatom (1991), for instance, uses another specification, with energy prices included and capacity utilisation entered multiplicatively to both the private and public capital stock, and finds little evidence that the public capital stock raises productivity. However, Duggal *et al.* (1999) criticise Tatom's approach arguing that the relative price of energy is a market cost factor that would be included in the firm's cost function and therefore also in the factor input demand functions.

Various approaches have been followed in the literature to deal with the problem of causality. One is to derive an appropriate test in such a way that it is clear how the causality runs. Other approaches that have been followed are: estimating panel models, estimating simultaneous-equation models, and using instrumental variables.

Fernald (1999) is a good example of the first approach. Using data for 29 sectors in the US economy for the years 1953-89, he finds that changes in road growth are associated with larger changes in productivity growth in industries that are more vehicle intensive. Fernald argues that if roads were endogenous, one would not expect any particular relationship between an industry's vehicle intensity and its relative productivity performance when road growth changes. According to Fernald, his results suggest that the massive road building in the US of the 1950s and 1960s offered a one-time boast to the level of productivity. His results have important policy implications: building an interstate highway network may be very productive, but building a second network may not.

Different empirical strategies have been employed to address the problem of reverse causality.

Another highly relevant study that belongs to the first approach is Canning and Pedroni (1999). They derive a reduced form of a model in which public and private capital are financed out of available savings so that there is a growth-maximising level of public capital. The nature of the long-run relationship and the short-run dynamics may vary across countries. Since they find that in each country the physical stock of infrastructure and per capita income are individually non-stationary but cointegrated, they can represent the series in the form of a dynamic error-correction model. By testing restrictions in this model, they can decide on the direction of causality. It appears that causality runs in both directions. For balanced panels of different countries they find that, on average, telephones and paved roads are supplied at around the growth-maximising level, but some countries have too few, others too many. Canning and Pedroni also find that long-run effects of investment in electricity generating capacity are positive in many countries, with negative effects being found in only a few.

Canning and Bennathan (2000) argue that a panel data approach may solve the causality problem. If the cointegrating equation (4) in a panel setting is a homogenous relationship, while equation (5) differs across countries, pooling the data across countries allows identifying the long-run production-function relationship. For two infrastructure stock variables (electricity generating capacity and the length of paved roads) they find higher rates of returns than for other types of capital, although there is some heterogeneity in their sample.

The most intuitive way to solve the causality problem is to develop a simultaneous-equations model, consisting of two equations. The first equation links production to public capital, the second equation links public capital to production. The main question is the functional form for the second equation. Demetriades and Mamuneas (2000) estimate a system of equations that is derived from an inter-temporal profit maximisation framework.[9] The estimates refer to a pooled model for 12 OECD countries over 1972-91. In the short run, the output effect of public capital varies from 0.36 percent in the UK to 2.06 percent in Norway. Also for the intermediate to long run, Demetriades and Mamuneas find diverging rates of return across countries. In their theoretical model, producers take at each point in time the publicly provided inputs as given and maximise the present value of future profits to determine their output, variable inputs, and quasi-fixed factor demands. In the first stage, firms decide on the optimal output and variable input demands, conditional on the private and public capital stocks. In the second stage, firms choose the optimal sequence of capital inputs. The authors claim that "by taking into account the optimising behaviour of firms we avoid

9 This paper belongs to the cost-function approach as discussed in the next section, but is taken up here since it is a good example of the simultaneous equations approach.

the simultaneity problem typical of the production-function approach" (pp. 688-89). Although this may be true for the private capital stock, it is not true for the public capital stock, which is simply assumed to be exogenous.

A better attempt to estimate a simultaneous-equations model is the cross-country growth study by Esfahani and Ramírez (2003), who develop a structural growth model that helps discern the reciprocal effects of infrastructure and the rest of the economy. The model specifies the ways in which country characteristics and policies enter the infrastructure–GDP interactions and lead to heterogeneity of outcomes across situations. The authors distinguish heterogeneity in the steady state and in the rate of convergence towards a steady state. They derive the infrastructure–output interactions as a recursive system that can be estimated simultaneously while solving the identification problem. The relationships between infrastructure and income are formulated as error-correction processes to account for the simultaneous effects of infrastructure innovations and responses to deviations from the steady state. Esfahani and Ramírez find that the contribution of infrastructure services to GDP is substantial and, in general, exceeds the cost of providing these services. The findings of Esfahani and Ramírez also shed light on the factors that shape a country's response to its infrastructure needs. An interesting result in this respect is that private ownership of infrastructure and government credibility (low risk of contract repudiation) matter for infrastructure growth, but mainly in speeding up the rate of adjustment rather than the steady-state infrastructure–income ratios

Empirical evidence suggests that political factors influence decisions on public infrastructure.

Cadot *et al.* (1999, 2002) also endogenise public capital formation by focusing on the decision-making process of public capital spending. The policy equation explicitly models the political decision process, including lobbying from different regions. Estimating the model for 21 regions in France over the period 1985-91, Cadot *et al.* (1999) find an elasticity of output with respect to public capital of 0.101 for France as a whole. This is very close to their simple single equation OLS estimates of 0.099, which suggests that the simultaneous-equation bias is only moderate. Interestingly, they find evidence that roads and railways are not built to reduce traffic jams: they are built essentially to get politicians re-elected. The number of large companies in a region seems to be an important determinant in explaining the total public investment allocated to that region.

Kemmerling and Stephan (2002) also focus on the political decision-making process on public investment. Using panel data for 87 German cities for the years 1980, 1986, and 1988 in a simultaneous-equations model, they estimate the relationship between infrastructure investments, investment grants, local manufacturing output, policy and lobbying variables. Their main findings are that political affiliation, measured by the coincidence of party colour between state and local government, is decisive in explaining the distribution of investment grants across cities, and that cities with 'marginal voters' neither spend more on public infrastructure nor receive more investment grants from higher-tier governments. Interestingly, they also conclude that efficiency considerations do not seem to determine the observed intergovernmental grant allocation across cities.[10]

Finally, some instrumental-variable approach has been used. Some of the older studies already applied the Generalized Method of Moments (GMM) estimator, which resembles an instrumental-variable procedure and therefore avoids the possible reverse-causation bias (Finn 1993, Ai and Cassou 1995).[11] A more recent study is Calderón and Servén (2002). They chose the instrumental-variable method

10 These studies point to an interesting area for future research, i.e., the explanation of differences in public investment spending across regions/countries and over time. So far, most of the theoretical literature assumes that decision-making on public capital spending is only based on efficiency considerations; the evidence presented by Cadot *et al.* (1999, 2002) and Kemmerling and Stephan (2002) suggest that this assumption is highly unrealistic.

11 Finn (1993) reports a significant elasticity of output with respect to the stock of public highways in the US of 0.16. The elasticity estimates of Ai and Cassou (1995) for the total stock of public capital in the US range between 0.15 and 0.26.

since this is easier to carry out than the simultaneous-equations model. These authors estimate a per capita Cobb-Douglas production function (in log-levels) for a panel of 101 countries for the period 1960–97. To solve the causality problem they use lagged values of the explanatory variables. Because of non-stationary data, they estimate a per capita Cobb-Douglas production function in first differences. Allowing for country-specific effects by a 'within' estimator they find an average elasticity of 0.16 for different types of infrastructure.

Table A2 of the Annex summarises key features and results of the papers reviewed above and other studies based on the production-function approach. The table is an update of Table 1 in the survey of Sturm *et al.* (1998) and has a similar set-up. The first column presents the study, the second to fourth columns show the aggregation level, the sample, the specification, and the way public capital has been measured, respectively, while the final column summarises the study's main findings. Although not all studies find a growth-enhancing impact of public capital, it is worth noting that – compared to the results surveyed by Sturm *et al.* (1998) – there is more consensus that public capital furthers economic growth. Another interesting result is that the impact as reported in recent studies is substantially less than suggested in earlier studies.

4. The cost-function approach

The cost-function approach avoids a shortcoming of the production-function approach, that is, the violation of marginal productivity theory.

A key shortcoming of the production-function approach is that it violates standard marginal productivity theory. Some studies have tried to get around the violation by focusing on the cost function and assuming that public capital is externally provided by the government as a free input. These studies specify a cost function for the private sector, with firms being assumed to aim at producing a given level of output at minimum private cost (C). Because the input prices (p_i) are exogenously determined, the instruments of the firm are the quantities of the private inputs (q_i). Alternatively, firms are assumed to maximise their profits (Π) given the output prices (p^Q) and input prices. In short, this can be presented as:

$$C(p_t^i, q_t^i, A_t, G_t) = \min \sum p_t^i q_t^i \quad \text{subject to } Q_t = f(q_t^i, A_t, G_t) \tag{9}$$

$$\Pi(p_t^Q, p_t^i, q_t^i, A_t, G_t) = \max p_t^Q Q_t - \sum_i p_t^i q_t^i \quad \text{subject to } Q_t = f(q_t^i, A_t, G_t) \tag{10}$$

When firms optimise, they take into account the environment in which they operate. One of these environmental variables is the state of technical knowledge (A). Another is the amount of public infrastructure capital available (G). The public capital stock enters the cost or profit function as an unpaid fixed input. Although the stock of infrastructure is considered externally given in the cost-function approach, each individual firm must still decide the amount it wants to use. This implies that a firm's use of the infrastructure is part of its optimisation problem, which, in turn, leads to the need of a demand function for infrastructure that must satisfy the conditions of standard marginal productivity theory (Duggal *et al.* 1999). To make this approach comparable with the production-function approach, various authors (e.g., Demetriades and Mamuneas 2004) use Hotelling's Lemma to obtain supply functions, which can be used to calculate output elasticities of public capital.

Sturm *et al.* (1998) note that many authors estimating a cost or profit function adjust the stock of public capital by an index, such as the capacity utilisation rate, to reflect its use by the private sector. Two reasons have been advocated for adjusting the stock of public capital. First, public capital is a collective input that a firm must share with the rest of the economy. However, since most types of public capital are subject to congestion, the amount of public capital that one firm may employ

will be less than the amount supplied. Moreover, the extent to which a capacity utilisation index measures congestion is dubious. Second, firms might have some control over the use of the existing public capital stock. For example, a firm may have no influence on the highways provided by the government, but can vary its use of existing highways by choosing routes. Therefore, there are significant swings in the intensity with which public capital is used.

As pointed out by Sturm *et al.* (1998), an important advantage of the cost-function approach is that it is less restrictive than the production-function approach. The use of a flexible functional form hardly enforces any restrictions on the production structure. For example, *a priori* restrictions placed on the substitutability of production factors, as in the production-function approach, do not apply. Apart from the focus on the direct effects in the production-function approach, public capital might also have indirect effects. Firms might adjust their demand for private inputs if public capital is a substitute or a complement to these other production factors. It seems very plausible that, for instance, a larger stock of infrastructure raises the quantity of private capital used and therefore indirectly raises production.

By using a flexible functional form, the influence of public capital through private inputs can be determined. A flexible function not only consists of many parameters that need to be estimated, but also of many second-order terms which are cross products of the inputs. These second-order variables can create multicollinearity problems. Therefore, the data set not only has to be relatively large, but must also contain enough variability so that multicollinearity can be dealt with. In other words, the most appealing feature of the cost-function approach also induces the biggest problem, i.e., the flexibility of the functional form requires considerable information to be included in the data. Most cost-function studies therefore use panel data, which combine a time dimension with either a regional dimension or a sectoral dimension.

The cost-function approach is more flexible than the production-function approach, but this flexibility requires that the data used must contain considerable information.

Interestingly, whereas Sturm *et al.* (1998) found that the cost-function approach was used in many studies they reviewed, we have found only a few studies that rest on the cost-function approach. Table A3 in the Annex summarises these studies, thereby updating Table 2 of Sturm *et al.* (1998). In what follows, we discuss two of these studies – probably the most interesting – in some detail.

Moreno *et al.* (2003) estimated cost functions for 12 manufacturing sectors in Spanish regions during the period 1980-91. They conclude that the average cost elasticity of public capital is only -0.022. However, there is wide variety in the effect across regions and industries; in fact, the range of values (-0.062 to 0.033) is wide enough to suggest the possibility that some regions and sectors did not benefit from public capital in some years. Costs in industries such as electric machinery, food and drinks, and textiles seem to have been most sensitive to a rise in infrastructure, while the opposite applies to sectors such as metallic and non-metallic minerals and chemistry. Among the regions with higher-than-average cost-infrastructure sensitivities are some of the least and most developed regions in Spain.

Cohen and Morrison Paul (2004) estimated a cost-function model by maximum likelihood techniques; they used data for 48 US states on prices and quantities of aggregate manufacturing output and inputs (specifically: capital, production and non-production labour, and materials) and on public highway infrastructure; their analysis covers the period 1982-96. They assume that manufacturing firms minimise short-run costs by choosing a combination of inputs for a given level of input prices, demand (output), and capacity (capital) and for given (external) technological and environmental conditions. The model also distinguishes between intra- and interstate effects of public infrastructure and accounts for interaction between the two. More specifically, for a given state, the model includes not only the public infrastructure of that state but also the

infrastructure in neighbouring states. Cohen and Morrison Paul find a significant contribution of public infrastructure investment to lowering manufacturing cost – an effect enhanced by spillover effects across states. If the stock of infrastructure of a neighbouring state is not included, as in most of this literature, the elasticity is around -0.15, which is comparable to those found in other studies. However, taking spillovers into account raises the average elasticity to –0.23. So recognising spatial linkages increases the estimated effects of intrastate infrastructure investment. They also find that the intra- and interstate effects of public capital increase over time.[12]

In conclusion, the results of the cost-function studies reviewed in this section are broadly in line with those of studies using the production-function approach: public capital reduces cost, but there is much heterogeneity across regions and/or industries.

5. Vector autoregression models

VAR models allow testing whether the causal relationship assumed by other approaches is valid or whether there are feedbacks from output to public capital.

Various recent studies use vector autoregression (VAR) models, which – unlike the production-function and cost-function approaches – do not impose causal links among the variables under investigation.[13] In a VAR model, all variables are jointly determined with no *a priori* assumptions about causality. So VAR models allow to test whether the causal relationship assumed in other approaches is valid or whether there are feedback effects from output to public capital. Furthermore, the VAR approach allows testing for indirect effects between the variables of the model. An unrestricted VAR model can be simply estimated by standard ordinary least squares (OLS). OLS will yield consistent and asymptotically normally distributed estimates, even if variables are integrated and possibly cointegrated (Sims *et al.* 1990).

However, even in a simple VAR model some choices with respect to the specification of the model have to be made, and all of them may affect the estimated responses and, thus, alter the conclusions about the link between public investment and economic growth. For instance, to simulate the cumulative response functions, restrictions with regard to ordering are imposed. These restrictions are rationalised by invoking assumptions of exogeneity and/or pre-determinedness, both of which can only be derived from theoretical considerations. In the absence of ordering assumptions, the non-structural VAR model can be used to characterise the data, but it cannot be used to spell out causation. Furthermore, Phillips (1998) shows that impulse responses and forecast error variance decompositions based on unrestricted VAR models are inconsistent at long-run horizons in the presence of non-stationary data. In contrast, Vector Error Correction Models (VECMs) yield consistent estimates of impulse responses and of forecast error decompositions if the number of cointegrating relationships is estimated consistently.

Table A4 in the Annex summarises VAR studies, updating Table 3 of Sturm *et al.* (1998). The following conclusions can be drawn. First, only few studies (for example, Mittnik and Neumann 2001 and Kamps 2004b) refer to a group of OECD countries; the rest focuses on one or two countries only. Second, most studies consist of a four-variables-VAR model with output, employment, private capital, and public capital. Third, there is a wide variety of model specifications. Some studies

12 The results of Cohen and Morrison Paul are also interesting from the viewpoint of the causality issue. To test for the potential endogeneity of infrastructure, they conducted a Hausman test and found that they could not reject the null hypothesis of infrastructure exogeneity, which they argue is "consistent with our *a priori* conjectures that manufacturing sector activity is unlikely to drive policy decisions across states (or even within a state), due to the small share of manufacturing production in states' overall GSP" (p. 555).

13 This section heavily draws on Kamps (2004b).

specify VAR models in first differences, without testing for cointegration, while others explicitly test for cointegration. Some studies specify VAR models in levels, following the argument of Sims *et al.* (1990) that OLS estimates of VAR coefficients are consistent even if the variables are non-stationary and possibly cointegrated. Fourth, in most studies, the long-run response of output to public capital shock is positive.[14] However, as pointed out by Kamps (2004b), most studies fail to provide any measure of uncertainty surrounding the impulse response estimates, making it is impossible to judge the statistical significance of the results. Kamps (2004b) employs bootstrapping techniques to provide confidence intervals. Fifth, many VAR studies report evidence for reverse causality, i.e., feedback from output to public capital. Finally, some studies (e.g., Everaert 2003) report that public capital has less impact on economic growth than reported by Aschauer (1989).

6. Cross-section studies

The study of economic growth and its policy implications has vigorously re-entered the research agenda.

Since the mid-1980s, the study of economic growth and its policy implications has vigorously re-entered the research agenda. Various studies tried to explain, theoretically and empirically, why differences in income over time and across countries did not disappear as the neoclassical models of growth predicted. The idea that emerged from this literature is that economic growth is endogenous. That is, economic growth is influenced by decisions of economic agents, and is not merely the outcome of an exogenous process. Endogenous growth theory assigns a central role to capital formation, where capital is not just confined to physical capital, but includes human capital, infrastructure and knowledge capital.

Initially, the econometric work on growth was dominated by cross-country regressions, in which growth of real per capita GDP is estimated by a catch-up variable, human capital, investment, and population factors like fertility. Some of these studies add government investment as an explanatory variable. The equations estimated in various studies can be summarised as follows:

$$\Delta \ln\left(\frac{Y}{L}\right)_{0,T} = \alpha + \beta\left(\frac{Y}{L}\right)_0 + \gamma\left(\frac{I^G}{Y}\right)_{0,T} + \delta \qquad (11)$$

where $(Y/L)_{0,T}$ is the average per capita GDP over a period $[0; T]$, $(Y/L)_0$ is the initial level of real per capita GDP, and $(I^G/Y)_{0,T}$ is the average rate of public investment (as percentage of GDP) over a period $[0; T]$. The variable δ captures a set of conditional variables such as private investment (as percentage of GDP) and primary and/or secondary enrolment (as a proxy for human capital). The parameter γ measures the effect of public investment on growth and is not the same as the marginal productivity of public capital.

Unfortunately, most empirical economic growth studies do not distinguish between public and private investment, instead relying on an aggregate measure of total investment. However, the services from public investment projects are likely to differ from those of private investment projects for a number of reasons, and this suggests that an aggregate investment measure is inappropriate (Milbourne *et al.* 2003). Table A5 in the Annex, which updates Table 4 in Sturm *et al.* (1998), provides a summary of cross-country growth models that include public investment.

14 Voss (2002) draws no conclusions regarding output effects of infrastructure as he focuses on possible 'crowding in' effects found by Aschauer (1989). These 'crowding in' effects enforce the positive effects of public investment, but using cointegrating techniques to correct for non-stationarity in the data, Voss does not find evidence for these effects in both the US and Canada. Only Ghali (1998) finds negative effects on growth, but these can easily be explained by the structure of the Tunisian economy where "highly subsidized and inefficient state owned enterprises [...] have often reduced the possibilities for private investment".

Probably the first study that included public capital in an empirical growth model is Easterly and Rebelo (1993), who ran pooled regressions (using decade averages for the 1960s, 1970s and 1980s) of per capita growth on (sectoral) public investment and conditional variables (see Sturm *et al.* 1998 for a summary). They found that the share of public investment in transport and communication infrastructure is correlated with growth. Likewise, Gwartney *et al.* (2004) find a significant positive effect of public investment, although its coefficient is always smaller than that of private investment.

However, other studies using the public investment share of GDP as regressor report different results. For instance, Sanchez-Robles (1998) finds a negative growth impact of infrastructure expenditure in a sample of 76 countries. Devarajan *et al.* (1996) report evidence for 43 developing countries, indicating that the share of total government expenditure (consumption plus investment) has no significant effect on economic growth. However, the authors find an important composition effect of government expenditure: increases in the share of consumption expenditure have a significant positive impact on economic growth whereas increases in the share of public investment expenditure have a significant negative effect. Devarajan *et al.* attribute their results to the fact that excessive amounts of transport and communication expenditures in those countries make them unproductive. Prichett (1996) suggested another explanation, arguing that public investment in developing countries is often used for unproductive projects. As a consequence, the share of public investment in GDP can be a poor measure of the actual increase in economically productive public capital.

Milbourne *et al.* (2003) report that for the steady-state model, there is no significant effect from public investment on the level of output per worker. Using standard ordinary least squares (OLS) methods for the transition model, they find that public investment has a significant effect on economic growth. However, when instrumental variables methods are used, the associated standard errors are much larger and the contribution of public investment is statistically insignificant.

The only study in this category that we are aware of that has used physical indicators of infrastructure instead of public investment spending is Sanchez-Robles (1998). When she includes indicators of physical units of infrastructure, she finds they are positively and significantly correlated with growth in a sample of 76 countries.

Cross-country growth regressions have largely ignored problems of model uncertainty, outliers, and parameter heterogeneity.

There are two important general problems in the cross-country growth regressions: one is model uncertainty and the other is outliers and parameter heterogeneity (Temple 2000 and Sturm and de Haan 2005). Model uncertainty has been discussed extensively in the literature. The main issue here is that several models may all seem reasonable given the data, but yield different conclusions about the parameters of interest. In these circumstances, presenting only the results of the model preferred by the author can be misleading (Temple 2000). Unfortunately, economic theory does not provide enough guidance to properly specify the empirical model. For instance, Sala-i-Martin (1997) identifies around 60 variables supposedly correlated with economic growth. The so-called extreme bound analysis (EBA) of Leamer (1983) and Levine and Renelt (1992) is therefore often used to examine how 'robust' the economic growth effect of a certain variable is. The key idea of EBA is to report an upper and lower bound for parameter estimates, thereby indicating the sensitivity to the choice of model specification. The upper and lower bounds are based on a set of regressions using different subsets of the set of explanatory variables. If the upper and lower bounds have a different sign, the relation is not robust.

The second problem – the role of outliers and parameter heterogeneity – has been largely ignored by the empirical growth literature. Although economists engaged in estimating cross-country growth models often test the residuals of their regressions for heteroskedasticity and structural

change, they hardly ever test for unusual observations. Still, their data sets may frequently contain unusual observations. In particular, less developed countries tend to have a lot of measurement error in national accounts and other data. This may have affected the conclusions of cross-country growth models.

Unfortunately, none of the studies reviewed in this section takes the issues of model uncertainty and outliers and parameter heterogeneity seriously into account, which casts considerable doubt on their findings. With this somewhat sober remark we finish the review of different empirical strategies to estimate the link between public capital and economic growth, and we move on to a brief discussion of what could constitute an optimal capital stock.

7. Optimal capital stock

In estimating the optimal stock of public capital, the assumption on the public good character of infrastructure is crucial. For pure public goods, one could define total marginal benefits of public capital as the sum of the shadow values over all firms plus the sum of corresponding marginal benefits over all final consumers, yielding what might be called the social or total marginal benefit of public capital. Alternatively, if there is no congestion in the consumption of public goods, the total marginal benefit could be the largest benefit accruing to any one or set of consumers and producers rather than the sum over all consumers and producers. The simplest rule to determine the optimal provision of public capital is to calculate the amount of infrastructure for which social marginal benefits just equal marginal costs.

Only a few studies have estimated the optimal stock of public capital and compared it with the actual stock of capital.

The difficulty in the empirical implementation of this rule lies in approximating the marginal costs of public capital. Sturm *et al.* (1998) found only a few studies that estimated the optimal amount of public capital and compared it with the actual stock of public capital. These studies use some measure for the cost of borrowing, such as the government bond yield, to approximate the marginal costs of public capital. Adopting this approach, Berndt and Hansson (1991), for instance, report excess public capital in the United States, which has declined over time, however. Alternatively, Conrad and Seitz (1994) interpret the case in which the social marginal benefit of public capital is greater than the price of private capital as a shortage of public capital, whereas the reverse indicates over-investment in public capital. These authors find that during 1961-79 the social marginal benefit of public capital in Germany was larger than the user cost of private capital, whereas in the 1980-88 period the opposite was true.

The more recent literature has taken other ways of modelling the optimal public capital stock. Canning and Pedroni (1999) develop a model in which public investment spending lowers investment in other types of capital because they all need to be financed out of savings. In this approach, there is a certain level of public capital that maximises economic growth, and if there is too much infrastructure, it diverts investment away from other productive uses to the point where income growth falls. In this setting, the effect of an increase in public investment on economic growth depends on the relative marginal productivity of private versus public capital. In other words, we need to know not only whether public capital is productive but also whether it is productive enough to boost economic growth. An interesting finding of this study is that the assumption of parameter homogeneity can clearly be rejected. In other words, there is much heterogeneity among countries with regard to the optimal level of public capital.

Aschauer (2000) has developed a nonlinear theoretical relationship between public capital and economic growth in order to obtain estimates of the growth-maximising ratio of public to private capital. Using data for 48 US states over the period 1970-90, Aschauer finds that for most of the

United States the actual levels of public capital were below the growth-maximising level. Kamps (this volume) is the first study to use the methodology of Aschauer (2000) in the European context to assess the gap between actual and optimal public capital stocks.

8. Concluding comments

There is currently more consensus than in the past that public capital positively affects economic growth, but the impact seems to be lower than previously thought.

Our review of recent studies that examine the relationship between public capital and economic growth suggests the following main results. First, although not all studies find a growth-enhancing effect of public capital, there is more consensus in the recent literature than in the older literature as summarised by Sturm *et al.* (1998). Second, according to most studies, the impact is much lower than found by Aschauer (1989), which is generally considered to be the starting point of this line of research. Third, many studies report that there is heterogeneity: the effect of public investment differs across countries, regions, and sectors. This is perhaps not a surprising result. After all, the effects of new investment spending will depend on the quantity and quality of the capital stock in place. In general, the larger the stock and the better its quality, the lower will be the impact of additions to this stock. The network character of public capital, notably infrastructure, causes non-linearities. The effect of new capital will crucially depend on the extent to which investment spending aims at alleviating bottlenecks in the existing network. Some studies also suggest that the effect of public investment spending may also depend on institutional and policy factors.

In concluding, we would like to mention a few issues we believe have not been well researched. First, attempts at explaining existing differences in capital stocks are only in their infancy. Second, only a few of the enormous bulk of studies on the output effects of infrastructure base their estimates on solid theoretical models. But to understand non-linearities and heterogeneity, we must understand the channels through which infrastructure affects economic growth. After all, government roads as such do not produce anything, and to include infrastructure or public capital as a separate input in a production function neglects the usually complex links. Third, most of the literature has focused on the importance of additional public investment spending, while maintenance of the existing stock is as important, if not more important, as additions to the stock. As pointed out by the World Bank (1994), inadequate maintenance imposes large and recurrent capital costs. For instance, paved roads will deteriorate fast without regular maintenance. Likewise, insufficient maintenance of a railroad system will lower its reliability, causing delays for travellers when parts of the system break down. Unfortunately, policymakers have a perverse incentive: given their higher visibility, new public investment projects are politically more attractive than economically crucial, but politically less rewarding spending on infrastructure maintenance.

Annex

Table A1. Public investment spending in 22 OECD countries as percentage of GDP, 1960-2001

Country:	1960-69	1970-79	1980-89	1990-99	2000-01
Australia	3.77	3.61	2.59	2.56	2.76
Austria	5.03	5.50	3.74	2.72	1.37
Belgium	2.06	3.44	3.15	1.74	1.62
Canada	3.40	2.65	2.36	2.59	2.48
Denmark	5.15	4.42	2.07	1.74	1.86
Finland	2.82	3.40	3.34	3.11	2.49
France	4.02[1]	3.55	2.97	3.23	2.99
Germany	4.05	3.86	2.61	2.37	1.95
Greece	3.90	3.34	2.78	3.12	3.86
Iceland	4.21	4.29	3.23	3.48	3.48
Ireland	5.65	6.24	4.56	2.29	3.01
Italy	3.31	2.88	3.15	2.58	2.39
Japan	7.50	9.32	7.47	7.68	6.91
Netherlands	6.21	4.88	3.18	2.96	3.27
New Zealand	5.65[2]	6.42	5.37	3.21	3.02
Norway	3.31	4.13	3.25	3.48	3.13
Portugal	2.37	2.08	2.60	3.69	3.92
Spain	2.82	2.54	2.98	3.86	3.14
Sweden	2.72	2.65	2.15	2.63	2.19
Switzerland	2.55	3.29	2.90	3.17	2.99
United Kingdom	3.96	3.52	1.85	1.99	1.57
United States	4.51	2.99	3.14	3.37	3.41

[1] 1963–1969, [2] 1962–1969

Source: Kamps (2004a)

Table A2. Studies using some kind of production-function approach

Study	Countries	Sample	Specification	Public capital variable	Conclusion
Albala-Bertrand & Mamatzakis (2004)	Chile	1960-98	Translog production function	Infrastructure capital stock (transportation, communication, general purpose)	Infrastructure capital growth appears to reduce productivity slightly up to 1971. From 1972 onwards, the reverse seems true
Albala-Bertrand (2004)	Chile and Mexico, regions	1950-2000	Gap approach using a Leontief production function (with private and public capital as inputs)	Infrastructure capital stock (transportation, communication, general purpose)	In Chile potential output is mostly constrained by shortages of 'normal' capital, in Mexico infrastructure is the binding factor
Bonaglia *et al.* (2000)	Italy, regions	1970-94	Cobb-Douglas production function with public capital as separate factor	Public capital stock	Elasticity is 0.05 (insignificant) for Italy as a whole, large variation between regions
Cadot *et al.* (1999)	France, regions	1985-91	Production function combined with policy equation for transport infrastructure	Infrastructure capital stock (transportation)	Elasticity is 0.10
Cadot *et al.* (2002)	France, regions	1985-92	Cobb-Douglas production function combined with policy equation for transport infrastructure	Infrastructure capital stock (transportation)	Elasticity is 0.08
Calderón & Servén (2002)	101 countries	1960-97	Cobb-Douglas production function with different types of infrastructure as separate factor	Infrastructure capital stock (transportation, communication, general purpose)	Elasticity is 0.16
Canning (1999)	57 countries	1960-90	Cobb-Douglas production function with different types of infrastructure as separate factor	Number of telephones, electricity generating capacity and kilometres of paved roads and railroads	Electricity and transportation routes have 'normal' capital's rate of return, telephone above normal
Canning and Pedroni (1999)	Panels of countries with different size	1950-92	Tests whether infrastructure has long-run effect on growth based on dynamic error-correction model	Number of telephones, electricity generating capacity and kilometres of paved roads and railroads	Evidence of long-run effects running from infrastructure to growth, but results differ across countries and type of infrastructure.
Canning & Bennathan (2000)	62 countries	1960-90	Cobb-Douglas and translog production function with different types of infrastructure as separate factor	Number of telephones, electricity generating capacity and kilometres of paved roads and railroads	On average, only the low- and middle-income countries benefit from more infrastructure
Charlot & Schmitt (1999)	France, regions	1982–93	Cobb-Douglas and translog production function with public capital as separate factor	Public capital stock	Elasticity is 0.3 (Cobb-Douglas), 0.4 (translog), but very sensitive to region and period
Delgado Rodriguez & Álvarez Ayuso (2000)	Spain, regions	1980-95	Cobb-Douglas	Productive capital stock (Factor model)	
Duggall *et al.* (1999)	USA, national	1960-89	Production function, technology index is non-linear function of infrastructure and time trend	Public capital stock	Elasticity for infrastructure is 0.27

Table A2. Studies using some kind of production-function approach (cont.)

Study	Countries	Sample	Specification	Public capital variable	Conclusion
Everaert & Heylen (2004)	Belgian regions	1965-96	Translog production function. Using a general equilibrium model, they analyse labour market effects of public investment. As a by-product they estimate the output elasticity.	Public investment	Elasticity is 0.31
Fernald (1999)	US, 29 sectors	1953-89	Sectoral productivity growth taking network approach.	Stock of roads	Roads contribute about 1.4 percent per year to growth before 1973 and about 0.4 percent thereafter.
Ferrara & Marcellino (2000)	Italy, total and per region	1970-94	Cobb-Douglas production function with physical capital stocks as separate input	Public capital stock	Italy: Negative output elasticity in the 1970s, positive in the 1980s and 1990s. Regions: Negative in 'North-West' and 'North-East', positive in 'Centre' and 'South'.
Holtz-Eakin & Schwartz (1995)	US states	1971-86	Neo-classical growth model that separates adjustment effects from steady state effects	Infrastructure capital (transportation and communications) and public capital stock	Infrastructure has a negligible effect on output nowadays
Kamps (2004a)	22 OECD countries	1960-2001	Aschauer (1989) model for individual countries and panel	Public capital stock	Elasticity is 0.22 in panel, but much higher in time-series models
Kemmerling & Stephan (2002)	87 large German cities	1980, 1986 and 1988	Cobb-Douglas production function combined with policy equation for transport infrastructure and investment function for private capital	Previous infrastructure capital stock and current infrastructure investments	Rate of return on infrastructure is 16%. Political colour is important determinant for receiving grants
Ligthart (2002)	Portugal	1965-95	Cobb-Douglas production function, with and without CRS	Public capital stock	Positive and significant output effects of public capital
Seung & Kraybill (2001)	Ohio	Calibrated on 1990	Computable general equilibrium model with congestion adjusted infrastructure as third factor in Cobb-Douglas production function	Public capital stock	Welfare effects of infrastructure are non-linear
Shioji (2001)	US states and Japanese regions	US: 1963-93, 5 year interval, Japan: 1955-95 (5 year interval)	Computable general equilibrium model with public capital in the technology term of a Cobb-Douglas production function	Public capital stock	Elasticity between 0.10 and 0.15
Stephan (2000)	West-German and French regions	Germany: 1970-95, France: 1978-92	Cobb-Douglas production function with public capital as separate factor and translog production function	Infrastructure capital stock (transportation)	Cobb Douglas gives elasticity of 0.11. Translog specification runs into multicolinearity problems.
Stephan (2003)	West-German regions (11)	1970-96	Cobb-Douglas production function with public capital as separate factor	Infrastructure capital (transportation and communications)	Elasticity between 0.38 (first differences) and 0.65 (log levels)
Vijverberg *et al.* (1997)	US, time series	1958-89	Cobb-Douglas and semi-translog	Net stock of non-military equipment in the hands of the government	Result are not reliable due to multicollinearity

Table A3. Studies using some kind of cost/profit-function approach

Study	Countries	Sample	Specification	Public capital variable	Conclusion
Bonaglia *et al.* (2000)	Italy, regions	1970-94	Cobb-Douglass variable cost function	Public capital stock	Inconclusive, no good measure of the social user cost of public capital available
Boscá *et al.* (2000)	Spain, regions	1980-93	Generalized Leontief	Infrastructure capital stock (transportation, communication, general purpose)	Elasticity is 0.08
Canaleta *et al.* (1998)	Spain, regions	1964-91	'Flexible' cost function	Infrastructure capital (transportation) and public capital stock	Public capital reduces private production costs, public and private capital factors are complementary; spillovers exist in Spain.
Cohen and Morrison Paul (2004)	US, states	1982-1996	Generalized Leontief	Public highway stock constructed using perpetual inventory method	Infrastructure investment reduces own costs and increases cost reducing effect of adjacent states
Demetriades & Mamuneas (2000)	12 OECD countries	1972-91	Quadratic cost function	Public capital stock	Output elasticity varies from 2.06 (Norway) to 0.36 (UK)
Ferrara & Marcellino (2000)	Italy, total and regions	1970-94	Cobb-Douglas and generalized Leontief with physical capital stocks as separate input	Public capital stock	Public capital is cost increasing over the whole sample (only cost decreasing in the 90's). Suggests over-investment in public capital
Mamatzakis (1999a)	Two digit Greek industries (20)	1959-90	Translog cost function	Infrastructure capital stock (transportation, communication)	Cost elasticity of public infrastructure ranges from 0.02% in food manufacturing to 0.78% in wood and cork
Moreno *et al.* (2003)	Spain, regions and sectors	1980–91	Translog cost function	Infrastructure capital stock (transportation, communication, general purpose)	Public and private investments increase efficiency.
Vijverberg *et al.* (1997)	US	1958-89	Translog cost and profit functions	Net stock of non-military equipment in the hands of the government	Both cost and profit function estimates suffer from multicollinearity

Table A4. Summary of VAR/VECM studies

Study	Countries	Sample [a)]	Specification	Variables [b)]	Public capital variable	Conclusion
Batina (1998)	US	1948-93 (A)	VAR and VECM	Y, L, different types of G and K	Public capital stock	Public capital has long-lasting effects on output and *vice versa*
Crowder and Himarios (1997)	US	1947-89 (A)	VECM	Y, K, G, L, E	Public capital stock	Public capital is at the margin slightly more productive or as productive as private capital
Everaert (2003)	Belgian regions	1953-96 (A)	VECM	Y, K, G	Public capital stock	Output elasticity of public capital is 0.14, which is only a fraction (0.4) of output elasticity of private capital
Flores de Frutos *et al.* (1998)	Spain	1964-92 (A)	VARMA (first differences log levels)	Y,K,G,L	Infrastructure capital (transport and communications)	Transitory increase of public capital growth implies a permanent increase of output, private capital and employment
Ghali (1998)	Tunesia	1963-93	VECM	Y, I^G, ,I^K	Public investment	Public investment has a negative effect on growth
Kamps (20004b)	22 OECD countries	1960-2001 (A)	VECM	Y, K, G, L	Public capital stock	For majority of countries there is a positive and significant effect on growth
Ligthart (2002)	Portugal	1965-95 (A)	VAR (log levels)	Y, K, G, L	Public capital stock	Positive output effects of public capital
Mamatzakis (1999b)	Greece	1959-93	VECM	Y, K, G, L	Public capital stock	Positive effect of public capital on productivity, no reverse effect
Mittnik & Neumann (2001)	Canada, France, UK, Japan, The Netherlands and Germany	Different periods per country (Q)	VECM	Y, I^G, C^G ,I^K	Public investment	Weak positive output effect of infrastructure, public investment induces private investment; no reverse causation from GDP to public capital
Pereira (2000)	US	1956-97 (A)	VAR, first differences log levels	Y, I^G, I^P, L	Public investment (different types)	Positive effect through crowding in of private investment
Pereira (2001)	US	1956-97 (A)	VAR, first differences log levels	Y, I^G, I^P, L	Public investment (different types)	All types of public investment are productive, but 'core infrastructure' displays the highest rate of return

Table A4. Summary of VAR/VECM studies (cont.)

Study	Countries	Sample [a]	Specification	Variables [b]	Public capital variable	Conclusion
Pereira & Andraz (2001)	US (sectoral and national)	1956-97 (A)	VAR, first differences log levels	Y, I^G, I^P, L	Public investment	Public investment positively affects private investment, employment and output
Pereira and Flores de Frutos (1999)	US	1956-89 (A)	VAR, first differences log levels	Y, K, G, L	Public capital stock	Public capital is productive, but substantially less than suggested by Aschauer (1989)
Pereira & Roca Sagales (1999)	Spain (regional and national)	1970-89 (A)	VAR, first differences log levels	Y, K, G, L	Infrastructure capital (transport and communications)	Positive and significant long-run effects on output, employment, and private capital
Pereira & Roca Sagales (2001)	Spain (sectoral and national)	1970-93 (A)	VAR, first differences log levels	Y, K, G, L	Infrastructure capital (transport and communications)	Positive and significant long-run effects on output, employment, and private capital
Pereira & Roca Sagales (2003)	Spain (regional and national)	1970-95 (A)	VAR, first differences log levels	Y, K, G, L	Infrastructure capital (transport and communications)	Positive and significant long-run effects on output, employment, and private capital
Sturm *et al.* (1999)	Netherlands	1853-1913	VAR, levels	Y, I^G, , I^K	Public investment	Positive and significant short-run effect; no long-run effect
Voss (2002)	US and Canada	US: 1947-88 (Q); Canada: 1947-96 (Q)	VAR (11 lags); first differences	Y, p^G, p^K, r, I^G/Q, I^K/Q	Public investment as share of output	Public investment tends to crowd out private investment

[a] A = annual, Q = Quarterly [b] Y = real GDP (output), K = private capital stock, G = public capital stock, L = number of employed persons, p^G = relative price of public investment, p^K = relative price of private investment, r = real interest rate, I^G = public investment, I^K = private investment, C^G = public consumption, E = energy price

Table A5. Summary of cross-section studies

Study	Countries	Sample	Government capital concept	Conclusion
Devarajan *et al.* (1996)	43 LDCs		Transportation and communication expenditure	Significant negative effect
Esfahani and Ramíres (2003)	75 countries	1965-95 (three decades)	Growth rates of telephones and power production per capita	Significant positive impact
Gwartney *et al.* (2004)	86 countries of which 66 LDCs	1980-2000	Public investment/GDP	Significant positive effect, but coefficient is less than coefficient of private investment
Milbourne, Otto and Voss (2003)	74 countries	1960-85	Public investment as share of GDP, total and disaggregated into 6 sectors	Not significantly different from zero in steady state model; in transition model with IV also not significantly different from zero
Sanchez-Robles (1998)	57 countries and 19 Latin American countries	1970-85 and 1980-92 for the large sample and 1970-85 for the smaller one	Index of physical units of infrastructure at beginning of the sample	Significant positive effect

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ABSTRACT

This paper investigates whether there is a lack of public capital in European Union countries. *The analysis builds on a new database providing internationally comparable capital stock estimates for 22 OECD countries, among these 14 EU countries, for the period 1960-2001. A simple model of endogenous growth is used in order to highlight the inherently nonlinear relationship between public capital and economic growth and to derive a measure of the growth-maximising public capital stock. Against this background, the empirical analysis provides estimates of the growth-maximising level of public capital for EU countries. The empirical results suggest that there currently is no lack of public capital in most 'old' EU countries.*

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Is there a lack of public capital in the European Union?

1. Introduction

Christophe Kamps

The decline in government investment in many OECD countries has alerted policy makers and researchers alike. In the Broad Economic Policy Guidelines, the European Commission (2001) recommended the member countries of the European Union to draw "an appropriate balance and sequencing […] between running down public debt, cutting taxes and financing public investment in key areas. To this end Member States should […] redirect public expenditures towards physical and human capital accumulation." Modigliani *et al.* (1998) and Blanchard and Giavazzi (2003), in turn, proposed to exclude net public investment from the measure of the budget deficit underlying the Stability and Growth Pact in order to prevent future fiscal consolidation in the euro area from negatively affecting public capital spending. Finally, at the end of the 1990s, the government in the United Kingdom launched a large multi-annual spending programme aimed at reversing the falling trend in the ratio of public capital spending to GDP, which had fallen to a very low level by 1997 (HM Treasury 2002).

Figure 1 displays the ratios of government investment and government capital stock to GDP for a group of 22 OECD countries and for a group of 14 European Union member states.[1] The left-hand panel of the figure shows that in both groups of countries government investment in relation to GDP declined strongly in the 1970s and remained roughly stable in the 1980s. In the 1990s, government investment in relation to GDP again fell in the EU, probably reflecting in part fiscal consolidation efforts in the run-up to Economic and Monetary Union, while in other OECD countries—especially in Japan—government investment grew. Based on the evolution of public investment, the right-hand panel of Figure 1 depicts the evolution of public capital stocks.

While government investment in relation to GDP has fallen strongly in OECD countries on average over the past three decades, the ratio of government capital to GDP has decreased only slightly. Had the high investment rates of the early 1970s been sustained, government capital to GDP ratios would even have increased. Whether the recent decline in the ratio of government capital to GDP is a reason for concern depends on the economic benefits and costs of additional government capital and is, thus, an empirical question.

The calls for an expansion of public capital spending, especially in European countries, share two important features: they build on the implicit assumptions that (i) public capital is productive and (ii) the decline in the ratios of public investment to GDP over the past decades has reduced the stock of public capital in many OECD countries below its optimal level.[2] The consensus view of the empirical literature is that public capital is indeed productive on average (see Romp and de Haan, this volume, for a survey). Yet, there is little empirical evidence showing that there is too little public capital in OECD countries. In fact, for most OECD countries no empirical evidence at all has been available so far. An exception is the study of Aschauer (2000), which suggests that the actual levels of public capital in the United States during the 1970s and 1980s were below the levels estimated to maximise economic growth.

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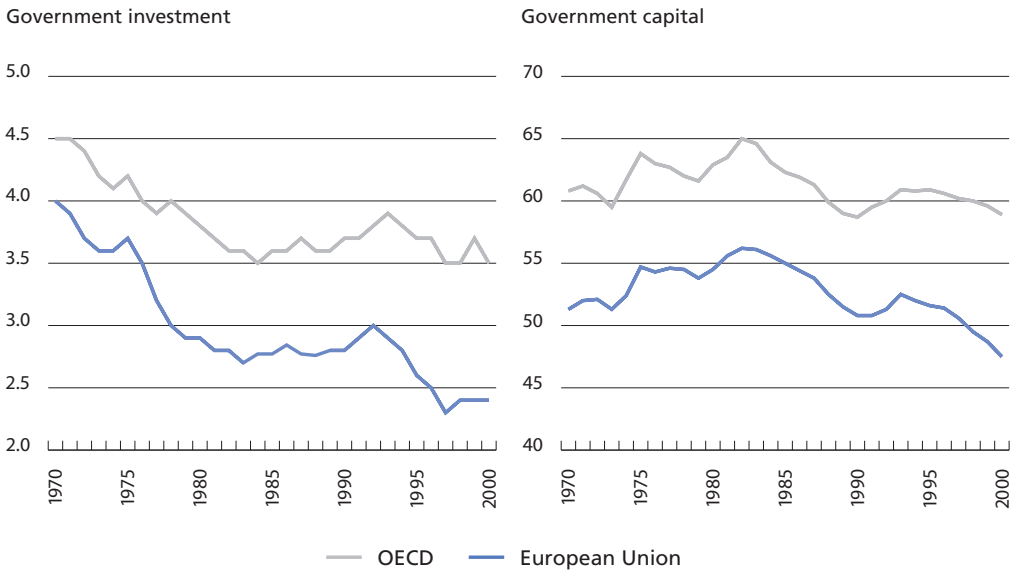
1 The European Union aggregate includes the following countries: Austria, Belgium, Denmark, France, Finland, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom. The OECD aggregate in addition includes also Australia, Canada, Iceland, Japan, New Zealand, Norway, Switzerland, and the United States. The data are drawn from Kamps (2005) who provides internationally comparable capital stock estimates for these 22 countries.

2 Insofar as an increase in government spending is asked for, these calls are also based on the assumption that the capital goods concerned—e.g., additions to the stock of infrastructure—should be provided by the government rather than by the private sector.

Figure 1. Real government gross fixed capital formation and real government net capital stock (in % of real GDP) in OECD and EU countries, 1970–2000



Sources: OECD, Kamps (2005).

This paper investigates whether there is a lack of public capital in EU countries.

This paper adopts Aschauer's methodology in order to investigate whether there is a lack of public capital in EU countries. The analysis builds on a new database providing internationally comparable capital stock estimates for 22 OECD countries, among these 14 EU countries, for the period 1960–2001. A simple model of endogenous growth is used to highlight the inherently nonlinear relationship between public capital and economic growth. Against this background, the empirical analysis attempts to estimate the growth-maximising level of public capital for EU countries as a group.

The remainder of the paper is organised as follows. Section 2 presents a simple model of endogenous growth with public capital, which is used to derive the empirical model for estimation purposes. Section 3 discusses the data used in the empirical analysis. Section 4 estimates the relationship between public capital and economic growth based on linear and nonlinear specifications. Section 5 combines the implications of the theoretical model and the regression results to construct an estimate of the growth-maximising ratio of public capital to GDP and then compares actual public capital stocks in individual EU member states with the level that maximises aggregate growth. Section 6 concludes by discussing limitations of the methodology employed in this study and suggests avenues for further research.

2. Modelling public capital and economic growth

This section outlines the most important features of a simple endogenous growth model that is often used in theoretical analyses of the growth effects of public capital, and which motivates our empirical analysis.

In endogenous growth models, government policy has the potential to affect the long-run growth rate of the economy. The growth effects of the flow of productive government spending are analysed, e.g., in Barro (1990), Barro and Sala-i-Martin (1992), and Greiner (1996). In Barro's (1990)

model the growth rate is maximised when the share of productive government spending in output is equal to the elasticity of output with respect to productive government spending. The growth effects of the stock of public capital are analysed, e.g., in Turnovsky (1997) and Aschauer (2000).

An important benefit of using Aschauer's (2000) endogenous growth model is that it allows to explicitly test for growth effects of public capital without—as is shown in Section 4.2—sacrificing potential level effects of public capital if growth effects turn out to be absent. That said, it does not seem to be central whether an endogenous or an exogenous growth model is used. Ultimately, what matters is to have a theoretical framework that allows the derivation of a measure of optimal fiscal policy. This can be done in both model frameworks. In his survey of the empirical growth literature, Temple (1999) concludes that while the debate whether policy affects the long-run growth rate or just the steady-state level of income is impossible to resolve, the distinction between exogenous and endogenous growth models is less important than it might seem because even if policy does not affect growth, it still has large effects on the level of income and welfare.

Policies that do not permanently raise the growth rate of an economy are nevertheless important if they raise the level of income.

The model used by Aschauer is outlined briefly in Box 1, and the Annex provides further details and variations to this model. Here we discuss the model's main economic implications, which follow from equations (B6) to (B9) in Box 1. First, as equation (B6) shows, the model implies a nonlinear relationship between public capital and economic growth. Second, equation (B7) gives the growth-maximising ratio of public to private capital, φ^{max}. It shows that the growth-maximising ratio of public to private capital is the larger, the larger the elasticity of output with respect to public capital, α_{kg}. Third, equation (B8) captures a straightforward economic feature of φ^{max}: the left-hand side of this equation is equal to the after-tax marginal product of private capital while the right-hand side shows the marginal product of public capital. Hence, the economic growth rate is maximised at the ratio of public to private capital for which the marginal product of public capital is equal to the after-tax marginal product of private capital. If the ratio of public to private capital is larger (smaller) than this value, the growth rate is smaller (larger) than the maximal growth rate. For completeness, we note that maximising economic growth also requires that the marginal product of public capital and the after-tax marginal product of private capital are equal to the interest rate, r, on government debt. Fourth, equation (B9) pictures a variation of the Aschauer model, with φ^* showing the welfare-maximising ratio of public to private capital. This ratio is smaller than the growth-maximising ratio for this model. The rationale for this result is the following: while growth maximisation implies that the marginal product of public capital should be equal to the after-tax marginal product of private capital, welfare maximisation implies that the marginal product of public capital should equal the gross marginal product of private capital. The distortions associated with taxation discourage the accumulation of private capital and, hence, the public to private capital ratio with growth maximisation is lower than in the first-best optimum. Maximising the growth rate involves a consumption loss and, thereby, lowers welfare.

In the empirical analysis, we follow Aschauer (2000) and focus on the growth-maximising public to private capital ratio. As it turns out, the main conclusions are unaffected by this choice. In Section 4, we present empirical results both for a linear specification of the relationship between public capital and economic growth and for a nonlinear specification, which is closely related to the growth model discussed above. The theoretical model implies that in the steady state the growth rate depends on the nonlinear term $\varphi^{\alpha_{kg}}/[1+(1-\alpha_{kg})\varphi]$, i.e, there is a nonlinear relationship between the growth rate on the one hand and the public to private capital ratio, φ, and the elasticity of output with respect to public capital, α_{kg}, on the other hand (see (A.10) in the Annex). This nonlinear term is used in the regressions reported in Section 4.2, providing estimates of the parameter α_{kg}, which is the determinant of both the growth-maximising and the welfare-maximising public to private capital ratio.

Box 1. Modelling the optimal stock of public capital

Consider an infinitively living representative agent who has preferences over consumption, c, as described by the lifetime utility function

(B1) $$V = \int_0^{\infty} (c^{1-\sigma} - 1)/(1-\sigma)\, e^{-\rho t}\, dt,$$

where σ is the inverse of the elasticity of intertemporal substitution and ρ is the rate of time preference. The agent has access to a Cobb-Douglas production function

(B2) $$y = k^{a_k} kg^{a_{kg}} \quad \text{with} \quad a_k + a_{kg} = 1,$$

where y is output, k is private capital, and kg is public capital. The production function specifies constant returns to scale in k and kg. For this reason, the economy is capable of endogenous growth. All variables are expressed in per worker terms. The model abstracts from a labour/leisure choice, from population growth, from technological progress, and from depreciation of both types of capital.

The government is assumed to maintain a particular ratio of public to private capital

(B3) $$\varphi = kg/k,$$

which requires that the public capital stock be increased in line with the steady-state growth rate of the economy, γ, so that $\dot{kg} = \gamma\, kg$. The government levies a tax on output at rate θ, which finances the interest payments on the stock of government debt, $r \cdot b$. The initial stock of public capital and public investment, instead, are financed by government debt. The flow government budget constraint is given by

(B4) $$\dot{b} = r \cdot b + \dot{kg} - \theta \cdot y.$$

3. On the data

This section describes the data used in the empirical analysis. It first looks in some detail at the measures of public and private capital used. It then provides information about the other variables needed for the empirical analysis, like output and employment. Until recently, no information about the magnitude of public and private capital stocks was available for most OECD countries. A recent study (Kamps 2005) provides new estimates of real government and private net capital stocks for 22 OECD countries for the period 1960–2001.

The capital stocks are estimated using the so-called perpetual inventory method, based on historical data on gross investment provided by the OECD. These investment series cover capital spending of the general government, i.e., the central, local, and regional governments, including social security funds.[3] The perpetual inventory method builds on a standard capital accumulation equation.

3 These investment series do not cover gross investment by public enterprises. General government and non-financial public enterprises together form the public sector. In this paper the terms 'government capital' and 'public capital' are used interchangeably and refer to the general government only.

The agent maximises lifetime utility subject to the resource constraint

(B5) $\dot{k}+\dot{b}+c=(1-\theta)y+r\cdot b$.

The steady state of this economy involves a common growth rate for consumption, output, public and private capital given by

(B6) $\gamma=\frac{1}{\sigma}[(1-\theta)(1-\alpha_{kg})\varphi^{\alpha_{kg}}-\rho]$,

where the first term in square brackets is the after-tax marginal product of private capital. Equation (B6) shows that the growth rate of the economy depends positively on the ratio of public to private capital, φ, and negatively on the tax rate, θ.

As shown in the Annex, the growth rate of per worker output is maximised at the value of the public to private capital ratio given by

(B7) $\varphi^{\max}=\alpha_{kg}/(1-\alpha_{kg})^2$.

As also shown in the Annex, the growth-maximising, steady-state public to private capital ratio is characterised by

(B8) $(1-\theta)(1-\alpha_{kg})\varphi^{\alpha_{kg}}=\alpha_{kg}\varphi^{\alpha_{kg}-1}$.

The economics of equation (B8) are discussed in the text.

The Annex also derives the welfare-maximising, as opposed to growth-maximising, steady-state growth path. Suffice to note here that the welfare-maximising public to private capital ratio, φ^*, is given by

(B9) $\varphi^*=\alpha_{kg}/(1-\alpha_{kg})$.

Bearing in mind that $\alpha_{kg}>0$, a comparison of (B9) with (B7) shows that $\varphi^*<\varphi^{\max}$.

Its implementation requires making assumptions on the magnitude of an initial-year capital stock, the depreciation method, and on the magnitude and time profile of the depreciation rate. Kamps (2005) estimates his capital stock series based on the geometric depreciation method and a time-varying depreciation rate; the initial-year problem is solved through the construction of an artificial investment series for the pre-1960 period (for details see Kamps 2005). Estimates are available for the government capital stock, the private non-residential capital stock, and for the private residential capital stock.[4]

Table 1 displays the ratios of public capital to GDP for three years of reference: 1980, 1990, and 2000. The average ratio for the 14 EU countries considered has declined by 7 percentage points over the period 1980–2000, reaching around 48 percent in 2000. Remarkably, there has been considerable convergence regarding public capital to GDP ratios in the EU—the standard deviation of the ratio of public capital to GDP has fallen from 17 percent in 1980 to less than 7 percent in 2000. Public capital as a share of GDP has declined in 9 countries since the early 1980s; it has increased slightly in 4 countries, while it has risen strongly in Greece, Portugal, and Spain.

4 The capital stock estimates are available on request to the author or at the website http://www.ifw-kiel.de/staff/kampsc.htm

Table 1. Government capital stock in % of GDP

Country	1980		1990		2000	
	Ratio	Rank	Ratio	Rank	Ratio	Rank
Austria	75.4	4	69.3	1	57.0	1
Belgium	40.2	12	45.5	11	37.9	13
Denmark	76.4	2	60.8	4	45.9	9
Finland	43.7	10	47.1	10	46.9	8
France	55.0	7	53.0	5	54.0	3
Germany	58.4	6	52.0	6	47.1	7
Greece	44.4	9	51.9	7	51.0	4
Ireland	75.9	3	66.8	3	35.2	14
Italy	44.7	8	49.0	8	47.9	6
Netherlands	80.2	1	68.9	2	56.4	2
Portugal	27.9	14	32.0	14	43.3	10
Spain	35.8	13	40.9	12	48.0	5
Sweden	42.1	11	40.2	13	42.0	11
United Kingdom	63.9	5	48.5	9	40.3	12
EU average	54.5		50.8		47.5	
Standard deviation	17.3		11.3		6.6	

Note: (1) 'Ratio' gives the ratio of the real government net capital stock and real GDP. (2) 'Rank' gives the ranking of the countries according to the size of their capital to GDP ratio. (3) The EU average is a weighted average, computed on the basis of 1995 GDP weights expressed in 1995 purchasing power parities, taken from OECD (2002). (4) Capital stock and GDP in 1995 prices.

Source: Kamps (2005) and own calculations.

According to the estimates, in 2000, Austria had the highest ratio of public capital to GDP among the EU countries considered in this paper, while Ireland had the lowest.[5] The large decline in the ratio of public capital to GDP in Ireland during the 1990s mirrors the strong fall in public investment as a share of GDP during this period. Notably, the Irish government views the lack of infrastructure as one of the major impediments to growth (see Fitz Gerald *et al.* 1999 for details).

The public capital stock (relative to GDP and private capital) has declined, on average, in pre-enlargement EU countries, as has its variation across countries.

Another way to compare the government capital stock across countries is to look at the ratio of government capital to private capital. This is especially interesting in view of the theoretical model presented in the previous section, which suggests a relationship between the growth rate, γ , and the government to private capital ratio, φ. Table 2 gives the ratio of public capital to private non-residential capital for the years 1980, 1990, and 2000. The average ratio for the 14 EU countries is somewhat smaller than the average ratio of public capital to GDP: it reached around 40 percent in 2000, down from about 44 percent in 1980. As in the case of public capital to GDP, there is evidence of substantial convergence, as the standard deviation of public to private capital has declined strongly over the period 1980–2000. As regards the ranking of countries, it is striking that Ireland ranks considerably higher than in Table 1. This discrepancy can be explained by the different dynamics of private capital and output in this country. Output growth in Ireland was very fast and much faster than growth in private capital in the 1990s, leading not only to a decreasing ratio of public capital to GDP but also to a decreasing ratio of private capital to GDP.

5 It has to be kept in mind, though, that the public capital to GDP ratio in Austria is much lower than that in Japan, which amounted to 117 percent in 2000 (see Kamps 2005).

Table 2. Government capital in % of private non-residential capital

Country	1980		1990		2000	
	Ratio	Rank	Ratio	Rank	Ratio	Rank
Austria	58.4	3	53.0	2	41.9	5
Belgium	33.0	12	38.8	10	30.5	13
Denmark	55.4	5	42.8	7	34.2	12
Finland	23.3	13	28.3	13	37.9	9
France	47.6	6	45.9	5	47.9	1
Germany	41.0	7	39.5	8	36.6	11
Greece	38.3	8	43.3	6	46.1	3
Ireland	65.6	1	60.2	1	44.4	4
Italy	33.6	11	38.9	9	39.1	7
Netherlands	57.0	4	52.3	3	47.8	2
Portugal	13.0	14	17.0	14	23.3	14
Spain	33.7	10	37.8	11	41.3	6
Sweden	36.5	9	34.9	12	37.9	8
United Kingdom	61.5	2	47.2	4	37.0	10
EU average	43.9		42.0		39.7	
Standard deviation	15.5		10.8		6.9	

Note: (1) 'Ratio' gives the ratio of the real government net capital stock and the real private non-residential net capital stock. (2) 'Rank' gives the ranking of countries. (3) For calculation of EU average, see Table 1. (4) Government and non-residential capital stocks in 1995 prices.

Source: Kamps (2005) and own calculations.

The ratio of public to private capital has fallen considerably in the average OECD country, contrasting with the experience in the EU.

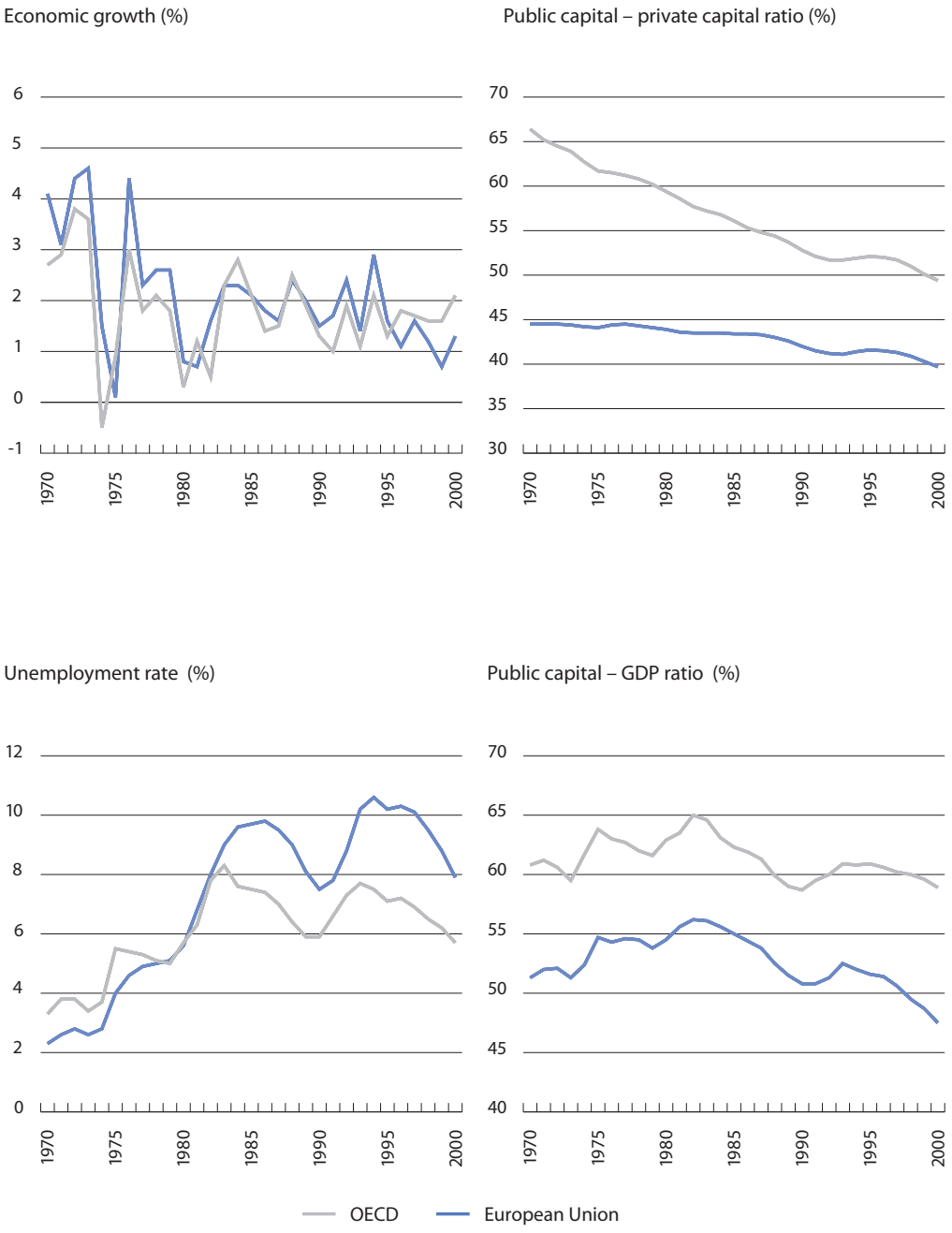
The empirical analysis in the next section is based on a panel consisting of the 22 OECD countries and on a smaller panel consisting of 14 EU countries. Figure 2 shows the dynamics of selected variables that will be used in the empirical analysis for both panels for the period 1970–2000. While the empirical analysis builds on data for the individual countries, this aggregate figure conveys some interesting summary findings. It shows that the volatility of growth rates has declined considerably in both panels. Another interesting finding is that in the EU, the ratio of public capital to private capital and the ratio of public capital to GDP have dropped only moderately over the sample period, whereas the same is not true for the ratio of public capital to private capital for the OECD aggregate. The constancy of the so-called great ratios (consumption-output, investment-output and capital-output ratios as well as labor and capital shares in income), which is an important concept in growth theory, can, thus, only be confirmed for the EU panel. The figure also shows the dynamics of the unemployment rate, which will be used as a variable controlling for business cycle effects in the empirical analysis.

Table 3 displays summary statistics for the variables used in the regressions in Section 4. The figures reported in the table are based on ten-year averages for the sub-periods 1971–1980, 1981–1990, and 1991–2000. The growth rate, y, is calculated as the average growth rate of real GDP per employed person, y, over a ten-year period.[6] The average growth rate for the period 1971–2000 amounted to 1.9 percent for the OECD panel and to 2.2 percent for the EU panel. The maximum growth rate in the sample was observed in Spain over the 1971–1980 period; the minimum growth rate for the OECD panel was observed in New Zealand over the 1971–1980 period; the minimum growth rate

6 More specifically: $y_{it} = 1/9[\log(y_{it+9}) - \log(y_{it})], \quad t = 1971, 1981, 1991, i = 1, ..., N.$

for the EU panel was observed in Greece over the 1981–1990 period. Finally, the table also reports descriptive statistics for the ten-year averages of the ratio of public to private capital, *kg/k*, and of the unemployment rate, *u*.

Figure 2. Selected macroeconomic variables for OECD Countries, 1970–2000



Note: (1) The OECD and EU aggregate comprises 22 and 14 countries, respectively (see Footnote 1); aggregate measures are computed on the basis of 1995 GDP weights expressed in 1995 purchasing power parities. (2) Economic growth reflects annual growth rates of real GDP per employed person. (3) Public capital-GDP ratio and public-private capital ratio as defined in Table 1 and 2, respectively.

Source: OECD Analytical Database (Version June 2002), OECD (2002), and Kamps (2005).

Table 3. Descriptive statistics of the variables employed (in %)

Variable	Region	Mean	Standard deviation	Minimum	Maximum
Economic growth rate γ	OECD	1.9	0.9	–0.2	3.9
	EU	2.2	0.8	0.3	3.9
Public-private capital ratio $\varphi = kg / k$	OECD	45.6	19.4	12.4	106.3
	EU	42.0	12.9	12.4	68.1
Unemployment rate u	OECD	6.0	3.6	0.2	16.2
	EU	7.0	3.6	1.3	16.2

Note: (1) Statistics are based on 10-year averages for individual countries for the respective variable; the sample period (1971–2000) is divided into three 10-year sub-periods (1971–1980, 1981–1990 and 1991–2000); the OECD panel comprises 22 countries and the EU panel comprises 14 countries. (2) Economic growth reflects real GDP growth per employed person. (3) Public-private capital ratio, φ , as defined in Table 2, with kg and k indicating public capital and private capital, respectively.

Source: Kamps (2005), OECD (2002), own calculations and estimations.

4. Empirical evidence on the growth effects of public capital

This section presents regression results on the relationship between public capital and economic growth. Regression results are presented both for a panel of 22 OECD countries and for a sub-panel of 14 EU countries. The regressions are based on averages of all variables for three ten-year periods in order to minimise the impact of the business cycle. This procedure considerably reduces the degrees of freedom in the regressions. However, regression results based on five-year averages—not reported here, but available on request—show that the regression results based on ten-year averages are robust. The regressions in Section 4.1 build on the assumption of a linear relationship between public capital and economic growth. As was shown in Section 2, economic theory suggests that the relationship between public capital and economic growth may be nonlinear. Section 4.2 takes this into account and presents regression results for a nonlinear specification of the empirical model.

4.1 Evidence from a linear model

The empirical approach in this section follows Aschauer (2000), who has carried out equivalent regressions for US states for the 1980s and 1990s. The first regression builds on the following specification:

$$(1) \qquad \gamma_{it} = a + b \cdot \varphi_{it} + c \cdot z_{it} + \varepsilon_{it}, \qquad t = 1971,\ 1981,\ 1991,\ i = 1, \ldots, N\ ,$$

where $\varphi \equiv kg / k$ is the public to private capital ratio (with kg and k indicating public capital and private capital, respectively), z is a vector of control variables such as the initial-year natural logarithm of real GDP per employed person, y, and the average unemployment rate, u. The number of cross sections, N, is 22 in the case of the OECD panel and 14 in the EU panel. Equation (1) does not allow for any individual-country effects by imposing a common constant and common slope coefficients. Table 4 presents regression results for this pooled specification for the two panels, with and without control variables. The results do not support the hypothesis that public capital affects economic growth. In neither specification is the coefficient of public capital statistically significant. As regards the effect of initial output per employed person, y, there is evidence for (conditional) convergence for the EU panel, but not for the larger OECD panel. Yet, the empirical fit of the pooled regressions is quite weak as witnessed by the low centred R^2. This might indicate that the assumed degree of homogeneity across countries is too high.

Empirical evidence from a linear growth model does not support the hypothesis that public capital affects economic growth.

Table 4. Government capital and economic growth – OLS regressions

	EU		OECD	
φ	0.001	0.004	−0.006	−0.006
y	—	−0.003**	—	−0.000
u	—	−0.000	—	−0.000
Constant	0.021***	0.014*	0.022***	0.022***
R^2	0.873	0.888	0.829	0.829
Centred R^2	0.000	0.042	0.018	0.020
N·T	42	42	66	66

Note: The independent variable is the economic growth rate *y*. *** (**, *) denotes statistical significance at the 1 (5, 10) percent level. For additional information see text.

The regressions in Table 5 therefore introduce separate fixed effects for the individual countries. In addition, these regressions include separate time effects for the decades of the 1970s (*d*70*s*) and 1980s (*d*80*s*). The regressions, thus, build on the following specification:

$$(2) \qquad y_{it} = a_{it} + b \cdot \varphi_{it} + c \cdot z_{it} + d \cdot d70s_{it} + e \cdot d80s_{it} + \varepsilon_{it}, \qquad t = 1971, 1981, 1991,\ i = 1, \ldots, N.$$

Table 5 shows that the main results remain unaffected. In the case of the EU panel, the coefficient of public capital is still statistically insignificant. In the case of the OECD panel, the coefficient of public capital is only (marginally) significant if all control variables are excluded from the regression (see the first OECD column in Table 5). However, initial-year output per employee, *y*, clearly should be included in the regressions (see the last column in Table 5).

Table 5. Government capital and economic growth – fixed effects regressions

	EU		OECD	
φ	−0.022	−0.018	−0.026*	−0.016
y	—	−0.031*	—	−0.053***
u	—	−0.000	—	−0.000
*d*70*s*	0.008***	0.014*	0.006***	−0.014**
*d*80*s*	0.001	−0.005	0.001	−0.008***
R^2	0.945	0.951	0.921	0.947
Centred R^2	0.565	0.615	0.546	0.696
N·T	42	42	66	66

Note: The independent variable is the economic growth rate *y*. *** (**, *) denotes statistical significance at the 1 (5, 10) percent level. The regressions allow both for individual country and time period effects. For additional information see text.

To sum up, the linear regression models do not support the hypothesis that public capital affects economic growth. This finding can be interpreted in two ways: (i) public capital and economic growth are unrelated in general, or (ii) public capital is at or near its optimal level so that the linear specification fails do detect any effect of public capital on economic growth even though there is a relationship—albeit a nonlinear one. The next section investigates which of these interpretations is supported by the data.

4.2 Evidence from a nonlinear model

This section builds on a regression equation of the form

$$(3) \qquad y_{it} = a_{it} + b \cdot f_{it} + c \cdot z_{it} + d \cdot d70s_{it} + e \cdot d80s_{it} + \varepsilon_{it}, \quad \text{with} \quad t = 1971, 1981, 1991 \quad \text{and} \quad i = 1, \ldots, N.$$

In (3), the variable f denotes the transformed ratio of public to private capital given by

$$(4) \qquad f_{it} = \frac{\varphi_{it}^{\alpha_{kg}}}{1 + (1 - \alpha_{kg})\varphi_{it}},$$

and z again represents control variables. The regressions allow for individual-country fixed effects as well as for decade effects. In the estimation of equation (3), we choose a different approach than Aschauer (2000). While his approach combines calibration and estimation by ordinary least squares (he estimates (3) for various assumed values of α_{kg}), we estimate the parameters of equation (3) by nonlinear least squares. This allows us to recover not only a point estimate for the elasticity of output with respect to public capital, α_{kg}, but also the standard error of this coefficient. This, in turn, allows us to calculate a point estimate and a confidence interval for the growth-maximising ratio of public to private capital.

Empirical evidence from a nonlinear growth model suggests a positive impact of public capital on economic growth for the panel of EU countries but not for the OECD panel.

Table 6 summarises the results of the nonlinear-least-squares regressions. It shows that the elasticity of output with respect to public capital, α_{kg}, is highly statistically significant across all specifications. It also suggests that initial-year output per employed person, y, has to be included as control variable. According to these estimates, α_{kg} varies between 0.21 for the EU panel and 0.20 for the OECD panel. These results are very similar to those obtained by Kamps (2005), who reported an elasticity of 0.22 for a panel of OECD countries based on the production function approach. The results on the growth effects of public capital are less conclusive. The coefficient of f is positive and statistically significant for the EU panel for the specification including control variables (see the second EU column in Table 6), thus indicating that public to private capital ratios are lower than their growth-maximising levels in the EU. However, this coefficient is insignificant in the case of the OECD panel. That said, the significant result for the elasticity of output with respect to public capital suggests that public capital has important effects on the level of output, if not on its growth rate.

Table 6. Government capital and economic growth – nonlinear least squares

	EU		OECD	
α_{kg}	0.201***	0.208***	0.157**	0.202***
f	0.383	0.546**	0.188	0.280
y	—	−0.041**	—	−0.055***
u	—	−0.000	—	−0.000
$d70s$	0.011***	−0.003	0.007**	−0.012*
$d80s$	0.002	−0.004	0.001	−0.007***
R^2	0.948	0.957	0.922	0.949
Centred R^2	0.591	0.658	0.551	0.708
$N{\cdot}T$	42	42	66	66

Note: The independent variable is the economic growth rate y. *** (**, *) denotes statistical significance at the 1 (5, 10) percent level. The regressions allow both for individual country and time period effects. For additional information see text.

Using the results reported in Table 6 and insights from Box 1, we can provide estimates for the optimal stock of public capital. Box 2 sets out details of the underlying calculations. We report here the main findings for the panel of EU countries. First, the point estimate for the growth-maximising ratio of public to private capital is about 34 percent. The associated 95-percent confidence interval for this estimate ranges from around 25 to 42 percent.

Box 2. Estimating the optimal stock of public capital

In this Box, we use the results reported in Table 6 and insights from Box 1 to provide estimates for the optimal stock of public capital. We limit ourselves to the panel of EU countries.

First, using equation (B7) and the estimate for the elasticity of output with respect to public capital, a_{kg}, the point estimate for the growth-maximising public to private capital ratio can be calculated as

(B10) $$\hat{\varphi}^{\max} = \frac{\hat{a}_{kg}}{(1-\hat{a}_{kg})^2} = \frac{0.21}{0.79^2} = 0.3365.$$

The growth-maximising ratio of public to private capital for the EU panel is, thus, estimated to amount to 33.7 percent.

Second, using the production function together with the assumption of constant returns to scale across the capital stocks (equation (B2)), the ratio of public capital to GDP can be expressed as $kg/y = \varphi^{1-a_{kg}}$. The point estimate of the growth-maximising ratio of public capital to GDP can then be easily calculated; for the EU panel, it amounts to 42.3 percent.

Third, using equation (B9) and $\hat{a}_{kg}$, the point estimate for the welfare-maximising public to private capital ratio is 26.6 percent, and the welfare-maximising ratio of public capital to GDP is 35.1 percent. Welfare-maximising public capital stocks are thus some 17 to 21 percent lower than growth-maximising public capital stocks.

Let us then assess the uncertainty surrounding these point estimates. The starting point is the standard deviation of the elasticity of output with respect to public capital, $\hat{\sigma}_{\hat{a}_{kg}}$, which is estimated to be 0.017. A 95-percent confidence interval for $\hat{a}_{kg}$ thus ranges from 0.175 to 0.245. Standard errors for the growth-maximising ratios can be derived using the so-called delta method (see, e.g., Greene 2000). The standard error for the growth-maximising ratio of public to private capital is given by

(B11) $$\hat{\sigma}_{\hat{\varphi}^{\max}} = \frac{1+\hat{a}_{kg}}{(1-\hat{a}_{kg})^3} \cdot \hat{\sigma}_{\hat{a}_{kg}}.$$

With (B11) we arrive at our fourth result: a 95-percent confidence interval for $\hat{\varphi}^{\max}$ that ranges from 25.3 to 42.0 percent.

Finally, the standard error for the growth-maximising ratio of public capital to GDP is given by

(B12) $$\hat{\sigma}_{\frac{kg}{y}^{\max}} = \left[\frac{1-\hat{a}_{kg}}{(\hat{\varphi}^{\max})^{\hat{a}_{kg}}} \cdot \frac{1+\hat{a}_{kg}}{(1-\hat{a}_{kg})^3} - \left(\frac{kg}{y}\right)^{\max} \cdot \log\left(\varphi^{\max}\right) \right] \cdot \hat{\sigma}_{\hat{a}_{kg}},$$

so that a 95-percent confidence interval for public capital to GDP ratio ranges from 32.4 to 52.1 percent.

Second, the point estimate for the growth-maximising ratio of public capital to GDP amounts to some 42 percent, with a 95-percent confidence interval for this ratio ranging from about 32 percent to 52 percent of GDP.

Finally, we note that – as expected – the welfare-maximising stock of public capital is lower than the growth-maximising stock of public capital. Specifically, the welfare-maximising public to private capital ratio is estimated at about 27 percent (which is around 21 percent lower than the growth-maximising ratio) and the welfare-maximising public capital to GDP ratio is estimated to amount to 35 percent (around 17 percent lower than the growth-maximising ratio).

Given these estimates for the optimal stock of public capital, a natural question to ask is whether there is a lack of public capital in the EU. We address this question next.

5. Is there a lack of public capital in the European Union?

This section compares actual public capital stocks in individual EU member states with the growth-maximising level estimated in the previous section. It should be kept in mind that this study takes a shortcut by assuming that the determinant of the optimal public capital stock – the elasticity of output with respect to public capital – takes on the same value across countries. This study thereby does not account for differences among the panel units as regards their individual optimal capital stocks. However, as the literature has documented, it would not be an attractive alternative to estimate individual-country models because estimates based on such models tend to be unreliable. In contrast, the panel approach promises more robust results since it also makes use of the cross-section dimension of the data. Also note that in the present context there are only three observations (three ten-year averages) per country, making it impossible to test for the growth effects of public capital in an individual-country setting.

Figure 3 plots the ratio of public to private capital in the year 2000 for the 14 EU countries as well as the EU average. The plot also contains three horizontal lines representing the growth-maximising ratio of public to private capital as well as the lower and upper bounds of a 95-percent confidence interval estimated in the previous section. The figure reveals that in the year 2000, all countries but two had ratios of public to private capital that exceeded the growth-maximising value. The same is true for the EU average. However, if one accounts for the uncertainty surrounding the point estimate of the growth-maximising ratio, only four countries (France, Greece, Ireland and the Netherlands) have a ratio of public to private capital that is significantly above the growth-maximising ratio, while there is only one country (Portugal) with a suboptimally low ratio.[7] This suggests that in most EU countries there is currently neither a shortage nor an excess of public capital—judged relative to the stock of private capital.

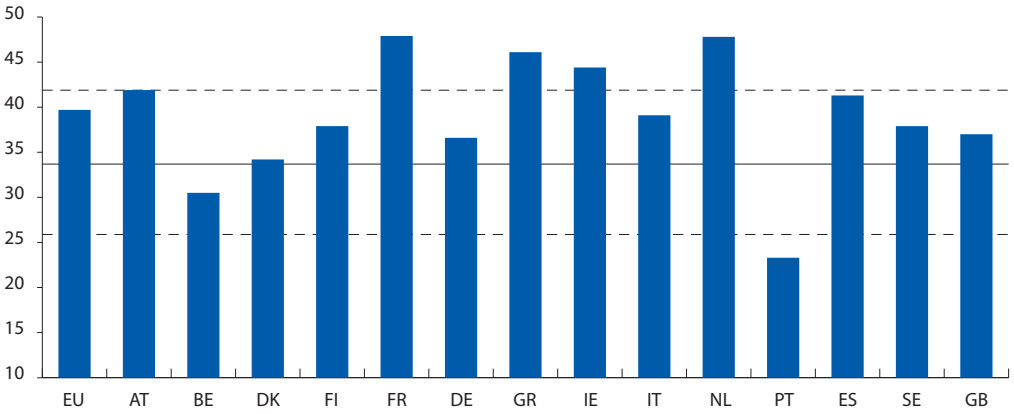
In most pre-enlargement EU countries, there is currently neither a shortage nor an excess of public capital.

An alternative way of looking at the evidence is to compare the actual and growth-maximising values of the ratio of public capital to GDP for the same group of countries. From a theoretical perspective, it does not make a difference which ratios one considers. However, any theoretical model is inevitably only an approximation of reality, and it would be surprising if both ways of

7 However, the figures for Portugal are not directly comparable to those for the other countries. The private investment series used to construct capital stocks for Portugal do not allow a breakdown of private investment into its non-residential and residential components. In the OECD Analytic Database, the series for non-residential and total private investment coincide in the case of Portugal. As a consequence, the private capital stock used to calculate the public to private capital ratio is the total private capital stock in the case of Portugal. Thus, the public to private capital ratio reported for Portugal in Figure 3 understates the public to private non-residential capital ratio.

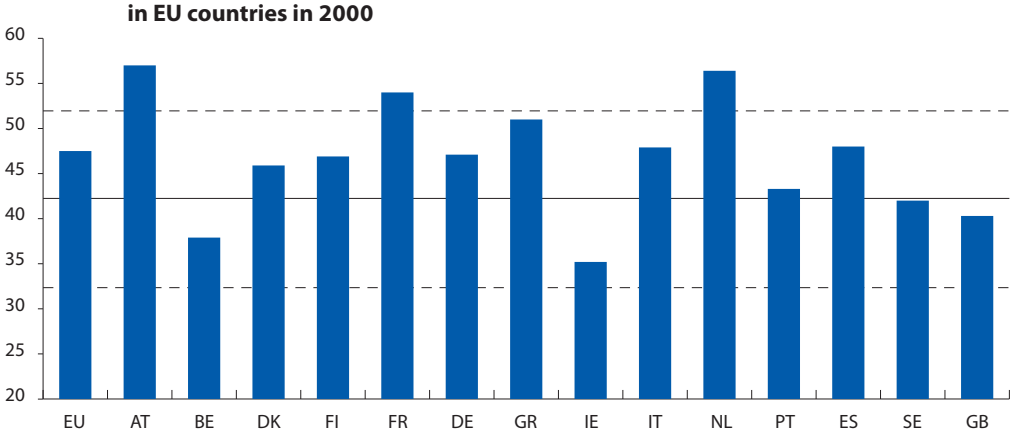
looking at the evidence gave exactly the same results. Figure 4 plots the ratios of public capital to GDP in the year 2000 for the 14 EU countries and the EU average as well as a measure of the growth-maximising ratio. As in Figure 3, most countries as well as the EU average exhibit a ratio above the growth-maximising value. And again, for most countries the deviation from the optimum is not statistically significant. The exceptions are Austria, France, and the Netherlands, which in 2000 had a ratio of public capital to GDP significantly above the growth-maximising value.

Figure 3. Actual and growth-maximising ratios of public-to-private capital (in %) in EU countries in 2000



Note: The solid line shows the growth-maximising government capital to private capital ratio; the dotted lines mark the boundaries of the 95-percent confidence interval for the growth-maximising ratio. The bars show the actual year-2000 government capital to private capital ratio for a EU aggregate as well as for 14 individual countries. The capital stock series for the individual countries are taken from Kamps (2005). The EU aggregate is computed on the basis of 1995 GDP weights expressed in 1995 purchasing power parities, taken from OECD (2002).

Figure 4. Actual and growth-maximising ratios of public capital to GDP (in %) in EU countries in 2000



Note: The explanations for this figure are similar to those of Figure 3.

A comparison of Figures 3 and 4 reveals some striking differences for two individual countries. While the evidence based on ratios of public to private capital suggests a shortage of public capital in Portugal and an excess of public capital in Ireland, the evidence based on public capital to GDP ratios suggests that there is a shortage of public capital in Ireland, while the ratio is roughly equal to

the growth-maximising level in the case of Portugal. However, for both countries, the public capital to GDP ratio seems to be the more appropriate indicator.[8]

The results reported above suggest that for most 'old' individual EU countries as well as for the 'old' EU as a whole there is currently evidence for neither a shortage nor an excess of public capital.[9] Now, an interesting question is whether a shortage of public capital might arise if current trends in public investment continue. As mentioned in the introduction, many policymakers and researchers fear that the current levels of government investment are too low.

Against this background, we use some simple arithmetics to explore two questions: first, how big is the gap between actual and optimal public investment and, second, what would happen to the public capital-GDP ratio in individual countries in the long run if these countries maintained their government investment to GDP at current levels? Box 3 explains these calculations, and Table 7 presents their results – the gist of which can be summarised as follows. To start with the first question, the growth-maximising ratio of public investment to GDP (shown in column 5 of Table 7) varies between 2.3 percent in Germany and Italy and 4.0 percent in Ireland. Comparing growth-maximising with actual public investment reveals that the actual level seems roughly appropriate for the 'old' EU as a whole (the gap in column 7 of Table 7 is close to zero). However, there are large discrepancies for some individual countries: Austria, Belgium, and the United Kingdom currently seem to grossly under-invest in public capital, while there is evidence for over-investment in the case of Portugal.

In most pre-enlargement EU countries, the current level of public investment is roughly in line with the growth-maximising level.

Turning to the second question, column 3 of Table 7 shows the long-run public capital to GDP ratio for individual countries and for the EU average if public investment (as a ratio to GDP) remained at its 2001 level. With 39 percent, the implied long-run ratio for the EU average is very close to the growth-maximising level of about 42 percent. Moreover, for most countries the long-run public capital to GDP ratio implied by current policy remains inside the confidence interval for the growth-maximising ratio; to recall from the previous section, this interval ranges from about 32 to 52 percent. Exceptions are Austria, Belgium, Denmark and the United Kingdom, for which the current level of public investment implies a shortage of public capital in the long run, as well as the Netherlands and Portugal, for which the current level of public investment implies an excess of public capital in the long run. Of course, there is no reason to believe that these countries will maintain their current levels of public investment indefinitely if they turn out to be suboptimal.

8 The previous footnote describes why the public to private capital ratio might be misleading in the case of Portugal. In the case of Ireland, the results taken together indicate that there might be a shortage of both public and private capital. During the 1990s, both public and private capital accumulation did not keep pace with the very strong output growth.

9 The term 'old' here characterises countries that were EU member states before the latest EU enlargement, which took effect on May 1, 2004.

Box 3. Calculating deviations of actual from optimal public capital stocks and investment

How big is the gap between actual and optimal public investment?

To illustrate an answer to this question, we calculate the constant country-specific public investment to GDP ratio that stabilises the ratio of public capital to GDP at its growth-maximising level. This investment ratio can be expressed as

$$\text{(B13)} \qquad \left(\frac{ig}{y}\right)_i^{\max} = (\delta_g + \gamma_i)\left(\frac{kg}{y}\right)^{\max}, \quad i = 1,\ldots,N.$$

where ig is public investment and δ_g is the depreciation rate of public capital. Following Kamps (2005), we assume that the depreciation rate of public capital amounts to 4 percent for the countries considered. The long-run growth rate γ_i is assumed to be country-specific and approximated by the growth rate of potential output in the year 2003 according to OECD (2004) estimates. Equation (B13) then determines the public investment to GDP ratio that, in the long run, stabilises the ratio of public capital to GDP at its growth-maximising level (which – as shown in the previous section – is 42.3 percent for the panel of EU countries). These investment ratios are shown in column 5 of Table 7. Column 6 shows actual (2001) investment ratios and, consequently, column 7 shows the gap between actual and the optimal level of public investment.

What if public investment-to-GDP ratios remained unchanged?

To shed light on this question, we need to calculate the long-run ratio of public capital to GDP implied by the current level of government investment. This long-run ratio (denoted by the superscript *LR*) can be expressed as

$$\text{(B14)} \qquad \left(\frac{kg}{y}\right)_i^{LR} = \frac{1}{\delta_g + \gamma_i}\left(\frac{ig}{y}\right)_{it}, \quad t = 2001,\ i = 1,\ldots,N.$$

To calculate these ratios for individual countries, we make the following assumptions: we use again a depreciation rate of public capital of 4 percent; assume that government investment ratios in individual countries remain constant at their current levels; and approximate long-run growth rates of individual countries by the respective growth rate of potential output. Column 3 of Table 7 shows the results of these calculations for individual countries and the EU average. Column 2 shows the optimal public capital stock to GDP ratio and, thus, column 4 shows the gap between optimal values and those resulting from unchanged public investment ratios.

Table 7. Public capital stock and investment ratios: comparing actual with 'optimal' figures

Country	Growth rate(in %)	Public capital to GDP (in %)			Public investment to GDP (in %)		
		'Optimal'	'Long-run' with actual (2001) public investment ratio	Gap	'Optimal'	Actual (in 2001)	Gap
	(1)	(2)	(3)	(4)=(2)-(3)	(5)	(6)	(7)=(5)-(6)
Austria	2.3	42.3	19.7	22.6	2.7	1.3	1.4
Belgium	2.1	42.3	24.6	17.7	2.6	1.5	1.1
Denmark	2.0	42.3	31.4	10.9	2.5	1.9	0.7
Finland	2.4	42.3	39.3	3.0	2.7	2.5	0.2
France	2.1	42.3	49.3	-7.0	2.6	3.0	-0.4
Germany	1.5	42.3	34.7	7.6	2.3	1.9	0.4
Greece	4.2	42.3	48.1	-5.8	3.5	3.9	-0.5
Ireland	5.5	42.3	33.5	8.8	4.0	3.2	0.8
Italy	1.4	42.3	42.9	-0.6	2.3	2.3	0.0
Netherlands	2.1	42.3	55.2	-12.9	2.6	3.3	-0.8
Portugal	1.9	42.3	70.1	-27.8	2.5	4.1	-1.6
Spain	3.0	42.3	45.5	-3.2	3.0	3.2	-0.2
Sweden	2.6	42.3	33.4	8.9	2.8	2.2	0.6
United Kingdom	2.4	42.3	25.7	16.6	2.7	1.7	1.1
EU average	2.0	42.3	39.1	3.2	2.6	2.4	0.2

Note: (i) growth rate reflects growth rate of potential output; (ii) public capital stock assumed to depreciate at 4% p.a.; (iii) 'optimal' in the sense of growth maximising; (iv) EU average: for country weighting see Table 1.

Source: Kamps (2005), OECD (2002, 2004) and own calculations.

6. Limitations of the study and avenues for further research

The analysis presented in this paper builds on a specific theoretical model and uses specific econometric methods as well as a small set of economic variables in the empirical application. This raises the question whether the results obtained are specific to the chosen setup or robust to alternative setups. This section discusses therefore modifications of the basic setup that could help to assess the robustness of the main results.

The findings of this paper rest on a specific theoretical model, using a limited number of variables. Future research could consider different specifications and/or more variables.

Regarding the theoretical model, a number of alternative setups could be considered, especially with respect to their implications for optimal public capital spending. Three modelling devices deserve special attention. First, the model considered in this study is an endogenous growth model. It would be of interest to compare optimal fiscal policy in this model with optimal fiscal policy in an exogenous growth model. Second, the model considered here assumes an infinitely lived representative agent, abstracting from questions relating to intergenerational redistribution. Yet, the benefits of public capital accumulation might be unevenly distributed across generations. The welfare implications could be addressed in an overlapping-generations model. Third, the financing decision plays an important role for the long-run effects of public capital spending. The model used here assumes that the government has access to government debt and to a distortionary output tax. It would be interesting to study the model's implications for alternative financing choices.

As regards the empirical analysis, three complementary approaches could be followed in order to explore the robustness of the results presented here. First, the empirical analysis presented in this study includes only a limited number of control variables. A number of studies in the empirical growth literature check for the robustness of the growth effects of specific explanatory variables using the so-called extreme bounds test (see, e.g., Levine and Renelt 1992 and Sala-i-Martin 1997). These studies consider in general 50 or more variables, such as the stock of human capital, and run regressions for many combinations of explanatory variables. Second, the empirical model used here estimates the steady-state relationship between public capital and economic growth. One could relax the assumption that the countries are in the steady state and account for transitional dynamics. Third, the empirical model used here does not explicitly take the government budget constraint into account. In their study on the growth effects of fiscal policy Bleaney *et al.* (1999) show that it is important to control for the way in which public spending is financed. It would therefore be interesting to explore whether the empirical growth effects of public capital in the sample of OECD countries vary across financing alternatives.

Finally, it should be kept in mind that this study makes a shortcut by assuming that the determinant of the optimal public capital stock – the elasticity of output with respect to public capital – takes on the same value across countries. At first sight it might, thus, be an interesting next step to estimate country-specific optimal public capital stocks. However, one conclusion to be drawn from the large body of empirical literature on the productivity of public capital is that estimates based on individual-country regressions often turn out to be unreliable, one important reason being that such regressions tend to be subject to multicollinearity problems. One way to deal with these problems is to use the cross-section dimension of the data and to carry out panel regressions. This is the approach followed in this study. An alternative could be to assemble regional data on capital stocks for individual countries and then carry out regressions using a regional panel. So far, however, regional data on public and private capital stocks are unavailable for the vast majority of OECD countries.

Annex

The growth model

A.1 Decentralised economy

The objective of the representative agent is to maximise his lifetime utility (B1) subject to his flow budget constraint (B5) and the production function (B2). To solve this optimisation problem we use the current-value Hamiltonian

$$H = \frac{c^{1-\sigma} - 1}{1-\sigma} + \lambda \left[(1-\theta)\, k^{\alpha} kg^{\alpha_{kg}} + rb - c \right]. \tag{A.1}$$

The representative agent takes kg and θ as given and maximises (A.1) with respect to c, k and b. The optimality conditions are

$$c^{-\sigma} = \lambda, \tag{A.2}$$

$$(1-\theta)\left(1-\alpha_{kg}\right)\varphi^{\alpha_{kg}} = \rho - \frac{\dot{\lambda}}{\lambda}, \tag{A.3}$$

$$r = \rho - \frac{\dot{\lambda}}{\lambda}. \tag{A.4}$$

Equation (A.2) equates the marginal utility of consumption to the shadow value of wealth, λ. Equation (A.3) asserts that the after-tax marginal product of private capital must equal the rate of return on consumption, while equation (A.4) equates the interest rate with the rate of return on consumption. (A.3) and (A.4) taken together, imply that in equilibrium the real interest rate must equal the after-tax marginal product of private capital,

$$r = (1-\theta)\left(1-\alpha_{kg}\right)\varphi^{\alpha_{kg}}. \tag{A.5}$$

In addition, the following transversality conditions must be met

$$\lim_{t\to\infty} \lambda\ ke^{-\rho t} = 0, \tag{A.6}$$

$$\lim_{t\to\infty} \lambda\ be^{-\rho t} = 0, \tag{A.7}$$

thereby ruling out explosive equilibria.

Recalling that the government finances public capital with government debt ($kg=b$), the governmentbudget constraint (B4) and the production function (B2) can be used to express the tax rate as $\theta = r\varphi^{\alpha_k}$.Substituting this expression for the tax rate in equation (A.5) yields

$$r = \frac{\left(1-\alpha_{kg}\right)\varphi^{\alpha_{kg}}}{1+\left(1-\alpha_{kg}\right)\varphi}. \tag{A.8}$$

In the following, we focus on the steady state of the model economy. Along the balanced growth path all variables grow at the same rate. Differentiating (A.2) with respect to time, and using (A.4), the common growth rate can be expressed as

$$\gamma = \frac{\dot{c}}{c} = \frac{1}{\sigma}[r-\rho]. \tag{A.9}$$

Now, using (A.8), the growth rate can be expressed as a nonlinear function of the public to private capital ratio,

$$\gamma = \frac{1}{\sigma}\left[\frac{\left(1-\alpha_{kg}\right)\varphi^{\alpha_{kg}}}{1+\left(1-\alpha_{kg}\right)\varphi} - \rho\right]. \tag{A.10}$$

Setting the derivative of γ with respect to φ to zero, yields the growth-maximising public to private capital ratio

$$\text{(A.11)} \qquad \varphi^{\max} = \frac{\alpha_{kg}}{\left(1-\alpha_{kg}\right)^2}.$$

In order to derive the tax rate associated with the growth-maximising public to private capital ratio, we use the expression $\theta = r\varphi^{\alpha_k}$, substituting (A.8) for the interest rate and (A.11) for φ. After some transformations this yields $\theta^{\max} = \alpha_{kg}$, i.e., the tax rate should be set equal to the elasticity of output with respect to public capital. Substituting α_{kg} for the tax rate in the expression $\theta = r\varphi^{\alpha_k}$ shows that, in the growth-maximising steady state, the marginal product of public capital is equal to the interest rate, $r = \alpha_{kg}\varphi^{\alpha_{kg}-1}$. Comparing this expression with (A.5) shows that in the growth-maximising steady state the after-tax marginal product of private capital is equal to the marginal product of public capital, $(1-\theta)(1-\alpha_{kg})\varphi^{\alpha_{kg}} = \alpha_{kg}\varphi^{\alpha_{kg}-1}$.

A.2 Optimal policy

This section derives the welfare-maximising public to private capital ratio, drawing on Turnovsky (1997). The objective of the social planner is to maximise the agent's utility (B1) subject to the production function (B2), the public capital accumulation equation $\dot{kg} = gy$, where g denotes the share of output devoted to public investment, and the economy-wide resource constraint $\dot{k} = y - \dot{kg} - c$. The current-value Hamiltonian now is

$$\text{(A.12)} \qquad H = \frac{c^{1-\sigma}-1}{1-\sigma} + \upsilon\left[(1-g)\,k^{\alpha_k}kg^{\alpha_{kg}} - c\right] + \mu\, gk^{\alpha_k}kg^{\alpha_{kg}}.$$

The social planner maximises (A.12) with respect to c, k, kg and g. The optimality conditions are

$$\text{(A.13)} \qquad c^{-\sigma} = \upsilon,$$

$$\text{(A.14)} \qquad (1-g)(1-\alpha_{kg})\varphi^{\alpha_{kg}} + qg(1-\alpha_{kg})\varphi^{\alpha_{kg}} = \rho - \frac{\dot{\upsilon}}{\upsilon},$$

$$\text{(A.15)} \qquad \frac{1}{q}(1-g)\alpha_{kg}\varphi^{\alpha_{kg}-1} + g\alpha_{kg}\varphi^{\alpha_{kg}-1} + \frac{\dot{q}}{q} = \rho - \frac{\dot{\upsilon}}{\upsilon},$$

$$\text{(A.16)} \qquad q = 1,$$

where $q \equiv \mu/\upsilon$ denotes the shadow price of public capital in terms of private capital. According to equation (A.16), the shadow values of public and private capital should be equal. Equating (A.14) and (A.15), using (A.16), yields the welfare-maximising public to private capital ratio (φ^*), which—as can easily be seen—for $\alpha_{kg} > 0$ is smaller than the growth-maximising ratio ($\varphi^{\max}$)

$$\text{(A.17)} \qquad \varphi^* = \frac{\alpha_{kg}}{1-\alpha_{kg}} < \varphi^{\max}.$$

The rationale for this result is the following: while growth maximisation implies that the marginal product of public capital should be equal to the *after-tax* marginal product of private capital, welfare maximisation implies that the marginal product of public capital should equal the *gross* marginal product of private capital. The distortions associated with taxation discourage the accumulation of private capital. As a result the public to private capital ratio with growth maximisation is lower than in the first-best optimum. Maximising the growth rate involves a consumption loss and, thereby, lowers welfare.

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ABSTRACT

Public-private partnerships have emerged as an alternative to traditional public procurement in financing and providing infrastructure services. *This paper considers public-private partnerships as another form of public sector intervention in the economy. It analyses the microeconomic pros and cons of public-private partnerships by identifying the sources of both higher benefits and higher costs associated with them, as compared to traditional public investment. Such analysis allows the outlining of the conditions under which public-private partnerships may be the optimal form of public sector intervention. In addition, the paper considers public-private partnerships from a macroeconomic perspective, focussing on their impact on fiscal policy and aggregate growth.*

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How expensive are cost savings? On the economics of public-private partnerships

Timo Välilä

1. Introduction

The emergence of public-private partnerships (PPPs) in the United Kingdom (UK) in the early 1990s constituted a structural change in the financing and provision of infrastructure services, at least qualitatively speaking. The mobilisation of private finance to fund infrastructure projects was not entirely unheard of in the pre-PPP Europe; after all, there had been a long tradition of concession agreements in countries like France. However, the establishment of an interactive partnership between the public and private sectors, characterised by the distribution of risks and rewards between them, was an innovation whose spread into and across the continent seems only to have started gathering pace.

There are diverging views about why PPPs emerged and gained popularity. On the one hand there is the view that they are but a vehicle for the government to shift investment spending off its own books, thereby creating room to spend on other, perhaps politically higher-yielding items, while still getting the infrastructure supplied. A less cynical variant of this view would have it that PPPs allow governments constrained by binding fiscal deficit rules to safeguard the execution of infrastructure projects that would otherwise never materialise, or would only materialise with a delay.

In contrast to the view that the emergence and popularity of PPPs derive from fiscal policy considerations, there is the argument that PPPs offer real benefits in terms of productive efficiency at the project level. In other words, the involvement of the private sector on a partnership-basis would allow the construction and operation of a road, tunnel, school or any other piece of infrastructure more cheaply than traditional public sector provision. According to this view, the microeconomic benefits of PPPs justify their existence and expansion.

There is undoubtedly something to both these polar views. It is easy to see that PPPs have an aspect of short-term political attractiveness to them and that there have been instances where the decision to set up a partnership has been dictated by such considerations. At the same time, it is not implausible to maintain that the provision of an infrastructure service could become more efficient if it were shifted from the public sector to the private sector, with the public sector remaining the ultimate guardian of its availability and quality.

The purpose of this paper is to assess the economic pros and cons of PPPs and to thereby examine the underpinnings of the divergent views on their *raison d'être*. To this end, the issues that will be addressed in what follows include the economic roles of the public sector and private sector partners, respectively (Sections 2 and 3); possible sources of higher cost-efficiency, but also higher costs in a PPP than in traditional public service provision (Sections 4 and 5); and macroeconomic implications of PPPs, including their fiscal impact and its effect on policymakers' incentives to resort to a PPP (Section 6).

2. Public intervention and allocative efficiency

For a PPP to make sense from an economic perspective, there must be an economic justification for the involvement of both public and private sectors in the partnership. This chapter recapitulates the case for public sector involvement in economic activity in general and in the provision of

infrastructure services in particular and also discusses the various forms the public sector's involvement can take. The economic case for private sector involvement in a PPP will be assessed in subsequent chapters.

Public intervention can in some cases improve society's welfare.

In general, competitive markets free of public sector intervention provide the most efficient way to allocate scarce economic resources to competing uses. There are, however, some cases where markets fail to supply the socially desirable quantity or quality of a good or a service, and in such cases intervention by the public sector can enhance the society's welfare. Cases where markets fail and public intervention is therefore justified are discussed briefly below. [1]

Market power and natural monopoly. Whenever a producer has the power to influence price-setting in a market, the market will be characterised by a price above the social optimum and by a quantity transacted below the social optimum. A special case of such a situation can occur in naturally monopolistic industries with high fixed costs of production. When the fixed costs of production are high, the average cost of production declines with the quantity produced while staying above the marginal cost of production for the demanded range of output. In other words, the production is characterised by economies of scale, which makes it unattractive for other potential producers to enter the market. The incumbent producer will charge a price above the social optimum (the marginal cost of production) to cover his costs, and the quantity transacted will therefore be below the social optimum. This is typically the case in network industries such as power transmission, where the fixed cost of the transmission network is so high as to render the production of power transmission services profitable for only one producer, who will thus become a 'natural' monopolist in supplying the market.[2]

Externalities. The production or consumption of a good or service may have spillover effects (either costs or benefits) on third parties, and unless these spillover effects are reflected in the price of the good or service in question, the quantity transacted will be socially suboptimal. For instance, if traffic on a highway causes noise and pollution that reduce the value of houses adjacent to it, and if the users of the highway are not tolled so as to allow the house owners to be fully compensated for their economic loss (i.e., if the private cost of using the highway is lower than the social cost), the amount of traffic will be too high from a social perspective.[3]

Public goods. Some goods and services are characterised by non-excludability and non-rivalry in consumption; that is, once the good or service is produced, individual consumers cannot be excluded from consuming it and, moreover, consumption by one individual does not reduce consumption possibilities for others. Consequently, the marginal cost of production is zero, as is the socially optimal price. Clearly, no private firm would enter the market and, without public sector intervention, there would be no supply of the public good. A classical example of a public good is law enforcement: jailing criminals benefits the whole society, but a private entrepreneur putting

1 For a more formal discussion, see any intermediate or advanced textbook in microeconomics or public economics. Examples include Varian (1992) and Stiglitz (1988). A concise overview is included in Brealey *et al*. (1997).

2 An alternative way to define a natural monopoly is to require the simultaneous presence of both sunk costs (representing, e.g., the initial investment in a power transmission network) and a subadditive cost function (meaning that it is cheaper to produce any quantity of output from a single source than from two or more separate sources).

3 According to the so-called Coase Theorem, the presence of unambiguous property rights can alleviate market failures due to externalities. Specifically, any externality can in principle be internalised through appropriate price-setting and transfers whereby, e.g., those causing negative externalities compensate those suffering economic loss due to them. To make such an internalisation possible, however, property rights must be clear enough to allow the assignment and payment of the appropriate amount of compensation.

criminals behind the bars would not be able to collect charges from individuals in the society to finance his undertaking.

In all cases mentioned above public sector intervention would aim at improving the economy's efficiency to allocate resources. Public intervention may, however, be justified even when markets generate efficient outcomes. This is the case with so-called merit goods and also on grounds on equity, as opposed to efficiency. Merit goods are defined as goods that individuals do not consume in sufficient quantity to ensure their own welfare. Education and health care are typical examples: individuals may be myopic and therefore acquire too little education or health care.[4] Through compulsory education, for instance, public intervention may increase both individual and social welfare. Education and health care are also areas where public sector intervention has taken place on equity rather than efficiency grounds. It has been perceived socially important that all individuals have equal access to education and health care services, and the public sector has intervened to improve the efficiency of resource distribution (as opposed to allocation) by, among other things, developing schemes to allow all individuals to access these services.

As illustrated in the examples above, market failures are a common feature of infrastructure and public services. Moreover, in many cases there are multiple market failures characterising a specific infrastructure or public service. Consider transport infrastructure: a road can constitute a natural monopoly because of the high fixed costs involved in its construction. The construction and use of roads is associated with externalities (noise, pollution, congestion, changes in the value of adjacent land). Furthermore, to the extent that collecting tolls from road users (i.e., to exclude individual consumers) is an expensive exercise, it is also a quasi-public good.[5] Similarly for education: it has some characteristics of a public good; it generates positive externalities for the society; and it is a merit good with strong equity arguments for public intervention.

The public sector can use a number of instruments to intervene.

Given the close association between infrastructure and market failures, public intervention has traditionally been an intrinsic characteristic of infrastructure provision. This intervention can take different forms, as exemplified below.[6]

Regulation. To prevent a natural monopolist from abusing his market power to the detriment of society, while allowing him to recuperate his costs, the government can regulate the tariffs the monopolist can charge his clients. Alternatively, the government can regulate the quantity of pollution cars or factories are allowed to emit, thereby alleviating negative externalities. Or the government may regulate the quality of educational services provided by private schools and universities. In all cases, the government needs to be able to monitor compliance and sanction non-compliance for regulation to be effective.

Taxes and subsidies. The government can tax activities that cause negative externalities, thereby raising the marginal cost of production to the socially optimal level. Alternatively, the government can ensure the socially optimal provision of public goods or the socially optimal consumption of merit goods by subsidising them. In both cases, the government needs to be able to determine the economically optimal level of taxes or subsidies as well as monitor and sanction their collection and use.

4 Both education and health care can also generate positive externalities, but that is separate from them being merit goods.

5 At times of light traffic the use of a road by one driver does not lessen the consumption possibilities of other drivers, but at times of congestion this non-rivalry in consumption no longer applies.

6 For further examples, see also Brealey *et al.* (1997).

Public production and ownership. In many infrastructure and public service sectors governments have chosen to nationalise the entire production and supply of the services concerned. For instance, the public sector owns road and rail networks, schools, hospitals, and prisons, and most, if not all, employees involved in the production of these services are on the public sector's payroll. While ownership can arguably reduce monitoring costs to the public sector, it is associated with a host of other costs related, among other things, to the financing, construction, operation, and maintenance of the underlying assets.

The above discussion on public intervention to rectify market failures suggests two conclusions that seem trivial at the outset but that, in fact, constitute the basis for assessing the economic case for involving the private sector in the provision of goods or services such as infrastructure and public services that are characterised by market failures.

First, public intervention can take many forms. The goal of intervention is to increase the society's welfare by rectifying a market's failure to allocate resources efficiently or to reach a desirable distribution of income. A particular market failure, or multiple market failures in the case of many infrastructure and public service markets, could conceivably be eliminated or alleviated equally effectively by means of more than one instrument for public intervention. Public ownership is just one among several possible instruments, and there is no *ex ante* reason to believe that it is economically superior to other forms of intervention capable of delivering the same improvement in economic efficiency (or equity). Consequently, there is a case for looking beyond the achievement of allocative efficiency when considering how the public sector should intervene.

Public intervention comes with costs as well as benefits.

Second, intervention is costly and distortionary. Public intervention may bring benefits in terms of improved resource allocation or equity in the economy, but these benefits come at a cost. The net benefit of public intervention to the economy depends both on the extent to which a market failure is alleviated and on the costs the chosen form of intervention causes to the economy (distortions) and the public sector. If several instruments of public intervention could be used to eliminate a particular market failure, the optimal instrument is the one associated with lowest overall costs, including distortions.

In other words, when public intervention is justified to correct a market failure, the optimal form of intervention needs to be assessed in terms of the economic costs and benefits the various alternatives can offer. Before we can proceed to an assessment of PPPs from this perspective, we need to specify the relevant characteristics of a PPP that determine its economic costs and benefits.

3. Economic characterisation of a PPP

The aim of this section is to pin down a PPP from an economic perspective. Such partnerships come in a wide variety of types and forms (see Box 1.), and it has therefore proven difficult to come up with a universally agreed and applicable definition of a PPP. Nevertheless, it is possible to suggest a set of fundamental economic features that are shared by most such arrangements to deliver infrastructure and public services.

To be clear, the rationale for spelling out the key economic characteristics of PPPs is to facilitate the analysis of their economic pros and cons, not to produce an exhaustive list of criteria for an arrangement to be classified as a PPP. As such, the set of characteristics should highlight the difference between a PPP and outright privatisation, and it should allow the comparison of PPPs

with traditional public provision. Such a comparison, in turn, will allow the assessment of the optimal form of public intervention, as discussed in the previous section.

Box 1. Different types of arrangements labelled 'public-private partnerships'

PPPs have assumed a range of different contractual and legal set-ups. The most typical one is a long-term service contract between the public sector and a private partner (a private firm or a special purpose vehicle) whereby the public sector partner commits to paying the private partner for the delivery of an (infrastructure) service (e.g., a motorway) over a long and pre-specified period of time (up to 30 years), with the private partner responsible for financing and producing the service using his own assets and for carrying some of the associated risks. An alternative arrangement, also sometimes dubbed a PPP, is an operating lease or a concession granted by the public sector to a private partner to use a public infrastructure asset (e.g., a tunnel) to provide associated services to the public. Again, the private partner carries some of the risks related to construction and operation, but he may finance his undertaking either by collecting user fees or by a combination of user fees and budgetary support. Finally, joint ventures to produce marketable public services (e.g., air traffic control) are also in some cases called PPPs.

The private partner may be in charge of any of the following main phases or aspects of the project: Design, Build, Develop, Finance, Operate, Maintain, Own (or Lease or Rent), and Transfer. Exaggerating somewhat, it may thus be possible to encounter a PPP on a DBDFOMOT–basis. Normally, the private partner would, however, assume the responsibility and risk for Design, Build, Finance, Operate, and Own aspects of a project.

Sources: Allen (2001), European Commission (2003a) and (2003b), IMF (2004a), Pollitt (2000), PROFIT (2001), United Nations Economic Commission for Europe (2000).

In distinguishing a PPP from other forms of infrastructure or public service provision, its characterisation must relate to the economic rationale for the involvement of both public and private sector partners in the service provision. As argued in the previous section, the rationale for public sector involvement must arise from the presence of a market failure. Consequently, a PPP would seek to alleviate a market failure inherent in the provision of infrastructure or public services exactly the same way as traditional public provision does. In addition, the role of the private sector partner must add some value in its own right for a PPP to be economically superior to traditional public provision, and it must not give rise to costs that would exceed the associated benefit.

In a PPP, the public sector safeguards allocative efficiency and the private sector productive efficiency.

The way private involvement could conceivably add value is by improving the productive, or technical, efficiency in the production and supply of the service. It has been suggested that such efficiency gains could arise from three specific sources in the context of PPPs, namely from the specific ownership structure of the assets needed to produce and provide the service in question; from the bundling together of the different phases of service production and provision; and from the appropriate sharing of risks and associated rewards inherent in the production and provision of the service.[7]

7 See, among others, Allan (1999), Allen (2001), Debande (2002), De Fraja (2002), European Commission (2003a) and (2003b), Grout (1997), Grout and Stevens (2003), Hart (2003), HM Treasury (2000) and (2003), IMF (2004a), Jenkinson (2003), Lundsgaard (2002), Pollitt (2000), PROFIT (2001), Schleifer (1998), and United Nations Economic Commission for Europe (2000).

Consequently, the following list should represent something of a consensus view of the key economic features that tend to characterise arrangements labelled PPPs: (i) a PPP serves a public policy objective, such as the provision of infrastructure and public services characterised by market failures; (ii) in a PPP, the public sector enters a long-term arrangement with a private sector partner to ensure the supply of services (output); (iii) the private sector partner supplying the services finances and, in many cases, owns the associated (often specific) asset to produce such services (input), with the different phases of asset construction and operation and even service provision bundled together; and (iv) each risk is transferred to the party best able to manage or bear it.

A PPP is distinctly different from both traditional public provision and privatisation.

Based on these characteristics, how does a PPP differ from traditional public and private provision, respectively? Traditional public provision would not encompass private ownership of the assets required to produce the service in question, nor would it involve the kind of long-term risk-sharing that a PPP does. While traditional public provision may involve some risk-sharing—for instance, a (local) government may contract out the construction of a school to a private building firm, with the firm carrying the risks associated with the construction phase—such risk-sharing does not cover the supply phase and is therefore not inherent to the provision of the service (output) in question.

Similarly, while private provision would be characterised by private ownership of the input assets, it would not fulfil any other criteria above. Most importantly, privatised activities are not expected to serve a public policy function and do not involve the kind of long-term risk-sharing that a PPP does.

The list above can also be used to identify arrangements that would in general not qualify as PPPs. In particular, whenever either the public or the private sector partner carries all of the risks related to production and supply, there would be no partnership in the current sense of the word. Contracting out the construction of an infrastructure asset or outsourcing the provision of auxiliary services to the private sector (such as food supply or cleaning services in schools, hospitals, or prisons) would not qualify as a PPP as long as the public sector owns the assets and carries the risks of producing and supplying the public service in question. Similarly, a concession agreement whereby the private sector partner owns and runs a tunnel or a toll road and where the public sector carries no risk at all would also not be a PPP. Finally, even when all criteria above appear to be fulfilled, risk-sharing may be watered down by a government guarantee on the private borrowing to finance the construction of the asset to produce the infrastructure or public service; after all, a guarantee implies that the public sector is the ultimate risk-carrier in the project.

We have so far asserted conceptually what might make a PPP economically superior to traditional public provision, but it remains to be assessed how and under what conditions such superiority could arise. This will be the topic of the following section.

4. Incentives and productive efficiency

The conclusion so far is that, to be economically sensible, a PPP has to generate a combination of allocative efficiency and productive efficiency that is superior to traditional public provision, bearing in mind that the public sector may be prepared to trade off some allocative efficiency to obtain higher productive efficiency. In the context of PPPs the term customarily used to describe productive efficiency is 'value for money'.[8] Hence, the creation of additional value for money as

8 The definition and measurement of value for money is discussed in detail by Grout (this volume).

compared with traditional public provision—while not unduly compromising allocative efficiency—would justify the involvement of the private sector in the partnership.

It was suggested in the previous section that three key sources of value for money creation in a PPP relate to asset ownership, bundling, and risk-sharing. After a brief survey of why productive efficiency can differ between the public and the private sectors in the first place, this section seeks to clarify why and when ownership, bundling and risk-sharing can affect productive efficiency.

4.1 Ownership and incentives

Both in the public and private sector, the production process is plagued by incentive problems due to different objectives of and asymmetric information between the 'principal' (the government and the shareholders of the private firm) and the 'agent' (the head of the public agency and the manager of the private firm).[9] However, as summarised by Brealey *et al.* (1997), there are a number of reasons to believe that it is easier for the private firm to deal with such incentive problems (also called agency problems) and that it will therefore lose less than the public agency in terms of productive efficiency. Notably, the public sector principal tends to be more heterogeneous and dispersed; have more ambiguous objectives, with no clear measure against which to assess his performance; and is more likely to face soft budget constraints.

For all these reasons, the private sector tends to exhibit higher productive efficiency than the public sector. However, even if one gives the public sector the benefit of the doubt and assumes that both sectors face equal agency problems and that both are equally able to deal with them, the case will be made in this section that the private sector can still be superior in terms of productive efficiency and, moreover, that the private sector's superior productive efficiency can be—under certain conditions—successfully combined with public intervention to safeguard allocative efficiency.

Specific assets are needed to produce infrastructure and public services.

As a starting point, let us separate the provision of a service from the good (asset) needed to produce that service. Virtually all markets for infrastructure and public services (power transmission, transport, law enforcement, etc.) are, indeed, markets for services, where government intervention is deemed necessary to ensure the provision of the socially desirable quantity and quality. Most of such services require the existence of productive assets (power transmission network, motorway, prison, etc.) that are specific to the production of the service in question; that is, they cannot be readily used for other purposes.

Governments' role in these markets has traditionally encompassed both the provision of the service in question and the ownership of the underlying asset. But is this the optimal form of intervention? While it is clear that the markets for most of the services mentioned above are plagued by various failures, it is by no means clear that alleviating of those failures would always require government ownership of the underlying asset. Therefore, there is a case for considering whether government intervention in the provision of a service to improve allocative efficiency could be combined with the promotion of productive efficiency through private ownership and operation of the asset.

As a benchmark, let us first establish the conditions under which the ownership of the asset does not make any difference. Consider the commissioning of the operation and maintenance of a pre-existing tunnel by the public sector to an agent, be it a public agency or a private firm. For the time being, ignore

9 See, e.g., Laffont and Martimort (2002) on principal-agent models more generally.

the question of who originally constructed, financed, and owned the tunnel—let it just be there. The public sector is interested in providing the society with tunnel services of a certain quality (output), not in the tunnel itself (input), so it wishes to set up a contract covering the long-term delivery of tunnel services alone. Assume that agency problems are equally severe in the public and private sectors. Assume also that the public sector is able to contract out the project in a way that allows it to exactly specify, monitor, and enforce the quality of tunnel services to be provided under all circumstances and that transaction costs relating to contracting are independent of the agent. Under these assumptions, the public sector principal is able to secure the same level of both allocative efficiency (due to same service quality) and productive efficiency (due to same agency problems) regardless of whether the agent is a public sector agency or a private firm.

PPPs are prone to contractual incompleteness.

However, the public sector principal can seldom specify and verify the output sufficiently well in order to make the agent provide the desired service quality under all possible circumstances. Instead, the principal will need to enter an incomplete contract with the agent, which specifies the provision of a service only to an incomplete extent because of informational and monitoring problems as well as genuine uncertainty about the future. This is particularly the case with PPPs, as they are set up to provide services, which are often hard to measure and monitor, and as they have long contract periods, which makes them susceptible to a great deal of uncertainty.

To illustrate contractual incompleteness, consider the example of the tunnel: the principal can ask the agent to provide uninterrupted tunnel services with certain safety standards (e.g., lighting and emergency exits), and he can monitor the condition of the tunnel and compliance with the safety standards, but he cannot specify how the agent should respond to all possible events that may have a bearing on service quality, i.e., on the output that the initial contract focusses on. Unanticipated future developments, such as technical innovation in the area of tunnel safety, could improve service quality if the agent invested in it. On the other hand, investment reducing production costs, for instance investment in cheaper methods of monitoring the condition of the tunnel, would improve productive efficiency, but might also have a detrimental impact on service quality (i.e., allocative efficiency).

How asset ownership affects the agent's incentives to make investments that have a bearing on allocative efficiency (service quality) and productive efficiency, and what asset ownership structure is therefore desirable from the society's perspective are clearly key issues in assessing the economic pros and cons of PPPs. These questions will therefore be considered below in some detail. The exposition emphasises contractual incompleteness as a possible source of inefficiency, with references made to another branch of literature that focusses on asymmetric information rather than contractual incompleteness.

To start with, it can be shown that when contracts are incomplete, incentives to promote productive efficiency do depend on asset ownership, and that private ownership can be superior in terms of productive efficiency. This conclusion was articulated by Hart *et al.* (1997) and Schleifer (1998), drawing on earlier work by Grossman and Hart (1986), Hart and Moore (1990), and Hart (1995). The fundamental insight paving the way to this conclusion is that the owner of the asset has the right to control its usage under all circumstances (i.e., he has 'residual control rights'), and any changes in this respect require the owner's consent. This is especially important when contracts are incomplete because ownership embeds bargaining power in non-contractible situations. If the owner wishes to make a new investment that would cut production costs without affecting service quality, he can

do so without renegotiating the contract, which only covers service provision (output). However, if an operator who is not the owner of the asset wishes to make the same investment, he needs the owner's consent, which, in turn, calls for a renegotiation of the contract. Therefore, the owner-operator has stronger incentives to enhance productive efficiency.

Consequently, if the above tunnel were owned and operated by a private firm, the latter would have the incentives to invest in improving the efficiency of supplying tunnel services as it could pocket the gain without the public sector's consent. On the other hand, if the tunnel were owned by the public sector, the latter would demand to approve any such investment in cost reduction. In this case, both a private tunnel operator and a public agency running the service would need to renegotiate the service delivery contract in order to implement the cost reduction; moreover, the public sector owner would extract its own share of the gain in the renegotiation process. This would weaken the incentives to improve productive efficiency.[10]

The need to seek the owner's consent for any efficiency-enhancing investment also implies that the public sector cannot set up a contract for the manager of a public agency that would generate the same level of productive efficiency as private ownership. The manager would need to negotiate every such investment with his principal, thereby losing at least part of the gains from the investment. How much the public sector principal-owner extracts from such gains depends on his ability to replace the manager of the public agency. If the manager is fully replaceable, the principal can extract the entire gain by replacing the manager with one assigned to implement the efficiency-enhancing investment. In this case the incumbent manager has no incentives at all to undertake such investment, since it would only lead to his replacement. Conversely, if the manager is irreplaceable, he can pocket the gain, but he will still need to get his principal's agreement for the investment.

The private sector's quest for productive efficiency may compromise service quality.

The interaction between investment in productive efficiency (cost-cutting) and service quality (innovation) may weaken the case for private ownership. If the contract concerning service quality is incomplete because it cannot be unambiguously measured and monitored, and if the agent's investment in cost-cutting has a detrimental impact on the quality of output, the agent will invest too much in cutting his costs from the social perspective.[11] A classic example is prison services, as illustrated by Hart *et al.* (1997). Their quality is difficult to measure and may fall below a socially acceptable level if the agent's incentive to cut costs cannot be controlled. In the context of the tunnel example, the private owner-operator's efforts to cut costs by employing cheaper methods to monitor the condition of the tunnel may also have a negative impact on service quality since deterioration may go unnoticed, thus reducing service quality either directly or indirectly through an increase in the risk of tunnel usage. Note, however, that the desired service quality can always be achieved under public ownership as the public sector can choose not to agree to any investment in cost-cutting that would reduce service quality. The price for safeguarding service quality in this case is, obviously, lower productive efficiency; in other words, under public ownership there is too little investment in productive efficiency, while under private ownership there is too much.

10 This reflects the more general problem of hold-up in relation-specific investment under incomplete contracts. To the extent that an operator expects the owner to renegotiate the contract after the operator has made some relation-specific investment, he will invest suboptimally little so as to lessen his own loss from the renegotiation. As discussed in the main body of the text, ownership transfer to the operator can alleviate the hold-up problem. See, e.g. Hart and Moore (1990).

11 Hart *et al.* (1997) point out that even if effort to cut costs did not reduce service quality, it could have an indirect negative impact by raising the marginal cost of effort to invest in quality improvement (the so-called effort substitution problem). In other words, the profitability of cost-cutting may induce the private partner to focus too much on it and too little on quality improvement.

What about the incentives to invest in enhancing service quality, for instance by adopting technical innovation? Given that the contract is on service provision, any change with respect to service quality would necessitate its renegotiation, regardless of who owns the asset. Therefore, a private contractor would always receive the same payoff from renegotiating the contract and implementing the quality-enhancing investment regardless of whether he owns the asset or not. That he would need to share the gain from the investment with the public sector reduces his incentives to invest in better service quality; hence, there will be suboptimally little investment in service quality. A public agent would have even weaker incentives to invest in improving service quality, as the public sector principal can replace him by another one who makes the quality-enhancing investment while leaving the entire payoff with the principal.

To sum up broadly the results so far, it would seem that contracting out a public service to a private owner-operator is economically justified when the quality of the output is readily contractible or when improvement in productive efficiency does not impair service quality, and when the absorption of technical innovation to improve productive efficiency is important (i.e., in sectors where technical progress is rapid). Under these conditions, the promotion of productive efficiency through private ownership and operation of the asset can be combined with safeguarding allocative efficiency (service quality). On the other hand, public ownership of the underlying asset would appear desirable when the quality of output is difficult to contract on and cost-reduction can have a detrimental impact on the quality; and when the adoption of technical innovation is unimportant. Then the attainment of the desired level of allocative efficiency requires sacrificing some productive efficiency.

4.2 Bundling and incentives

So far, the discussion focussed on the issue of who owns the asset needed to produce a public service, without considering the construction of that asset or any possible interaction between asset construction and service provision. However, the essence of a PPP lies in the public sector's decision to purchase a service rather than an asset and to leave asset construction and service provision to a private partner. Therefore, it needs to be considered what difference the bundling of asset construction and service provision can make, as compared to more traditional public service provision ('unbundling') whereby the public sector purchases an asset from one agent and contracts out service provision using that asset with another agent. The analysis below is based on Hart (2003).

Bundling different phases of a project may reduce life-cycle costs.

Take the earlier tunnel example, but consider now the difference between contracting out the construction and maintenance of the tunnel either separately or bundled together. To the extent that the same firm undertakes both the construction of a tunnel and its subsequent long-term operation, it may be able to make investments in the construction phase that will allow it to reduce maintenance costs in the operation phase and thereby enhance productive efficiency. In contrast, if two separate firms undertake the construction and operation phases, such investments will not be made in the construction phase and, consequently, productive efficiency will be lower.

To illustrate, let us consider two types of investment at the construction phase that improve productive efficiency, one with a negative and the other with a positive effect on service quality. In the tunnel context, the former could be the installation of durable but unsuitable lighting, and the

latter could be the installation of 'cats eyes' (reflective, uneven sidelines) that reduce maintenance costs while increasing tunnel safety.

When the construction and operation phases are bundled, the private partner will choose the optimal level of the quality-improving investment—after all, it will reduce his costs—but too much of the quality-shading investment, especially if the public sector principal cannot monitor service quality precisely. Unbundling, in contrast, will not lead to excessive quality-shading investment, as the construction firm ignores subsequent maintenance costs altogether and simply aims at fulfilling the construction contract. For the same reason, unbundling will yield too little quality-improving investment.

In other words, whenever there are positive externalities between the production and provision phases, whole-life-cycle contracting will enable their internalisation and thereby improve productive efficiency.[12] Bundling the phases together encourages up-front investment that will contribute to cost reduction over the asset's life cycle. However, as cost reduction may have a detrimental impact on the quality of the service to be supplied, bundling is superior to unbundling only when the quality of the service can be sufficiently specified and verified—or at least more so than the quality of the asset needed to produce the service. This is arguably the case with a tunnel, where it is relatively speaking easier to contract on the service than on the underlying asset. On the other hand, this might not be the case with prison services, where the asset (a prison building) is relatively easy to contract on while the service itself (quality of prison services) is not.[13]

4.3 Risk transfer and incentives

It has been noted above that the long contract period and the difficulty of measuring and monitoring some infrastructure and public services to be supplied by PPPs make them particularly susceptible to uncertainty and risks. Moreover, the transfer of at least some such risks to the private sector partner is one of the key characteristics of a PPP. This section aims therefore to survey the link between risk transfer and the incentives to promote productive efficiency (for a more detailed analysis of this topic, see Dewatripont and Legros in this volume). But before doing so, let us specify what is meant by risk and risk transfer in the present context, and what types of risks there are to be transferred.

Risk must be quantified to be transferable and priceable.

In the present context, transferable risk refers to an uncertain but quantifiable outcome in terms of some of the project's costs or benefits. That outcome may refer to the production of the underlying asset (timely and on-budget completion of the construction of a tunnel); to the provision of related services (uninterrupted availability of the tunnel); or to the financial viability of the project (demand for the services provided and the project's profitability). For any of these, or other, risks to be transferable from the public to the private sector, there must be a way to quantify the uncertain outcome in terms of its magnitude, timing, and probability of occurrence. This will allow the pricing of the risk by the private sector partner and by the project's financiers, which is a precondition for the transfer to be sensible in the first place.

12 The same argument for bundling applies naturally to other phases of the project cycle as well. A fully-fledged PPP would be expected to generate efficiency gains from the bundling of the design, build, finance, operate, and maintain phases of the project's life cycle, for instance.

13 Bentz *et al.* (2001) focus on asymmetric information rather than contractual incompleteness as a source of incentive problems, and they suggest that bundling is better at resolving the incentive problems when the cost of building and operating the asset is low.

When talking about risk transfer in a concession-type PPP, one usually refers to the division of the risks associated with a project rather than to the sharing of them, as pointed out in PROFIT (2001). Once all project risks have been identified by the partners, an agreement is reached as to which partner carries each of the identified risks; that is, some of the identified risks are transferred to be carried by the private partner while others are carried by the public sector partner. Risk-sharing, in contrast, is more common in joint ventures where all risks are collectively shared between the partners in proportion to the share capital that they have contributed to the enterprise.

There are many ways of classifying the numerous risks that can be present in infrastructure or public service provision. At the most general level, von Hirschhausen (2001) distinguishes between technical, economic, and political risks. From the perspective of risk transfer, de Lemos *et al*. (2001) and PROFIT (2001) divide the risks into external risks to the project (global risks)—including political and economic risks—and internal risks to the project (elemental risks).[14] Following Eurostat's (2004) risk classification for national income accounting purposes, elemental risks can be further divided into risks related to the construction of the underlying asset; to the availability of that asset for service provision; and to the demand for the service in question. Additional elemental risk categories, identified in their own right by, e.g., Allan (1999) and IMF (2004a), include design risks; technology or obsolescence risks; financial risks; and risks related to the residual value of the asset at the end of the project period.

Risk transfer can affect cost efficiency through risk assessment and management.

Risk transfer improves productive efficiency to the extent that it improves the assessment and management of the project's risks. When a partner has to carry a risk, he will attempt to minimise any negative impact the risk could have on the project.[15] To the extent that his risk assessment and risk management capability reduce the project's costs, value for money is being created. An obvious precondition for the management of a risk is that it is manageable; that is, every risk should be allocated to the partner who is in the best position to affect the risky outcome and minimise any negative impact of the underlying uncertainty on the project. If none of the partners can control and hence manage a risk, the issue is to find the partner who can best bear the risk. Should more than one partner be in the position to control and manage a risk, productive efficiency is maximised by allocating the risk to the partner who can manage it most cost-effectively.

Starting with the global project risks, it seems obvious that the public sector partner is in a better position to influence events in the political, legal, economic and regulatory environment and should therefore assume the associated risks. Some global risks are outside the control of both parties (e.g., risks related to *force majeure* events), and they may therefore be either allocated to the party best able to bear them (presumably the public sector partner) or, alternatively, they may be shared between the partners.

Turning to the elemental risks, a key characteristic of a PPP is that the public sector partner acts as a purchaser of services, not the underlying assets, which are constructed and operated by the private partner. According to Lewis (2001) for instance, this implies that the risks associated with the asset itself—including design, construction, technology, operation (i.e., asset availability), maintenance, and residual value risks—should be primarily carried by the private partner. As the private partner also finances the construction and operation of the asset, financial risks would rest with the private partner and third-party investors.[16]

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14 See also the discussion by Grout (this volume) on specific and systematic risk.

15 For simplicity, the discussion refers to 'the private sector partner', although a PPP normally consists of a consortium of private firms, organised as a special purpose vehicle to execute the project. Each of such firms will have its own advantages in terms of risk management, so there will be further risk transfer within the consortium.

16 For a detailed analysis of the individual risks and their allocation between the partners, see for instance Lewis (2001) or Debande (2002).

A special mention is in place regarding the allocation of the demand risk, which can be influenced and hence managed only to a limited extent by either one of the partners. On the one hand, it can be argued that the public sector should assume the demand risk because demand is relatively more influenced by factors under the public sector's control, such as general economic policies or sector-specific policy measures. In other words, the public sector principal's actions can determine whether or not the project is financially viable and, consequently, whether or not any private agent is interested in participating in it (known in the microeconomic literature as the agent's 'participation constraint'). On the other hand, it can also be argued that the private sector partner should carry the demand risk, as it is the ultimate way to ensure that the private partner has the right incentives to act in the principal's interest and promote efficiency ('incentive compatibility constraint').

To satisfy both the participation constraint and the incentive compatibility constraint, one possible method to deal with demand risk is to agree on a formula to share it. For instance, the parties can agree on a rule whereby the public sector guarantees a minimum level of revenues to the private partner, thus satisfying the participation constraint. For the sake of symmetry, the principal might also choose to tax away any revenues exceeding a pre-specified ceiling. Within this band, the agent carries the demand risk, which serves to satisfy the incentive compatibility constraint. Outside the band, the principal carries the demand risk, thereby reducing revenue risk to the agent.

Transfer of demand risk can influence both productive and allocative efficiency.

The distinction between demand and revenue risks is key to understanding how risk transfer can influence allocative efficiency, as opposed to productive efficiency discussed above. Consider first the polar case where the agent carries the demand risk alone: in this case, the revenues and profitability of the project are market-determined and cannot be directly used by the principal to influence the agent's incentives. Consider then the case where the agent provides the public with services paid for by the principal on availability basis either in full or in part: in this case, the agent faces no or limited demand risk, but faces revenue risk to the extent that the principal makes his payment for the services provided they are delivered in agreed quantity and quality and over an agreed period in time. In other words, the principal can translate some or all of the demand risk into revenue risk facing the agent, thereby gaining an instrument to safeguard allocative efficiency. This obviously requires that the service output is contractible in the sense discussed in the section above.

4.4 The case for public-private partnerships: taking stock

Having examined the economic rationale for public sector participation in a PPP in Section 2 and for private sector participation in this section, it is time to put the pieces together and draw some conclusions about why and when a PPP may be economically sensible.

Starting with the 'why', recall that Section 2 concluded that the economic rationale for public sector intervention is the mitigation of a market failure, and that such intervention may take different forms, each of which is associated with its own costs. The design of public intervention will therefore need to aim at mitigating the market failure (maximising allocative efficiency) at the lowest possible cost. Whether or not private sector participation can then serve to lower that cost by improving productive efficiency beyond what can be achieved in traditional public provision—while not unduly compromising allocative efficiency—is the litmus test of whether a PPP is economically sensible or not.

This section has identified three possible sources of higher productive efficiency in a PPP than in traditional public provision. The first source is private ownership of the assets needed to produce infrastructure or public services, which can improve the incentives to undertake cost-reducing investments in those assets. This source can be particularly important over the whole life cycle of the project if there are gains from bundling (second source) due to positive externalities between

the different phases of the project. The third source is the division of risks associated with the provision of the services in question between the partners, which can improve the incentives to assess and manage those risks and thereby reduce costs.

All in all, it is conceivable that a PPP can be more efficient than the public sector alone in delivering the desired level of allocative efficiency. The ultimate source of such efficiency gains is the change of the instrument the public sector uses to mitigate a market failure, with the original instrument of public ownership and service provision being given up and replaced by private ownership and service provision.

As an instrument for public intervention, PPP boils down to a subsidy to the private sector.

What is then the intervention instrument that the public sector uses in a PPP? Essentially, by assuming some of the risks associated with the production and provision of a service by the private partner, the public sector extends a subsidy to the private partner, on the condition that the private partner delivers the desired level of allocative efficiency. The fundamental role of this subsidy is to satisfy both the private partner's participation constraint as well as the incentive compatibility constraint in a market characterised by failures: in the absence of the subsidy, the private partner would not enter the market in the first place or if he entered he would produce a socially suboptimal quantity or quality of the service in question.

Risk assumption by the public sector can also be thought of as a hedge extended by the public sector to the private partner free of charge, provided that the private partner satisfies the public sector's quest for allocative efficiency. If the public sector assumes all demand risk, it is effectively providing the private partner with a forward contract for free, guaranteeing a certain level of revenues for the provision of the service. Alternatively, if the public sector assumes the downside demand risk by guaranteeing a minimum level of revenues to the private partner, it is effectively providing the private partner with a put option for free, allowing the private partner to sell the service either at the market price or at the price stipulated by the option. In either case, the value of the instrument reflects the private partner's participation constraint.

To think of a PPP in terms of a subsidy or a free hedge provided by the public sector to the private partner through the partial assumption of project risks highlights that a PPP hinges upon appropriate risk transfer, formalised in the long-term contract between the parties. Any failure in risk transfer or contract design will undermine the efficiency gains that could potentially be achieved through PPPs.

To conclude, let us address the question 'when' can a PPP be economically sensible. Private asset ownership, construction, and operation were found to be conducive to efficiency when service quality is readily contractible; efforts to improve productive efficiency through cost-cutting do not significantly impair service quality; adoption of technical innovation is important for productive efficiency; when there are positive externalities between the construction and operation phases, and when it is relatively easier to contract on the service than the asset. To what extent these conditions are met in various infrastructure and public service sectors is discussed in detail by Riess (this volume).

Having seen why and when a PPP can be superior to traditional public procurement in terms of productive efficiency, the cost of the higher productive efficiency still needs to be examined. After all, the creation of value for money through a PPP is not a 'free lunch'—if it were, one would not expect to observe any traditional public provision at all. The cost of higher productive efficiency is the topic of the next section.

5. Transaction costs

The establishment and management of a PPP is associated with high transaction costs that undermine the gross efficiency gains, both directly and indirectly by limiting *ex ante* competition through high entry (bidding) costs, as elaborated below. Nevertheless, one should emphasise that little rigorous analysis has been devoted to transaction costs in PPPs, and it is ultimately up to future empirical research to establish whether or not transaction costs can wipe out the gross benefits of otherwise economically sensible partnerships.

The main sources of higher transaction costs in PPPs as compared to traditional public procurement and service provision are their long-term character, ownership and financing structures, and risk-sharing features. For all these reasons the search (tendering and bidding), contracting, and monitoring processes become more resource-consuming than in traditional short-term contracting aimed at supplying the public sector with assets rather than services. Negotiating the contract is especially costly, not least due to the high cost of advisory services, (see Box 2. for some anecdotal evidence from the UK), and such costs are not limited to the pre-delivery phase, as renegotiation is almost inevitable in contracts that stretch over decades.

PPPs are prone to higher transaction costs than traditional public procurement.

There is little systematic information about search and contracting costs in PPPs. In the UK, a project size of at least GBP 20 million is regarded as a minimum for a partnership to be viable according to HM Treasury (2003), exactly because of the high costs associated with tendering and contracting. According to Allen (2001), bidding costs to all potential contractors have reached as much as 3 percent of expected total project costs, regardless of project size, which is 3 times higher than in traditional public procurement.

The high cost of bidding is obviously a hurdle preventing potential bidders from entering the bidding process. This, in turn, undermines the power of *ex ante* competition—that is, competition for the market as opposed to competition in the market—which in many infrastructure and public service sectors is the only possible form of competition. The inability to harness the power of *ex ante* competition to support the quest for productive efficiency will, in turn, deter the creation of value for money through a PPP. Besides, as auction theory demonstrates,[17] designing the bidding process so as to avoid inefficiencies due to collusion or opportunistic behaviour is difficult as such, and all the more in the case of long-term contracts.

Besides, that a PPP is established for service provision using privately owned assets might entail higher monitoring costs than in-house provision of the same service. The provision of most services is relatively difficult to measure and monitor, especially in terms of quality. While in-house provision, too, necessitates quality control, it can be argued in view of the interaction between productive efficiency and service quality discussed earlier that private asset ownership implies higher monitoring costs for the public sector. After all, if the asset were in public ownership the public sector could always ensure the desired service quality, while private ownership can jeopardise service quality due to excessive investment in productive efficiency. It is therefore more costly to maintain the desired service quality under private asset ownership.

Some empirical evidence to this effect has been provided in the United States (US), as reported by Torres and Pina (2001). It has been reported that the monitoring of the performance of the

17 See Klemperer (1999) for an overview.

Box 2. Transaction costs in PPPs

The cost of negotiating deals

"PFI deals remain very costly to negotiate and these costs need to be factored into the assessment. At the outset of a deal departments need to set realistic budgets for their own administrative costs, to monitor these costs and seek to keep them under control. They must also be mindful of the costs to bidders. Imposing excessive costs on bidders is likely to result in higher charges in the long run and might deter firms from bidding." *(UK National Audit Office, Delivering better value for money from the Private Finance Initiative, June 2003.)*

"The procurement of PFI deals is inherently more complex than the procurement of conventional deals and can involve departments and bidders in heavy administrative costs. For example, on the Newcastle Estate deal (19th Report, Session 1999-2000), the cost of the procurement to the Department of Social Security rose from an initial estimate of £ 0.4 million to £ 4.4 million [about 2 percent of the discounted contract value], an eleven-fold increase, reflecting the complexity of this type of procurement and the Department's inability to undertake many of the tasks required to negotiate the deal. On the Prime deal to transfer the Department of Social Security estate to the private sector (41st Report, Session 1998-99), the Department's costs totalled £ 10.9 million, compared with an initial budget of £ 1.7 million, and the final three bidders spent around £ 27 million in preparing their bids." *(UK National Audit Office, Delivering better value for money from the Private Finance Initiative, June 2003.)*

"London Underground had always understood that it would be expensive to negotiate such large and complex deals and in February 1999 budgeted to spend £ 150 million. The outturn was £ 180 million (£ 170 million in 1999 prices). In addition, having decided to reimburse bidders' costs, London Underground agreed to add £ 57 million to the total deal to cover bidders' costs up to the point of selecting preferred bidders. London Underground required the preferred bidders to disclose the level of bid costs they intended to recover from the service charge. After prolonged negotiations the accepted level amounted to a further £ 218 million of bidders' costs and fees. In total 275 million of bidders' costs are reimbursed...As they were based mainly on output specifications rather than inputs, the costs of the programme could only be known when firm bids came in. It was then that the Department came to realise that the total costs falling on the taxpayer were far more than those considered affordable. There followed a review

private sector partner in PPP type of arrangements entails extra costs anywhere between 3 and 25 percent of the contract value. As a consequence, it has been recommended in the US context that monitoring costs of 10 percent of the contract value be budgeted in such arrangements.

Long contract periods give rise to a host of costs.

Apart from the direct costs related to tendering, contract negotiation, and monitoring, Domberger and Jensen (1997) emphasise that the long contract period also gives rise to economic costs indirectly. As noted above, the enforcement of a long-term contract can be difficult because contract termination can only be used as a threat if the public sector commits to buy the asset at fair value in case of termination; otherwise, expropriation risk would need to be factored into project costs. This cost is obviously the less important the smaller and less specific is the initial investment in the underlying asset. In addition, a long contract period lessens the disciplining power of *ex ante* competition, and increases the likelihood of costly contract renegotiation.

of the specification to reduce the total cost of the programme. The review and the subsequent re-bidding added some five months to the process therefore increasing costs." *(UK National Audit Office, London Underground PPP: Were they good deals? June 2004.)*

The cost of advisers

"Large amounts are being spent on advisory costs in taking forward NHS PFI deals despite there being considerable similarity between the deals. Over £ 70 million of taxpayers' money has been spent on NHS PFI advisory costs. The costs vary between 1 and 8 percent of the capital value of the projects with the average being 3.7 percent. This average is broadly consistent with the range of costs which the Ministry of Defence told us previously it expected to incur on major projects based on costs as a proportion of total contract value. In addition, the private sector is also incurring substantial costs on PFI deals which, it says, generally represent between 2 and 2.5 percent of the capital cost of each deal, with the costs being 10 percent of the capital costs of smaller projects. It is inevitable that these costs will be reflected in the pricing of PFI deals. In taking forward a series of PFI hospital deals the NHS seems to be paying repeatedly for the costs of similar advice." *(House of Commons, Public Accounts Committee, 19th Report, Session 2002-03.)*

"The cost of employing advisers also remains very high and in many cases continues to exceed budgets by a substantial margin. A fall in advisers' costs should have resulted from growing experience of doing deals. Departments need to drive down advisers' costs and ensure that sensible budgets are set and adhered to." *(UK National Audit Office, Delivering better value for money from the Private Finance Initiative, June 2003.)*

"Advisers' costs in PFI deals can exceed budgets by significant margins. For example, on the Newcastle Estate deal (19th Report, Session 1999-2000), the cost of legal advice increased from an initial estimate of £ 70,000 to an outturn of £ 2.3 million. On the Dartford and Gravesham Hospital deal (12th Report, Session 1999-2000) the Trust incurred advisers' costs of £2.4 million, which exceeded the initial estimates by almost 700%. After a series of hospital PFI deals, the Trust spent £ 2.3 million on advisers on the West Middlesex Hospital deal (19th Report, Session 2002-03), virtually the same amount as at Dartford and Gravesham four years earlier." *(UK National Audit Office, Delivering better value for money from the Private Finance Initiative, June 2003.)*

While it would thus seem clear that a PPP is associated with higher transaction costs than traditional public procurement and service provision, it is conceivable that such transaction costs decline over time. Both public and private partners undergo a learning process that will allow them to lower search and contracting costs and to establish a reputation that will reduce monitoring costs. A concrete example of how to lower contracting costs as a result of learning is the standardisation of PPP contracts that has started in the UK.

Transaction costs may decrease with experience.

6. PPP financing and macroeconomic impact

The discussion above has focussed on economic efficiency in the operational, or 'real economy' sphere of PPPs. However, the financing arrangements for such partnerships give rise to a host of

issues related to economic efficiency as well. The financing arrangements can also affect the design and conduct of fiscal policy, which suggests there is a macroeconomic dimension to PPPs as well.

The financial and macroeconomic aspects of PPPs are discussed under three separate headings below. The first concerns the cost of capital to the public and private sectors, and the key issue there is what difference, if any, does it make for economic efficiency who finances the investment. The second set of issues relates to the fiscal policy dimension of PPPs. By transforming the public sector from a service producer and provider into a service purchaser, a public-private partnership changes the composition and time profile of public spending. To what extent that change has a real macroeconomic impact is assessed below. Finally, the link between microeconomic efficiency and growth at the aggregate level is reviewed to assess whether or not PPPs have a broader macroeconomic impact.

To start with the cost of capital, there is no denying that the public sector can in general raise funds at a lower cost than the private sector. This being the case, why should the dearer private financing be considered in the first place?

As shown in Grout (1997), it does not make any difference for the population in terms of utility or risk who finances, produces, and provides the service. The only difference between the public and private alternatives is that risk is explicitly accounted for in the private sector's cost of capital, while it is not in the case of the public sector. As it is obvious that the risk is there in both cases, it appears puzzling why the public sector can still borrow at a lower cost.

The public sector's ability to tax makes it possible to separate the risks related to the project outcome and the repayment of the credit used to finance the initial investment. The former will be borne by the users of the infrastructure or public service, while the latter will be spread across taxpayers. The public sector is therefore able to transfer and spread risks more extensively than the private sector, allowing it to raise seemingly cheaper financing without, however, eliminating them. The risks will be there, they will just be borne by others, none of whom is actually compensated for bearing them. Hence the seemingly lower cost of capital.

Explicit pricing of risk is beneficial.

While the difference in the cost of capital between the public and private sectors is therefore more apparent than real, there are nevertheless some important differences between public and private sector financing of one and the same project. The fact that investors are explicitly and directly compensated for the credit risk they assume in the case of private sector financing improves project selection in the economy and allocative efficiency. Note that this also applies when the transfer of project risks is suboptimal, i.e., when the private sector partner has to carry risks it cannot manage or bear. In this case, the suboptimal risk transfer translates directly into higher cost of capital, as discussed by Grout (this volume). In addition, the explicit recognition and pricing of risk encourages better risk management and contributes to higher productive efficiency.

Turning to the link between PPPs and fiscal policy, let us first review their accounting treatment to see how exactly they can affect the measured fiscal position. To start with, the accounting treatment in national accounts statistics is based on the principle that any economic unit, including a PPP, can only be recorded in national accounts statistics in one institutional sector (Eurostat 1995). That is, a PPP can only be a public sector entity or a private sector entity. Even when a PPP is a joint venture with shared equity participation by the public and private sector partners, it cannot be split between the institutional sectors.

Whether a PPP is included in the public or private sector makes all the difference for the measured fiscal position. If the partnership is part of the public sector (general government), the financing and acquisition of the underlying assets appear on the public sector's balance sheet, directly affecting the measured fiscal deficit and public debt. If, on the other hand, the partnership is recorded as a private sector entity it has only a limited short-term impact on the fiscal accounts. The financing and acquisition of the underlying assets appear on the private sector's balance sheet, and the public sector only incurs current expenditure for paying for the service itself once its supply starts.

The practices for recording PPPs have varied across countries. Some countries have recorded all of them on the public sector's balance sheet, others have recorded at least some of them off the public sector's balance sheet. To harmonise the varying recording practices, Eurostat (2004) contains a decision on the treatment of PPPs in the national accounts.[18] It is based on an assessment of the distribution of risks between the partners, and it stipulates that a partnership should be recorded off the public sector's balance sheet if the private partner carries the construction risk and either the availability or the demand risk for the project in question. In other words, the partnership will be recorded as a private entity and thereby outside the public sector's deficit and debt calculation provided the private partner carries at least one of the major long-term risks, in addition to the shorter-term construction risk. Otherwise, the partnership will be recorded on the public sector's balance sheet.

Statistical treatment of PPPs affects incentives to use them.

The either-or treatment of PPPs in national accounts statistics has an unfortunate impact on the public sector's incentives to use them as a vehicle for infrastructure and public service provision. The recording of investment through partnerships on the public sector's balance sheet alone can introduce an unwarranted bias against them as this would exaggerate their impact on public deficits and debt. On the other hand, IMF (2004b) suggests that the recording of investment through partnerships on the private sector's balance sheet alone can introduce an unwarranted bias in their favour as it would belittle their impact on public deficits and debt. This, in turn, could appear as a relaxation of the public-sector's short term budget constraint. As such a 'relaxation' does not interfere with the supply of infrastructure and public services to the population, a PPP may seem appealing even when it does not yield any microeconomic efficiency gains. It is, however, important to recognise that a PPP—even when recorded off the public sector's balance sheet—generates a future liability for the public sector as it commits itself to purchasing the service.

The relaxation of the public sector's budget constraint is indeed more apparent than real even from a short-term macroeconomic perspective. As an instrument for short to medium-term macroeconomic stabilisation policy, fiscal policy should be calibrated to the prevailing cyclical situation, and the level of public spending should be neither too high to induce overheating and inflationary pressure, nor too low to unduly contract economic activity. The mere shifting of investment projects in terms of accounting from the public to the private sector does not create any fiscal leeway—it just reallocates a given level of economic activity between institutional sectors in national accounting. If some investment through PPPs has been reallocated from the public to the private sector, and if the public sector increases spending by the same amount, it increases aggregate demand in the economy. If the initial fiscal stance, with the investment projects on-budget, were optimal from the cyclical perspective, the new stance, with the investment outside the budget but with an unchanged amount of total expenditure, would be too expansionary. In other words, PPPs do not create any fiscal leeway, they just create a false impression of such a leeway.

18 Donaghue (2002) and IMF (2004a) review the details of the fiscal accounting of different types of PPPs.

The apparent relaxation of the public sector's budget constraint may have a particularly strong incentive impact in the presence of fiscal rules such as the Stability and Growth Pact, which sets an implicit ceiling on overall public spending.[19] In the worst of cases, political economy considerations prompt the government to resort to PPPs to deliver infrastructure and public services in order to create budgetary room for increasing unproductive fiscal spending. If the government's economic policy is not determined by economic considerations alone, as is often the case, PPPs can be introduced where traditional public service provision would have been more efficient, for the purpose of increasing unproductive public spending while satisfying a fiscal rule.

Choice of a PPP should not rest on fiscal policy considerations.

For these reasons, a PPP should not be regarded at all as a fiscal policy instrument and, consequently, its apparent fiscal impact should not be the tail wagging the dog. The decision to undertake an investment project through a PPP should be solely based on the microeconomic merits of such an arrangement in terms of economic efficiency, with no role for fiscal policy considerations in the decision-making process.

Having said that, the fiscal and macroeconomic consequences of PPPs need to be explicitly recognised, recorded, and reported. The current rules and practices for recording them, as reviewed above, remain unsatisfactory. Not only do they hamper the macroeconomic analysis of PPPs, but they also create incentives for policymakers to use partnerships when not economically sensible or reject partnerships that would be economically sensible. The development of an incentive-neutral fiscal recording system based on the actual and contingent costs and benefits arising from the distribution of risks and rewards between the partners seems therefore like a high-priority measure to exploit PPPs' economic potential while containing the economic abuse of their political potential.

To conclude with brief remarks on PPPs and economic growth, it has been argued that a PPP may under certain circumstances be associated with higher productive efficiency than traditional public financing and service provision. It is, however, important to acknowledge that an improvement in productive efficiency does not automatically translate into higher economic growth at the aggregate level. Higher productive efficiency just implies that a smaller share of the economy's total savings is required to finance the project in question. However, there is no guarantee *ex ante* that the savings thus freed for other purposes will be used productively. In principle, anything is possible: they can be used to finance productive investment, but they can equally well be used to finance unproductive investment. This being the case, one cannot unambiguously conclude whether the choice of a PPP structure in the context of an individual project will have a positive, negative, or no impact on aggregate growth.

19 Apart from creating incentives to use PPPs to shift public investment off the public sector's balance sheet, such rules have been criticised more broadly for failing to recognise the long-term character of public investment and therefore introducing a bias against it. Proposed solutions to this failure include the introduction of a 'golden rule' that excludes public investment from the calculation of the fiscal deficit and debt measure to which the fiscal rule is applied. Going one step further, Blanchard and Giavazzi (2004) propose the establishment of a separate public investment agency that would be responsible for managing all public investment and that could issue public debt for the financing of net investment. However, such proposals have met criticism as they allegedly introduce a bias in favour of physical and against human capital investment; as they fail to recognise the fiscal sustainability concerns that underlie the fiscal rules in the first place; and as measurement problems related to depreciation make them difficult to implement in practice. See European Commission (2003b).

7. Conclusions

This paper has reviewed the economic pros and cons of undertaking investment in infrastructure and public services through PPPs. The broad conclusion that arises from the analysis above is – perhaps unsurprisingly for an economics paper—that PPPs can offer benefits over traditional public provision in terms of economic efficiency, but that such benefits come with costs, which may or may not outweigh the benefits.

A PPP can be seen as an alternative instrument for public sector intervention to alleviate a market failure and safeguard allocative efficiency in the economy. In contrast to the more traditional way of supplying infrastructure and public services whereby the public sector finances and owns the assets needed to produce them, a PPP is based on the notion that the public sector can safeguard allocative efficiency even when the assets are financed and owned by the private sector, who also provides the final services to the population. The public sector retains control over allocative efficiency by means of a long-term contract with the private sector partner that stipulates the quantity and quality of the service to be supplied.

A PPP can offer microeconomic benefits.

The private sector partner, as the owner of the assets, decides on the best way to supply the service in order to fulfil the contract. The private partner, being profit-driven, will seek to maximise the efficiency with which the service is produced and supplied. Private asset ownership may therefore improve productive efficiency beyond the level that can be achieved with traditional public service provision. Such efficiency gains could, in principle, be reinforced through market liberalisation. In practice, however, competition is unlikely to become a significant source of efficiency gains in many markets for infrastructure and public services.

The essence of the partnership lies in the division of risks and returns associated with the project. The assumption by the public sector of some of the risks may be a necessary precondition for the private sector partner to get involved in the project in the first place. This highlights the fundamental character of a PPP as a subsidy vehicle: by assuming some of the risks free of charge, the public sector extends an implicit subsidy to the private sector partner so as to make the partnership economically attractive. This subsidy replaces the traditional service provision as the policy instrument that the public sector uses to safeguard allocative efficiency.

However, these potential strengths of a partnership can turn into weaknesses. The pursuit of productive efficiency may jeopardise allocative efficiency, as cost-cutting may lead to quality-cutting. The division of risks, in turn, can become a source of productive inefficiency if it fails to allocate each risk to the partner in the best position to manage or bear it. And, finally, the fact that the partnership requires the establishment of a long-term contract with a high degree of incompleteness imposes a significant cost on it.

Indeed, the high transaction costs are perhaps the worst, and least studied, drawback of PPPs. The need to find the right private sector partner, and to negotiate, monitor and renegotiate a long-term contract giving him the right incentives to strive for service quality while containing costs makes a PPP dearer to set up and follow up than in-house public sector service production and provision. Furthermore, the high search costs (tendering and bidding) serve to limit the power of *ex ante* competition in creating the right incentives to promote productive efficiency.

Higher transaction costs, along with higher credit risk, also raise the financing costs for a PPP above those of the public sector. While the higher financing costs make it more difficult to attain the

project's hurdle rate of return, the economic rate of return and allocative efficiency might well be higher under private financing as risk is explicitly recognised and priced, and as risk assumption by investors is rewarded.

If the circumstances are such that private financing (and service production and provision) is superior to public financing (and service production and provision), it would appear that public finances receive a windfall. It is easy to grasp how political economy considerations suggest that there will be a rush to seize the room for manoeuvre in public finances that is seen to emerge. Moreover, it is easy to grasp how similar considerations suggest that the creation of such leeway becomes an argument in its own right for using PPPs for supplying infrastructure and public services.

There is no macroeconomic case for or against PPPs.

However, fiscal policy should be a non-issue in deciding how to produce and provide services. The shifting of investment between public and private sector books does not create any leeway in public finances or in the economy more broadly. In other words, there is no macroeconomic case for—or against—PPPs.

There is a case, though, against the current accounting treatment of PPPs in the national accounts as it does not recognise the real costs and benefits to the respective partners based on the agreed division of risks and returns. The fact that a partnership is either not at all or fully included in public sector and fiscal statistics makes the public sector either love or despise it. This further skews the public sector's incentives to establish partnerships, increasing the risk that their use is driven by political and accounting considerations rather than by economic efficiency considerations.

Despite all these caveats, there is an economic case for a PPP if it can deliver a combinatin of allocative efficiency and productive efficiency, at non-prohibitive transaction costs, that is superior to traditional public provision of an infrastructure or public service. Under such circumstances a PPP is the optimal instrument for public sector intervention.

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ABSTRACT

This paper critically assesses the implications of contract design and risk transfer on the provision of public services under public-private partnerships (PPPs). *Two results stand out. First, the alleged strength of PPPs in delivering infrastructure projects on budget more often than traditional public procurement could be illusory. This is – to put it simply – because there are costs of avoiding cost overruns and, indeed, cost overruns can be viewed as equilibrium phenomena. Second, the use of external (i.e., third-party) finance in PPPs, while bringing discipline to project appraisal and implementation, implies that part of the return on efforts exerted by the private-sector partner accrues to outside investors; this may undo whatever beneficial effects arise from 'bundling' the construction and operation of infrastructure projects, which is a hallmark of PPPs.*

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Public-private partnerships: contract design and risk transfer

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1. Introduction

The financing and development of large projects, for example to provide physical infrastructure (roads, water supply, dams and the like) or public goods (schools, jails, information networks), often span many years, involve a variety of economic and political participants, and depend for their success on the efforts and investments of these participants. The main purpose of this paper is to argue that the risk assessment of such projects cannot be separated from the contracting terms that will be established between the parties. We should not consider the risk of these projects as purely exogenous and assess only the risk before contracting. This does not mean that exogenous risk is absent – for instance, a storm may destroy a bridge. But there are also endogenous risks, i.e., risks that are influenced by the contracting terms – for instance, if the contractor is paid just for the completion of the bridge, he may use sub-performing cement, with the consequences of this choice appearing only after many years, possibly at the same time as an event like the storm we alluded to before.

Endogenous risk can be due to a host of imperfections in the economic environment, but two are especially relevant. First, the sponsor of the project, the oversight committees, the builder, and the operator of the project usually have conflicting preferences about the quality that should be achieved and the costs that should be incurred: the builder wants to minimise the cost of building, but this may increase the cost of operating the project; if the sponsor is subject to budgetary approval, he may want the best quality for the project while the oversight committee may want to minimise costs. Because of exogenous risk or imperfect monitoring, the outcome of the actions taken by the different parties may not be perfectly verifiable. Second, given the complexities of the technologies involved and the difficulty to audit, participants have private information about contractual variables (for example, the costs for the builder and operator, information about budgetary or monetary policies for the sponsor) and cannot identify all possible contingencies that could affect the timely delivery of the project or the cost of building and operating it.

Disentangling exogenous and endogenous risk is the objective of the economics of regulation under asymmetric information and the theory of incomplete contracts, which we review in Section 2. Both literatures stress that – in addition to the standard cost-benefit analysis that could be applied if the environment were of perfect and symmetric information – it is necessary to consider endogenous contracting costs linked to the agency problems generated by asymmetric and incomplete information. Despite the natural application of this literature to public-private partnerships (PPPs), there is, somewhat surprisingly, a paucity of papers on the topic. Obviously, whether endogenous costs of contracting are important will depend on the extent of the agency problems and on the institutional possibilities to correct for them, for example, whether the sponsor can perform *ex ante* and *ex post* audits, whether contracts can include enough contingencies, and whether the result of the audits can be used as contingencies in contracts. In recent years, there have been applications of this theory to public-private partnerships. These applications have focused on the costs and benefits of bundling the building and operation of infrastructure, as also surveyed in Section 2.

In Sections 3 and 4 we turn to analysing two key aspects of PPPs that have hardly been touched upon in the literature. First, many PPP projects are by essence exposed to political risks due to changing objectives, which often manifest themselves in cost overruns. In Section 3 we assess the potential of PPPs to remedy such soft objectives and to help avoid cost overruns. Second, although PPPs are also called PFI (for Private Finance Initiative), the financial dimension of contracting has – somewhat

surprisingly – been missing. We introduce financing in Section 4, borrowing insights from the recent financial contracting literature. We analyse the consequences of shifting the investment risk of public projects to private parties, and we look at the pros and cons of involving external (i.e., third-party) investors in the financing of PPPs.

2. New economics of regulation and contract theory: overview and applications to PPPs

2.1 Insights from the new economics of regulation and contract theory

The purpose of this section is to sketch insights from two strands of literature relevant for the analysis of contract design and risk transfer in PPPs. We will use these insights in subsequent sections.

The new economics of regulation stress the trade-off between efficiency and rent extraction.

One strand of literature is the 'new economics of regulation' associated in particular with the book by Laffont and Tirole (1993). This literature stresses the trade-off between efficiency and rent extraction when the regulated firm has an informational advantage. This advantage has two components. One is that the firm is better informed about itself than the regulator; the firm has thus information that is hidden from the regulator. The other is that the firm knows its actions but the regulator may not; in other words, the firm can take actions that are hidden from the regulator. Box 1 describes a simple version of this trade-off between rent extraction and efficiency in the presence of hidden information and hidden action.

This model can be extended to a dynamic setting and be used to analyse the consequences of limited commitment of the government, a topic to which we will return later on. Schmidt (1996) considers regulation with asymmetric information in a model *à la* Laffont-Tirole. Its starting point is that of a government owning a firm and being plagued by a commitment problem: the government cannot commit not to expropriate (public) managerial investment by lowering the price it offers the firm for its service.

Schmidt (1996) considers that the public firm is run by a utility-maximising manager, just as a privately owned firm would be. The manager may invest to improve efficiency, or in the notation of Box 1, the intrinsic efficiency parameter β (that is taken as an exogenous random variable in Box 1). The key aspect of public ownership is that the government has access to all information about the firm after the efficiency-enhancing investment has been made (or not), so there is no asymmetric information**.** This is good in terms of short-term incentives because the trade-off between efficiency and rent extraction is avoided. But it means that the government completely appropriates any surplus generated *ex post* by managerial investment.

In this context, privatisation reduces the information the government can access about the firm. This allows the firm to appropriate an informational rent and induces it to underprovide effort e compared to a situation where its intrinsic efficiency β is known. Privatisation is thus bad for short-term or *ex post* incentives. However, a lower β means a higher informational rent, so that privatisation and the asymmetry of information it induces raise the firm's incentives to invest in lowering β (when it is possible to influence one's intrinsic efficiency), which is good from an *ex ante* incentive point of view.

The other strand of literature relevant for the analysis of contract design and risk transfer in PPPs is on 'incomplete contracting'. This literature is associated in particular with the papers by Grossman and Hart (1986) and Hart and Moore (1990) and also the book by Hart (1995). Its starting point is the work of Williamson (1975, 1985), which stresses that market relations are problematic when they require

Box 1. The trade-off between rent extraction and efficiency

Assume that the firm has an intrinsic productivity parameter β and reports an accounting cost level C such that:

$$C = \beta - e.$$

The cost level C is thus influenced not only by the firm's intrinsic productivity parameter β but also by a level of effort e, costly for the firm and which it privately chooses (the firm's choice of e is a hidden action). To be specific, define $\psi(e)$ (increasing and convex in e) to be the cost of effort for the firm. In this simple example, productive efficiency requires:

$$\psi'(e) = 1.$$

Such an outcome can be achieved through a fixed-price contract, whereby the firm gets a fixed amount of money for its services and therefore is residual claimant on its cost savings. Such a high-powered incentive scheme, while good in terms of efficiency, does imply a potential problem when the regulated firm has private and, thus, hidden information on the parameter β. In this case, an excessively generous price allows a 'low-β firm' (i.e., a firm with a high intrinsic productivity) to keep any productivity advantage $\Delta\beta$ (which is then the informational rent of the firm) while a lower price runs the risk of inducing a 'high-β firm' (i.e., a firm with a low intrinsic productivity) to shut down.

As Laffont and Tirole (1993) have shown, one way to get around this challenge and limit rents while making sure the service is always provided is to offer a not-too-generous price, but with an option to move (partly) to a cost-plus contract (which is a low-powered incentive scheme) in case the firm claims to have a relatively high β. In essence, what is offered to firms is a menu of contracts designed so that firms with a high intrinsic productivity choose high-powered incentive schemes whereas those with a lower productivity choose a low-powered incentive scheme. The advantage of such an approach is that it lowers the rents to be conceded to the 'low-β firm' while guaranteeing that the service is provided. Its disadvantage is that when less intrinsically productive, the firm reduces its effort since it knows that part of the cost saving is shared with the regulator through the partial cost-plus scheme.

relation-specific investments while taking place in a complex environment. This complexity makes contractual incompleteness unavoidable, leading to underinvestment in the relationship due to the fear of *ex post* 'hold-up'. Specifically, higher investment by one party can trigger tougher *ex post* bargaining by the other party, which is tempted to grab a share of the surplus generated by the investment. Incomplete contracts typically fail to fully protect the parties against such opportunistic behaviour when it is difficult for a court to distinguish good-faith renegotiation demands (for example, when exogenous market conditions have changed) from bad-faith ones (those specifically triggered to take advantage of higher investment by the other party).

The theory of incomplete contracting suggests that market relations can result in too little relation-specific investment.

Without considering the details of intra-firm relations, Williamson stressed that a way out of the underinvestment trap was to resort to integration. Grossman, Hart and Moore (hereinafter GHM) take a more symmetric view of inter-firm and intra-firm relations by considering two (or more) individuals who each have to make relation-specific investments in a situation where the firm structure is defined by asset ownership. Asset ownership is assumed to confer residual rights of control over the asset, and it motivates individuals to invest by giving them bargaining power *ex post* (since they retain control over the asset they own in case of disagreement) and thus higher returns on their investments.

Integration is not a panacea, however: while being a 'boss' and owning one's asset as well as the other party's asset raises one's incentives to invest, *mutatis mutandis*, having a 'boss' reduces one's incentives to invest.

The literature therefore stresses that in a simple two-party world when (i) one party's investment is much more important than the other's, integration is the optimum with the former party as boss, whereas when (ii) both parties' investments are roughly equally important, separation is the desirable outcome. These results assume that both parties have large levels of wealth and can optimally trade ownership of assets *ex ante*. With limited liability or wealth, the transfer of ownership may not be efficient in the sense of maximising the total expected surplus from the relationship.

The new economics of regulation and incomplete contract theory provide important lessons for contract design and risk transfer in PPPs.

To conclude, the new economics of regulation and incomplete contract theory provide four lessons relevant for the analysis of contract design and risk transfer in PPPs. First, when information is asymmetric, the regulator faces a trade-off between the goal of reaching an efficient supply of the regulated economic activity and the goal of extracting part of the regulated industry's informational advantage. As we will see in the next section, the government faces a similar trade-off when procuring public services under a PPP. Second, as contracts are incomplete, there is a trade-off between *ex post* decisions rights and *ex ante* effort choices, implying that if economic agents have *ex post* decisions rights, they will exert greater efforts *ex ante*. Third, as public owners of an asset cannot commit not to expropriate the returns on managerial effort, private ownership may be best. Fourth, the choice of contracts modifies project returns or their distribution and, thus, impacts on endogenous project risks.

While the literature reviewed so far captures important dimensions of the constraints in contracting for public-private relationships, two important dimensions are missing: (i) the bundling of decision rights for building and operating an asset and (ii) the shifting of investment risk from the public to the private sector. We will address the first issue in the next sub-section and the second issue in Section 4.

2.2 Application to PPPs: bundling decision rights

Abstracting from short-term political motives, the value for the public sponsor of a PPP lies in the cost and the quality of the service produced, with cost and quality depending on the financing, building, and operation of the project infrastructure used for delivering the service. There are clear links between financing, building, and operating the infrastructure. To illustrate, building determines the quality of the infrastructure, which – in turn – influences positively or negatively the cost of operating and maintaining it: a high-quality infrastructure may make its maintenance technically challenging and costly – for instance requiring skilled workers – or it may ease maintenance by lowering the likelihood of failure; on the other hand, a poorly designed bridge or a poor cement quality may raise the risk that the bridge collapses during a storm.

Unless the party responsible for building is induced to internalise possible externalities on the operating phase of the infrastructure, inefficiencies may arise. The potential cost of these inefficiencies can be large, for instance, when poor construction raises the risk of a bridge collapsing during a storm. As recent work has shown the builder has an incentive to internalise externalities if he also has the right to operate and maintain the infrastructure.

There are two strands in the literature on the bundling of decision rights that echo the two approaches reviewed in Section 2. One focuses on the role of asymmetric information and analyses how informational rents and incentives to undertake efficiency-enhancing efforts change if building

and operating decisions are separated. The other strand focuses on the role of contract incompleteness for the efficient allocation of decision rights. In what follows we will discuss both strands of literature. In addition, we investigate the role of PPPs in limiting cost overruns and ask to what extent avoiding cost overruns is desirable in the first place.

2.2.1 The role of asymmetric information

PPPs can mitigate or exacerbate inefficiencies arising from asymmetric information.

There can be two types of information asymmetries: hidden information and hidden action. In the former, an economic agent has superior information compared to other agents. In the context of PPPs, we could think of a situation where the government agency procuring a service has private information about service delivery costs that the firms bidding for this PPP do not have. With hidden action, an economic agent can take actions that are not observable by other agents. A case in point is an effort by a builder to cut construction costs even if this leads to higher operating costs. It should be added that hidden information and hidden action are closely related to the possibility of adverse selection and moral hazard, respectively. In what follows we look at two papers (Iossa and Legros 2004 and Bentz *et al.* 2002) that consider adverse selection and moral hazard in a world where complete contracts can be written. Both papers consider a sequential contracting setting in which effort in the first period is valuable for operation in the second period; both papers also stress private information about operating costs.

Iossa and Legros (2004) present a general model of regulation under soft audit information, but it can be easily applied to PPPs. There are two periods, and one can think of the first one as the building stage and the second one as the operating stage of an infrastructure project. The public sponsor of the project can allocate the right to operate to the builder or another agent (call this an entrant). An entrant does not have information about building effort in the first period but may acquire it by doing costly auditing.

In these circumstances, it is optimal to give the potential entrant the option to buy the right to operate the project in the second period and to have the builder (i.e., the first-period agent) receive the monetary payment from the operator in this case. If the entrant does not exercise his option, the builder continues to operate the asset. The entrant exercises his option if auditing shows that the underlying asset is in a good state: this solves both the problem of revelation in the second period and also induces the entrant to exert audit effort. Because the builder collects a high monetary payoff when the entrant exercises his option to operate, this contract provides incentives for effort in the first period. The model therefore suggests that creating competition for the right to operate the asset dominates contracts where one party both builds and operates the asset and contracts where one party builds and the other operates the asset. Key assumptions of this model are that information about the outcome of the building stage of the project can be obtained only through third-party audit and that information about the outcome of the operating stage is hard to verify.

In Bentz *et al.* (2002), the operator learns – without incurring costs – whether operating costs will be low or high; in the latter case, he can exert effort during the building phase with a view to cutting operating cost. For instance, the builder of a bridge may learn during the building phase of a new technology that will reduce the stress on the beams and therefore decrease maintenance costs. This leads to two types of inefficiencies in contracting. First, since the operator privately knows whether operating costs are high or low, even an optimal operating contract will leave an informational rent with the operator (as in the model of Box 1). Second, since there is moral hazard at the building stage with positive probability, the builder needs to be given incentives to invest in the reduction of operating cost; note that such incentives may be inefficient if the increase in the probability of lowering operating cost is small relative to the required investment.

Bentz *et al.* define a PPP as the ability to contract with only one agent, the consortium, who builds and operates the infrastructure. Without a PPP, the (risk-neutral) builder contracts without private information and, as a result, has to be paid only for the expected cost of the investment; but the informed operator gets an informational rent to reveal operating cost, enabling him to give incentives to the builder. Under a PPP, the builder-operator consortium knows at the contracting stage whether investing in the new technology can be helpful or not; this raises the informational rent to be conceded. On the other hand, an advantage of a PPP is that the consortium will invest 'for free' to obtain this informational rent. The main result is that when the cost of investment is low, a PPP is better (because the first effect dominates); otherwise it is worse (because the second effect dominates).

2.2.2 The role of incomplete contracting

PPPs can mitigate or exacerbate inefficiencies arising from incomplete contracts.

We now change perspectives by looking at two papers (Hart 2003 and Bennett and Iossa 2004) that assume symmetric information but account for the fact that contracts are incomplete. Both papers use the GHM paradigm to investigate the effects that the bundling of decision rights has on the incentives for investment in cost savings and quality improvements. The public sponsor (the government), the builder, and the operator have conflicting preferences for these investments: the private parties tend to consider mainly the cost effects of these investments while the sponsor also cares about the social benefits they bring. For instance, adding a traffic lane on a bridge may reduce congestion, but will increase significantly the cost of building the bridge.

Box 2 summarises Hart's model. In his model, the builder can make two types of non-contractible investments that would result in lower operating costs: one investment (e) not only lowers operating costs but also leads to an increase in the social quality of the service, another (i) cuts operating costs at the expense of service quality. Therefore, while both investments reduce operating costs, only e brings social benefits. For instance, in the bridge example, e can be the use of a new technology that reduces the stress on the beams, which is socially valuable since it lowers the frequency of repairs and, thus, of traffic interruptions; i can be the use of a design with fewer traffic lanes, which lowers the cost of cleaning, painting, and maintaining the bridge but increases traffic congestion.

Hart chooses a parameterisation that makes investment i socially wasteful independent of its cost. However, such an investment may not be wasteful for the contractor if the cost of investment is small enough. The benefit of bundling construction and operation of an infrastructure asset under a PPP is to induce the builder to internalise the savings in operating cost. But this comes at the expense of service quality, which – in Hart's model – outweighs operating cost savings. In these circumstances, traditional public procurement results in the socially optimal level of this type of investment ($i = 0$). That said, bundling also induces the builder to internalise the positive effect of e on operating cost; and as this investment improves the quality of the service, it is socially beneficial. In other words, bundling construction and operation under a PPP contract leads to a higher level of the socially beneficial, quality-improving investment than traditional public procurement.

So, if a PPP stimulates both the socially desirable and the undesirable investment, when is a PPP better than traditional public procurement? Hart concludes as follows: (i) if the cost-cutting, quality-improving investment e can be verified, traditional procurement is better than a PPP because $i = 0$ is optimal and e can be set at the efficient level by contracting with the builder; (ii) instead, if the cost-cutting though potentially quality-shading investment i can be verified, PPP dominates traditional procurement since the contractor has better incentives to carry out the quality-improving investment ($e = 1$).

Box 2. Public-private partnerships – insights from Hart (2003)

At the operating stage of an infrastructure asset, the benefits (B) of the service to society and operating costs (C) incurred by the operator are as follows:

$$B = B_0 + e - i$$
$$C = C_0 - e - i$$

B_0 and C_0 are the normalised benefits and costs when none of the two investments are realised. Assume that e and i take values in {0,1}, a value of 1 meaning that the investment is made. Further assume that the costs of carrying out the non-contractible investments are c_e and c_i. The optimal outcome involves choosing e and i so that social benefits are maximised, with social benefits being the difference between the benefits of the service, on the one hand, and operating cost and the cost of investing in a reduction of operating cost on the other hand. In other words, the optimal outcome involves choosing e and i to solve:

$$max\ B - C - (e\,c_e + i\,c_i)$$

This means choosing $i = 0$ for all c_i (because the cost-reducing investment is costly and its net social value is 0). On the other hand, e (i.e., the investment that lowers operating cost and raises the quality of the service) does improve social benefit if it is not too costly. Specifically, we should have: $e = 1$ if $c_e < 2$.

How does contracting for a PPP (under which the right to build and operate the asset is given to one party) and traditional public procurement (under which the public sponsor contracts first with a builder and then with an operator) fare in comparison with this optimal outcome?

Under traditional procurement, the builder does not internalise the impact of e and i on operating cost and service quality and, thus, chooses $e = i = 0$. He therefore chooses the right level for i but underinvests in e. The government ends up paying C_0 at the operating stage, and society obtains a surplus of $B_0 - C_0$.

Under a PPP instead, at stage 1, the contractor internalises the effect of e and i on operating cost and, therefore, chooses e and i to minimise $C + ec_e + ic_i$. Consequently, he chooses $i = 1$ if $c_i < 1$ and $e = 1$ if $c_e < 1$. Under a PPP, one may thus end up with the optimal level of e but too much of the quality-shading investment i.

PPP introduces a long-run profit motive, which can lead to good or bad results.

Hart's setting is thus similar to that of Hart *et al.* (1997) on privatisation: by giving ownership of the second stage (i.e., the operating stage) to the first-stage contractor (i.e., the builder), PPP introduces a long-run profit motive. This is what makes it attractive for the first-stage contractor to potentially invest in quality improvement and cost savings. Of course, this is good only insofar as private and social interests are aligned. In fact, Hart *et al.* show that the profit motive can lead to good or bad results. To make this point they consider a multitask model *à la* Holmström and Milgrom (1991), namely the government cares not only about cost efficiency but also about quality provision. Privatisation strengthens incentives, which means that cost efficiency is improved, but if quality is non-contractible (or if not all aspects of quality can be contracted on), it may be sacrificed as a result. Hart *et al.* argue that the optimal ownership outcome depends on the nature of contract incompleteness: private ownership is better if cost efficiency is key and quality can be more or less controlled by the contract. In the opposite circumstances, public ownership may be preferred.

The main contribution of Bennett and Iossa (2004) to the literature on the allocation of ownership rights and to the literature on PPP is the observation that in the presence of externalities (for example when actions at the building stage affect the operating stage of a project or when actions at the building/operating stage affect service quality), giving ownership rights to an agent may decrease his bargaining power if the outside option of the other party is high because of the externality. Bennett and Iossa emphasise the role of renegotiation and the right of the owner to accept or refuse implementing a cost-cutting improvement.

The gist of the Bennett-Iossa model can be summarised as follows. Let us first recall that under a PPP the builder and the operator are the same entity – they form a consortium. By contrast, in the case of traditional procurement, the builder (first-period contractor) and the operator (second-period contractor) are two different entities. The builder suggests an innovation that reduces his cost and that is also socially beneficial – for instance the use of beams made of new alloy that lower the probability of them breaking. Furthermore, the innovation affects operating costs. In this regard, Bennett and Iossa distinguish two cases: in one the innovation at the building stage raises operating costs, in the other it lowers them; to illustrate, the new alloy may require more frequent painting than regular alloy, thus raising operating costs.

With bundling, the consortium (consisting of the builder and operator) will consider the overall effect of the innovation on costs. If the innovation at the building stage raises operating cost, the consortium will have lower incentives to innovate than a builder under traditional procurement since he can realise a larger cost reduction than the consortium. In these circumstances, traditional public procurement may be the better choice from society's viewpoint. By contrast, if the innovation at the building stage lowers operating cost, bundling dominates traditional procurement because the consortium internalises the effect of an innovation that reduces operating cost and, at the same time, is socially beneficial; it is worth adding that this result holds irrespective of whether the public or the private sector owns the infrastructure.

3. Can PPPs remedy soft objectives and cost overruns?

Transferring ownership to the contractor under a PPP could provide protection against political risk.

Another source of contractual incompleteness that may influence the choice of procurement is a possible change in the objectives of the parties. To illustrate: a highway from point *A* to point *B* could be viewed as the right design when the sponsor invites contractors to bid for the project, but large migration or relocation of industries may make a highway from *B* to *C* the better design when project implementation starts. This could suggest that transferring ownership to the contractor reduces the risk associated with a change in objective of the sponsor. In that sense, transferring ownership to the contractor under a PPP could provide protection against political risk or 'soft objectives'.

However, this view assumes that there is no way to protect *ex ante* the contractor under traditional procurement against such a change in objectives. Furthermore, since protection has to be provided when ownership rights are allocated, it is not clear that PPP is the best contract. As the example in Box 3 illustrates, a PPP also creates a hold-up problem: the contractor may choose to start working on a design that will maximise his expected payoff in case the sponsor changes his mind and enters into a renegotiation with the contractor. The free-rider problem makes it too costly for the sponsor to protect the contractor against changes in design, and traditional procurement is preferred.

That said, PPPs have potential to help avoid cost overruns resulting from soft objectives. We will now turn to examining how and under what circumstances this can be the case.

Box 3. PPP is not a foolproof protection against 'soft objectives'

Consider a highway that can be designed in two ways: design *A* and design *B*. The public sponsor will prefer design *B* with probability π, with $\pi < 0.5$ (this is without loss of generality). The sponsor has an additional utility of *v* if his preferred design is implemented. The initial contract specifies the price *p* for delivery of a highway whose design will be decided 'along the way'. After the contract is signed, the contractor starts working towards a specific design. While the total cost is the same for each design, there is an adjustment cost *a* (with $a<v$) if the contractor has to adapt his work to a new design. The contractor would have to bear the adjustment cost unless there are contractual provisions to the contrary.

Under traditional procurement, the sponsor has decision rights. If the contractor invests in design *A*, and the sponsor learns that he would like design *B*, the contractor suffers a cost of *a* and his expected payoff is

$$U^{trad}(p) = (1 - \pi)\, p + \pi\, (p - a).$$

Since $\pi < 0.5$, it is never optimal for the contractor to start working towards design *B*.

Under a PPP, the contractor has decision rights and is only obliged to deliver the highway while the sponsor is obliged to pay a price *p*. Suppose the contractor does preparatory works on design *B*. If the sponsor learns that his preferred design is *A*, the contractor can extract *v* from the sponsor for changing the design and his expected payoff is

$$U^{PPP}(p) = (1 - \pi)\, (p + v - a) + \pi\, p.$$

The contractor does not want to start work on design *A* since he will extract *v* from the sponsor with a lower probability (π rather than $1 - \pi$).

Suppose that the competitive payoff to the contractor is $\underline{u}$. Under traditional procurement, the price will be $U^{trad}(p^{trad}) = \underline{u}$ for highway delivery, and the contractor will start work on design *A*. Expected payoffs are then $\underline{u}$ for the contractor and $v - p^{trad} = v - \underline{u} - \pi a$ for the sponsor (recall that the sponsor does not have to pay the contractor for a change in design).

Under a PPP, the price will be such that $U^{PPP}(p^{PPP}) = \underline{u}$ and the contractor will start work on design *B*. The final payoff to the contractor under a PPP is still $\underline{u}$, but the sponsor has a payoff of $v - p^{PPP} - (1 - \pi)v = v - \underline{u} - (1 - \pi)a$ (note that the contractor will extract *v* when there is renegotiation, but this is compensated by a lower initial price). This is less than what the sponsor gets under traditional procurement, because here PPP leads to a strategic, but inefficient, choice of design *ex ante*. It follows that the sponsor chooses traditional procurement.

Large projects seem to be plagued by cost overruns (see for example Peck and Scherer 1962 and Flyvberg *et al.* 2003). When the initial contract specifies a cost target and when there is uncertainty about the performance of the technology that will be used for building and operating the project (or about other variables that affect the project), it is a tautology that *ex post* cost realisations will differ from the target. Against this background, one may ask why initial contracts do not specify finer contingencies and why the sharing of cost overruns is settled through *ex post* negotiation rather than *ex ante* refinement of the contract.

Some observers (Flyvberg *et al.* 2003, for instance) have suggested that cost overruns are due to the desire of firms to get the contract and, therefore, to bid well below what they expect the cost of delivering the project to be. We know from Laffont and Tirole (1993) and other work on auctioning procurement contracts that cost-plus contracts could correct for this problem and force the firms to bear the risk of too optimistic bids. However, that literature assumes that the parties can commit to the cost-plus contract; if firms are financially constrained or can hold up the sponsor at the stage of renegotiation,[1] cost-plus contracts may be sufficiently constrained with respect to the risk that can be shifted to the bidders and, thus, bids may turn out to be too optimistic.[2]

Another explanation for cost overruns could be that costs are not observable *ex post* and that cost-plus contracts depend on the willingness of the contractor to reveal his costs in a verifiable way, or on the efforts of the sponsor to audit. Without audit, the contractor has little incentives to report 'good' news and will only announce 'bad' news, i.e., cost overruns. Audit may modulate this conclusion, but since audit is costly, some of these effects may explain why we often see cost overruns in practice.

Changes in the design of projects after awarding contracts often explain cost overruns.

A third explanation is related to the endogenous choice by the sponsor of the objectives the project should fulfil, for instance, the design of a highway, its exact location, and the building material. Changes in objectives and, thus, the design of projects are often cited as a source of cost overruns in procurement. For example, Ganuza (2003) cites an empirical study on public works in Spain showing that close to two-thirds of cost overruns can be traced to changes in design during construction. One could argue that transferring decision rights to contractors under a PPP is a means of avoiding cost overruns that result from changes in objectives under traditional procurement. Indeed, the success of PPPs in delivering projects on time and budget more often than traditionally procured projects is frequently stressed as one of their main strengths (see NAO 2003, for instance). But what are the mechanisms that give PPPs an advantage in this respect, and is avoiding cost overruns an unmixed blessing?

To shed light on these questions, we start by noting that the literature on property rights emphasises the role of *ex ante* contracting on *ex post* outcomes and *ex ante* efficiency when renegotiation cannot be prevented. In the simplest models, renegotiation leads to an efficient decision independent of the bargaining power of the parties. However, despite this *ex post* efficiency, *ex ante* outcomes may be inefficient since the agents taking actions (the builder, for example) will consider their own marginal future benefits.

Besides this *ex ante* inefficiency, there will also be an *ex post* inefficiency if bargaining takes place under asymmetric information, a case of concern for PPPs. For instance, the sponsor may not know the quality of the investment made by the contractor before the bargaining starts, or the contractor may not be aware of future budgetary constraints that are known by the sponsor. In this case, the efficiency of bargaining will depend on the outside options of the parties, which are given by the initial contracting terms. There is then a trade-off between specifying many contingencies in the initial contract – which is usually positive in the absence of renegotiation – and modifying the outside options of parties – the effect of which is ambiguous when renegotiation cannot be prevented and when there is still asymmetric information.

The issues of transparency, specification of strict performance targets, and completeness of contracts are key elements of the European Directive for public work contracts (European Commission green

1 This may be so, for instance, if the project becomes 'too big to fail' from a political point of view.

2 This reasoning has been advanced in the recent auctions for wave spectrum, where bidders may have felt that they could submit an 'optimistic' (i.e., high) bid for spectrum because they reckoned that they did not bear the downward risk of no-payment.

paper 1986 and the 2004 Directive).[3] There, the main concerns are about the ability to increase competition for public work contracts. In the presence of agency costs and renegotiation, we want to point out that *ex ante* transparency is also subject to incentive problems. For instance, while a sponsor may learn about his preferred design for a highway by making the right surveys and developing models that will take into account the evolution of economic variables like the cost of petrol, the growth of urban population, and the effect of corporate taxes on the location of firms and industries, these studies are expensive and time consuming. The sponsor may then decide to wait and negotiate a change in design rather than invest *ex ante* with a view to giving more information to the potential contractors. Clearly, the decision to invest (or not) in acquiring information also depends on the benefits to the sponsor of having better-informed potential contractors. The main benefit are a lower probability of having to renegotiate the design after the contract has been awarded and the effect that information may have on the behaviour of contractors bidding for contracts, such as PPPs. As we show in Box 4 (based on Ganuza 2004), the effect of more information on bidding behaviour is a function of the competitiveness of the bidding process.

Cost overruns are not necessarily bad.

More specifically, the role of competition is to increase the probability that the winning bid is low, which implies – from an *ex ante* perspective – low rents captured by the winning firm. However, if the design is poorly specified, the surplus that has to be shared *ex post* – when the sponsor knows his preferred design – is large. Since the sponsor can avoid paying large *ex ante* rents when competition is stronger, he has an incentive to specify and commit to a design in order to avoid paying *ex post* rents to the contractor. Simple cost-benefit analysis may therefore explain why the design of projects – whether traditionally procured or launched as a PPP – may be renegotiated and lead to cost overruns even if such *ex post* costs could be avoided by investing *ex ante* in acquiring information. To put it differently, cost-benefit analyses of specifying a design and of keeping it suggest that observed cost overruns may be welfare-enhancing, equilibrium outcomes.

This example illustrates, first, that cost overruns should be expected in particular when *ex ante* competition is limited. In these circumstances, introducing a private monitor, such as outside shareholders and creditors, in PPPs may be particularly desirable. We will return to the role of external finance in PPPs in Section 4. Second, note that the possibility of private-public contracting may modify, for the reasons we developed above, the expectation of cost realisations but also their variance. Therefore, the sponsor's incentives to invest in specifying the design and to maintain it may be reduced, leading in the end to more observed cost overruns. This suggests that we should treat carefully the relationship between cost overruns and the efficiency of contracting. What matters is the *ex post* quality and costs of projects. A project of a given quality costing 200 without cost overruns is less desirable than a project with the same quality planned to cost initially 100 and experiencing a 50-percent cost overrun.

The analysis has so far assumed that the structure of costs is independent of contracting (PPP *vs.* traditional). However, as we will emphasise in the next section, traditional contracting modifies the claims to the financial returns of the project and often requires the contractor to use third-party finance. A potential benefit of traditional contracting may then be an increase in cost discipline: indeed, since the (private) financier does not internalise some of the social benefits – as the sponsor would do if he were financing directly the project – he has generally more incentives to engage into cost-monitoring or cost-saving initiatives.

3 The performance of contracts based on objective measures of performance or 'scores' is beginning to be analysed in the literature (for example, Cantillon and Asker 2003).

Box 4. Project design, cost overruns, and competition

Suppose there are two firms *A* and *B* that can bid for procurement of a public service. Like in Box 3, consider two potential designs for a highway: *A* and *B*. But now suppose that firm *k* (*A* or *B*) is specialised in design *k*: it has cost *c* of procuring design *k* and cost $c + a$ (where *a* stands for 'additional cost') for procuring the other design.

The sponsor has valuation *v* for having the right design and zero for the wrong one. *Ex ante*, there is an equal chance that the sponsor will prefer design *A*. The sponsor can invest *ex ante* to learn about his preferred design, for instance by doing macroeconomic simulations of labour demand, collecting information about the reliability of different designs, etc. We assume – to make the case most difficult for us – that this *ex ante* investment is not costly for the sponsor.

Contractors know whether the sponsor knows his best design and then bid for the contract. If the design is not specified and firm *A* is selected, there is a 50-percent chance that the sponsor learns that design *B* is best: we assume that renegotiation enables the firm to extract a compensation *r* from the sponsor (obviously $r \leq v$). If the sponsor knows his preferred design he specifies it prior to the bidding stage. We consider both situations in turn.

Suppose the design is not specified: the two firms are in fact in a symmetric situation since they each face renegotiation with probability ½. Competing for the contract leads them to offer a price $p = c + (a - r)/2$ and the sponsor obtains $v - r/2 - p = v - c - a/2$.

We now turn to the other situation. If the sponsor specifies the design prior to bidding, the two firms are no longer symmetric: for instance if design *A* is specified, firm *A* can bid slightly less than $p = c + a$ and gets the contract. Firm *A* obtains a rent of *a* while the sponsor has a payoff of $v - c - a$, which is strictly less than what he gets when the design is not specified.

Hence, even if there are no cost of specifying the design, it is better for the sponsor to keep the firms in a symmetric situation: this increases competition for the contract between the firms, though the sponsor must accept an increase in the likelihood of renegotiation or cost overruns.

4. The financial side of PPPs

The theoretical literature on PPPs has given little attention to the financial dimension of contracting.

While the theoretical literature on PPPs discusses at length the incentive consequences of bundling the construction and operation stages of service provision, it is surprising that it does not deal more explicitly with the other key aspect of PPPs: that the government relies on private sector finance. This is indeed an important dimension of PPPs, which has led to the name used for them in the United Kingdom: Private Finance Initiative (PFI).

What are the economic consequences of private finance for providing public services? In political economy terms, it is clear that PPPs have been attractive for governments trying to make their accounts look good, thereby (ab)using public accounting rules that do not correctly capture government assets and liabilities. PPPs then create the impression that public debt has not grown as much following an investment project. We will abstract here from such public accounting motives since they do not alter the efficiency of PPPs (see for example the discussion in Välilä, this volume). We will instead analyse the real impact of financing modes on economic outcomes, with the analysis proceeding in two steps: Section 4.1 considers the rationale of risk sharing between the public

and the private sectors and the consequences of risk-bearing arrangements on incentives for PPP contractors; Section 4.2 examines how private finance affects these incentives.

4.1 Is it good to transfer risk to the private sector?

Can we justify the financing pattern of PPPs from a risk-sharing viewpoint? Note first that the total risk to be borne by society as a whole is given once the project has been identified and incentives are taken as given. Risk-sharing arrangements thus offer no 'free lunch': the total risk has to be borne.

Pure risk-sharing considerations do not seem to offer a justification for PPPs.

Having said this, we know that optimal risk sharing means it is efficient for less risk-averse parties to take a bigger proportion of the risk. One could argue that the government should be less risk averse than private operators, for which large infrastructure projects would potentially imply large risks that are not easy to diversify. This casts doubts on the government's ability to save money through PPP financing schemes. Instead, one should expect the private contractors to demand a higher remuneration from the government for having to bear significant risks. Moreover, private contractors will face less favourable financing conditions in capital markets because they are 'worse risks', having a higher default probability than the government, which benefits from its ability to tax. Pure risk-sharing considerations, therefore, do not seem to offer a justification for PPP.

It is worth adding a qualification, however. It is of course too simple to consider the government risk neutral. If we consider the cost of taxation to be convex in the tax rate (Barro 1990), the government is anxious to stabilise its tax rate across 'states of the world'. This idea has been used, for instance, to look at optimal public debt indexing policies as a function of the correlation between unexpected inflation and real GDP growth. With this perspective, it is reasonable to think of much of the random component of the returns of specific public projects as uncorrelated with macroeconomic performance, so that one could argue that risk neutrality of the government is not an unjustifiable assumption.

Classical agency theory then tells us how to think about the relationship between risk sharing and incentives in optimal contracting. From a pure risk-sharing perspective, a risk-neutral government should bear all the risk. This is the solution that maximises efficiency, but also the one giving the government the highest payoff. If the contractor can be limited to its competitive (i.e., 'individually rational') payoff, the government will end up paying the risk premium to the contractor for his risk bearing. It is thus in the interest of the government to insulate the contractor against exogenous risk.

In reality, the problem comes from the difficulty of disentangling exogenous risk from endogenous risk, that is, what the contractor can influence through his action. In Section 3, we have looked at endogenous risk but assumed for simplicity that the contractor was risk neutral; this allowed us to abstract from risk-sharing considerations. Classical agency theory instead focuses on the trade-off between risk sharing and incentive provision (see for example Mirrlees 1975 and Holmström 1979, 1982). It assumes that the outcome delivered by the agent (the contractor in our case), in terms of cost and quality for example, is a random variable, but with its distribution being a function of the effort exerted by the contractor. When setting up the contract, the government has to trade off risk-sharing and incentive-provision considerations. Indeed, when effort is not contractible, passing on no risk to the contractor will lead to zero effort.[4]

4 For completeness, note that we normalised to zero the effort level the contractor would choose in the absence of any financial reward. We thus concentrate on 'costly effort' or, equivalently, we focus on a situation where the government benefits from the effort exerted by the contractor and therefore induces him to exert more effort than he would 'naturally'.

Optimal risk sharing implies that the marginal cost of shifting risk from the public to the private sector equals its marginal benefit.

At the other extreme, having the contractor bear the whole risk induces him to fully internalise the benefits of his efforts since he is the residual claimant of these benefits. But this is disastrous in terms of risk sharing, and the government will have to pay a sizable risk premium if the contractor is very risk averse. The optimum is to find a middle ground, where the degree of risk sharing is such that the marginal loss incurred by shifting risk from the government to the contractor equals the marginal gain from increased effort by the contractor. Details of this trade-off between risk sharing and incentive provision are set out in Box 5. In the solution, we can see that the amount of risk borne by the contractor depends on three variables: the exogenous randomness of the contractor's performance (i.e., its variance σ^2), the contractor's degree of risk aversion (η), and his cost of effort (c).

More specifically, the risk borne by the contractor decreases as the exogenous randomness of performance rises. Indeed, a higher variance means that performance becomes less informative about the chosen effort level. Thus, a given rise in the variable component of the contractor's compensation, and his effort level, implies a proportionately higher risk bearing. Giving the contractor more incentives for effort provision is the more expensive, the higher the exogenous randomness in performance. And then, the risk borne by the contractor decreases with a rise in the contractor's risk aversion. Intuitively, giving the contractor more incentives to exert effort is the more expensive the higher his risk aversion is; this is because the higher his risk aversion, the higher the risk premium for each unit of risk. Finally, the risk borne by the contractor decreases with the contractor's cost of effort, which is again intuitive: a given increase in the contractor's effort involves a higher exposure to risk (and associated increase in the risk premium).

These results have other implications. First, any means of creating a more precise relationship between performance and effort is valuable. It is therefore a good idea to neutralise the effect on the contractor's compensation of purely random shocks that can be independently observed.[5] Independent observations are important, otherwise the government and/or the contractor would be inclined to temper with the observation to increase their own payoff at the other's expense.

Second, there may be indirect ways to improve performance measurement. A natural one is relative-performance evaluation, meaning that the contractor's pay is based not only on his absolute performance but also on his performance relative to a benchmark. In this respect, there is value in having competition in the market, because competitors provide a natural benchmark. To be specific, we could add to the setting presented in Box 5 another contractor whose performance is also linear in effort, with an additional error term that is normally distributed. It can then be shown[6] that each contractor's performance should enter negatively the other contractor's compensation scheme whenever the two performance levels, conditional on their respective efforts, are positively correlated. This is intuitive: one can think of this positive correlation as a common random shock that affects both performance levels. For a given performance of one contractor, the higher (lower) the performance of the other contractor, the more probable the common shock was positive (negative), so that it makes sense to neutralise the effect of the common shock – at least partly – rather than rewarding (punishing) the contractor for good (bad) luck. It is only when the two performance levels are conditionally independent that relative-performance evaluation is suboptimal because it would only add randomness to the contractor's compensation.

Relative-performance evaluation is thus about partly filtering out common shocks to lower the risk borne by each contractor for a given strength of incentive pay. Its goal is not primarily to induce contractors to work harder by pitting one against the other. But it is true that the availability of

5 On the other hand, it can be shown that optimal contracts typically should include all 'relevant' contingencies, namely all variables that improve the correlation between effort and performance, however meagre their contributions in this respect (see Holmström's classical 1979 and 1982 papers on the subject).

6 See for example Bolton and Dewatripont (2005, chapter 8).

another contractor's performance measure leads to higher effort at the optimum by strengthening the relation between individual effort and performance. Note a caveat, however: one should make sure to avoid collusion between contractors; when relative-performance evaluation is used,

Box 5. The trade-off between risk sharing and incentive provision

Consider the performance of the agent (a contractor in our case) to be $q = e + \varepsilon$, where e is effort and ε is a normally distributed error term with zero mean and variance σ^2. Assume effort e costs the agent $ce^2/2$. Suppose the risk-neutral principal (the government in our case) offers the agent a linear contract, $w = t + sq$, where t is the fixed compensation level and s the variable, performance-related component of compensation. The agent is assumed to have a utility function of the constant absolute risk-aversion type, which means that the payoff he derives from the contract can be written as

$$E(w) - \eta Var(w)/2 - ce^2/2.$$

So the agent's payoff depends on his expected compensation, $E(w)$, minus a risk premium (which equals the variance of this compensation, $Var(w)$, times half of his coefficient of absolute risk aversion η) and the cost of effort $ce^2/2$. With the linear contract introduced above and the assumptions about q and ε, the agent's payoff can be written as

$$t + se - \eta s^2\sigma^2/2 - ce^2/2.$$

The agent's optimisation problem is to choose his effort e so that his payoff becomes as large as possible. It is easy to show that, faced with a variable compensation s, the agent's optimal effort will be $e = s/c$. The agent thus raises his effort with an increase in the performance-related pay, and he would exert no effort ($e = 0$) if the principal offered only a fixed payment t and no performance-related reward ($s = 0$).

Turning to the principal's optimisation problem, it is obvious that he wants to maximise the difference between the performance of the agent q and the compensation w that he pays the agent. The choice variables of the principal are t and s, but in choosing them he has to consider that the agent can get an outside certainty-equivalent compensation w_0, which implies that the agent's expected payoff under the contract has to be a least as high as w_0. The principal's optimisation problem is thus:

$$\begin{aligned} &Max_{\,t,s}\ E\,(q - w) \\ &s.t. \quad E(w) - \eta Var(w)/2 - ce^2/2 \geq w_0 \ \text{ and } \ e = s/c. \end{aligned}$$

With the notation introduced above and $e = s/c$, this can be rewritten as:

$$\begin{aligned} &Max_{\,t,s}\ s/c - (t + s^2/c) \\ &s.t. \quad t + s^2/c - \eta s^2\sigma^2/2 - cs^2/(2c^2) \geq w_0. \end{aligned}$$

Solving for this maximisation problem implies: $s = 1/(1 + \eta c\sigma^2)$. So the performance-related compensation and, thus, the risk borne by the agent should fall with a rise in η, c, and σ.

A caveat should be made: assuming a linear incentive scheme (here: $w = t + sq$) is typically not without loss of generality, even if Holmström and Milgrom (1987) have identified conditions where the optimal contract is indeed linear in performance.

it is in the interest of contractors to simultaneously reduce effort since each contractor exerts a negative externality on others by working harder.[7]

To conclude, we sketch the relevance of the insights derived here for risk allocation in PPPs. Consider a highway concession, for instance, where the government wants to align toll fees, at least in part, with the performance of the concessionaire. In this case, it would be bad to pass on risks to the concessionaire that are beyond his control – like GDP fluctuations, oil price variations, and changes in petrol taxes. It would be desirable to put in place a predictable regulatory regime of toll fees that controls for inflation and exerts relative-performance discipline by taking advantage of the potential multiplicity of concession owners.

4.2 Pros and cons of external finance for PPPs

Beyond pure risk sharing, it is important to think about the effects of the funding mechanism on incentives. While the literature surveyed above stresses incentives linked to allocating ownership rights under traditional service provision and PPP, it does not explicitly take into account that the contractor has to honour and remunerate external finance such as outside equity and debt.

Large outside equity or debt can lower the incentives for PPP contractors to exert the socially optimal level of effort.

Traditional corporate finance has stressed, however, that large outside equity or debt can lower incentives to exert effort (see, for example, Jensen and Meckling 1976 and Myers 1977) since effort partly benefits external investors (outside shareholders or creditors). One should therefore be aware of potential drawbacks of relying on highly leveraged private contractors to undertake public projects. To illustrate, consider a stylised infrastructure project with a building stage and an operating stage. Assume that building the project requires an investment I and that total consumer willingness to pay for the service delivered at the operating stage of the project is a random variable, being either a low V_0 or a high V_1. Moreover, assume that the realisation of consumer willingness to pay depends on effort exerted at the building stage. Specifically, the realised willingness to pay will be V_0 with probability $1-k-e$ and V_1 with probability $k+e$, where k is a positive constant and e is the effort exerted at the building stage. Assume for simplicity that e can only take two values: 0 and $e^* > 0$. Let us normalise to e the cost of exerting effort e; and to keep things simple, we normalise operating cost to zero, so that the profit generated by the project does not depend on operating costs**.** Assume finally that maximising profits implies that undertaking effort e^* is desirable.

Traditional public procurement and service provision (i.e., building and operation are not bundled under one contract) do not yield effort e^* since the builder does not internalise the effect of his effort on consumers' willingness to pay. By contrast, as stressed in Section 3.2, bundling the building and operating phases can deliver this desirable outcome provided $(V_1 - V_0)e^* > e^*$, or $V_1 - V_0 > 1$. Indeed, by giving the builder-operator consortium ownership of the asset and allowing it to extract consumers' willingness to pay, the consortium chooses its effort at the building stage to maximise $(1-k-e)V_0 + (k+e)V_1 - e$. In this case, effort e^* (rather than $e=0$) is the preferred option. This result is not surprising: we are considering here the most favourable situation for a PPP, that is, the case where there is a positive externality of effort at the building stage on the operating stage and where – in contrast with Hart's model described in Box 2 – there are no 'multitask problems', for example a cost-cutting effort (at the building and/or operating stage) that has a quality-reducing effect not borne by the consortium**.** In this case, it is indeed an unmixed blessing to get the consortium to internalise the profit effect of its effort on consumers' willingness to pay.

Things may be different, however, if 'bundling' also concerns the financing of the project. Indeed, assume that bundling requires the consortium to buy and finance the asset. Typically, the consortium will have to seek external finance, unless it has enough funds: this implies that part of the return of

7 See, for example, Holmström and Milgrom (1990).

the project will accrue to outside investors, and not just to the consortium. This raises the incentive issues that have been the subject of much of the theoretical literature on corporate finance since Jensen and Meckling (1976)[8]. The first effect of external finance is that it introduces a new agency problem, that is one between the consortium and the external investor. Starting from a first-best outcome, like the one above where bundling without the need to bring in external investors results in e^*, this can be bad news, as we will see in the next sub-section. That said, adding a third partner in the relationship, besides the government and the consortium, may help some of the incentive problems. We will turn to the bright side of external finance in Section 4.2.2.

4.2.1 Negative effect of external finance

A PPP consortium needing external finance may not choose the optimal level of effort.

We will now argue that a consortium needing external finance may not choose the socially optimal effort e^*. To make the point as clear as possible, we assume that the consortium has no money to start with and has to raise the amount I entirely from outsiders. This corresponds to the case where the government does not want to fund I upfront but relies on the consortium to find the money on the capital market. Such money can be raised in different forms. We consider here the two most conventional forms: outside equity and debt.

With outside equity, the consortium offers outside shareholders a constant share of what it gets by extracting consumers' willingness to pay. If this share is β, the consortium keeps a share $1-\beta$ of the surplus generated by its effort. Having to share the returns on its efforts with outside shareholders, the consortium has less incentive to exert effort. In fact, the incentive for the consortium can be preserved only if the share accruing to outside equity is not too high. The problem is that the share accruing to outside shareholders must not be too low either, because if it is too low, outside shareholders would not find it worthwhile to supply the initial financing I. As shown in Box 6, which sets out the underlying model in greater detail, these two constraints can be incompatible, that is, outside shareholders cannot be convinced to finance the project for a profit share small enough to convince the consortium to exert effort.

This is a case where PPP backfires: on the one hand, the bundling of building and construction gives appropriate effort incentives to the consortium; on the other hand, since the consortium has to rely on outside equity to finance the asset, the positive incentive of bundling is undone because outside shareholders end up getting too much of the return on the consortium's effort.

In fact, outside equity is not the optimal external financing mode in this case: one can do better with debt, which maximises effort incentives for a given expected repayment to the outside financiers by maximising the difference between the consortium's payoff in 'good' states of the world (V_1) and 'bad' ones (V_0). Indeed, for a debt with face value D, the consortium gets a payoff of max $[0, V_i - D]$ when the return is V_i, since creditors receive min $[V_i, D]$. As shown in Box 6, all this implies that debt finance makes it easier than outside equity to simultaneously induce the consortium to exert effort and investors to supply finance.[9]

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8 See Tirole (2005), for example, for a synthesis of this literature.

9 The idea that debt maximises incentives to undertake effort has already been stressed by Jensen and Meckling (1976). The conditions for the optimality of debt in a moral hazard setting have been analysed more thoroughly by Innes (1990) and, more recently, by Matthews (2001) and Dewatripont *et al.* (2003). Innes (1990) shows that debt is the effort-maximising financing mechanism in a principal-agent relationship where: (i) both the principal-financier and the agent-entrepreneur are risk neutral; (ii) the agent is wealth-constrained; (iii) both parties' payoff are constrained to be monotonic in total performance. Allowing for a risk-averse agent would typically invalidate the optimality of debt, because it puts too much of the risk on the agent. As shown by Matthews (2001) and Dewatripont *et al.* (2003), this is not the case when one applies the Innes conditions to a modified principal-agent setting – put forward by Fudenberg and Tirole (1990) and Hermalin and Katz (1991) – where, after effort has been chosen but before performance is realised, the principal and the agent can renegotiate the contract to improve risk sharing. In such a case, starting from a debt contract initially is a good idea, knowing that the excessive risk it implies for the agent can be renegotiated away later on.

Box 6. Why outside finance may stifle the efforts of PPP contractors

As sketched at the beginning of Section 4.2, we consider a stylised infrastructure project. The willingness of consumers to pay for the infrastructure service is a random variable being either a low V_0 or a high V_1. The realisation of consumer willingness to pay depends on effort exerted at the building stage. Specifically, the realised willingness to pay will be V_0 with probability $1 - k - e$ and V_1 with probability $k + e$, where k is a positive constant and e is the effort exerted at the building stage. Effort, e, can only take two values: 0 and $e^* > 0$, with e^* indicating the profitmaximising level of effort.

With **outside equity**, the consortium keeps a share $1-\beta$ of profits and chooses e to maximise:

$$(1 - \beta)(1 - k - e)\, V_0 + (1 - \beta)(k + e)V_1 - e.$$

This will lead to a choice of effort e^* only if:

(1) $$(1 - \beta)\,(V_1 - V_0) \geq 1 \quad \text{or}$$

(2) $$\beta \leq 1 - 1/(V_1 - V_0).$$

The left-hand side and the right-hand side, respectively, of (*1*) show marginal benefit and marginal cost to the consortium of exerting effort. Condition (*1*) – which can be rewritten as condition (2) – thus says that the share of profits retained by the consortium ($1-\beta$) must be big enough to induce the consortium to exert effort.

At the same time, the share of profits accruing to outside shareholders has to be large enough to induce them to supply the initial financing I. Specifically, shareholders' participation constraint is:

(3) $$\beta\,(1 - k - e^*)\, V_0 + (k + e^*)V_1 \geq I \quad \text{or}$$

(4) $$\beta \geq I / (V_0 + (k + e^*)(V_1 - V_0))$$

Debt is better than outside equity at preserving consortia's incentives to exert effort.

Although debt is better than equity at preserving the consortium's incentive to exert effort, it is true nonetheless that there will be cases where it cannot be done while satisfying investors' participation constraint. The general lesson from this sub-section is that, by insisting on external finance, a PPP can undo the desirable incentive effect that bundling the construction and operation phases may achieve.

In discussing the downsides of external financing for PPPs we have so far attributed a minimalist role to outside equity and debt: we have stressed the income rights attached to these instruments, but we have abstracted from their associated control rights, an issue that has attracted the attention of the corporate finance literature since the work of Aghion and Bolton (1992)[10]. Here, this is not so much of a problem for debt: while creditors have control rights in case of default by borrowers, they will not be able to get more than the value of the firm in the bad state of nature (i.e., V_0 in our case).

By contrast, it must be said that we have considered completely passive outside shareholders, effectively holding non-voting equity. In reality, there are many debates about the various ways in which, in the parlance of Aghion and Tirole (1997), shareholders can transform their 'formal authority' – managers are by law instructed to pursue shareholder interests – into 'real authority' through the

10 See also the work summarised in Hart (1995).

For a sufficiently high investment level I , conditions (2) and (4) are incompatible: any β high enough to make the provision of equity profitable for outside shareholders is then too high to induce the consortium to exert the socially optimal level of effort e^*.

With **debt finance** D, the consortium's profit is zero if consumers' willingness to pay turns out to be V_0, with $V_0 < D$ being the payment to creditors in this state of the world. But the consortium will earn $V_1 - D$ if consumers' willingness to pay is V_1, with D being the payment to creditors in this state of the world. Overall, the consortium chooses e to maximise:

$$(k + e)(V_1 - D) - e.$$

This will lead to a choice of effort e^* only if:

(1′) $$(V_1 - D) \geq 1$$

where the left-hand side and the right-hand side of (1′) shows, respectively, the marginal benefit and marginal cost to the consortium of exerting effort

With risky debt D, the participation constraint of lenders is:

(3′) $$(1 - k - e^*) V_0 + (k + e^*) D \geq I$$

As shown in the Annex, (1′) and (3′) are easier to satisfy than (1) and (3), implying that debt finance is more likely than outside equity to induce outside investors to provide finance and to encourage the consortium to exert the optimal level of effort e^*. Intuitively, debt provides more incentives to exert effort, for a given expected repayment to outside investors, than outside equity for the following reason: while outside equity gives the builder and the investor a constant fraction of the realised return, whether performance was good or bad, debt leaves the builder the minimum possible fraction of the return (that is, zero) after poor performance, and therefore a relatively high fraction after good performance. The reward for exerting effort is thus maximised under debt finance.

various mechanisms of corporate governance. The corporate finance literature has analysed the various safeguards against the divergence between managerial conduct and shareholder interests, for example the role of boards of directors, transparency of information, and the regulation of takeovers (these are discussed in much detail in the survey by Becht *et al.* 2002).

The result that creditors may be better than outside shareholders in controlling managers is quite robust.

Notice, however, that the above lesson – according to which creditors may be better in controlling managers than outside shareholders – may be quite robust, especially if one contrasts expert, concentrated debt investors (banks for instance) with small dispersed shareholders. Dispersion does indeed create a free-rider problem in monitoring, as we discuss in more detail next.

4.2.2 Positive effects of external finance

The contingencies of financial contracting can affect in a non-trivial way the performance of PPPs. Consider for instance how the rights are licensed when contractors face the risk of bankruptcy. If contractors are financially constrained, the risk of bankruptcy is not internalised when contracts are awarded. This is relevant, for example, at the auction stage: it can lead to aggressive bidding and success at the auction, with the government/sponsor paying the consequences later. Things are worse if, because of 'too important to fail' considerations, the sponsor finds it optimal *ex post* to intervene and rescue the project. The anticipation of such 'soft budget constraints' would contribute

to a further distortion of competition at the auction. This could provide an argument for the sponsor to contribute to the initial financing of the project, but could also justify PPPs in order to transfer decision rights in the case of bankruptcy to a third party – external investors – who is not subject to such soft budget constraints.

Softness of budget constraints is an illustration of a lack of commitment or lack of completeness of contracts, and the question is whether external finance can help in making budget constraints bind, thereby avoiding the opportunistic behaviour of contractors sketched above. For complex projects, auditing and monitoring could alleviate some of the problems posed by opportunistic behaviour of contractors. However, auditing and monitoring are effective when the auditors and monitors are experts in the area they control and when they have themselves the incentives to spend the resources needed to discover useful information. A result of external finance is that investors have the stake to incur monitoring costs and – if they specialise in financing large projects – the expertise and reputation for being credible monitors.

This is a central idea in the literature that views financial intermediation as delegated monitoring (Diamond 1984), or the recent literature on venture capital that models the active monitoring and sometimes executive role of the financial intermediary (see Kaplan and Stromberg (2003) for references and evidence). Whether finance is obtained through equity or debt, that literature underlines a trade-off between the benefits of risk diversification, which leads to a dilution of ownership of individual firms, and the benefits of monitoring resulting from a more concentrated ownership structure.[11] Indeed, as Berle and Means (1932) had pointed out, since monitoring has public good characteristics, firms with dispersed ownership generate a free-rider problem in monitoring. Intuitively, if a stakeholder can claim only 1 percent of a project's return, his incentives to invest in monitoring will be less than those of a creditor having a 10-percent claim; as long as there are economies of scale in monitoring, concentrating external finance on a few investors will lead to more investment in monitoring.

PPPs financed through a few intermediaries are likely to perform better than others.

This suggests that special attention should be paid to the way projects are financed when they are technically complex and when information on performance may be hard to obtain. A reasonable conjecture is that PPPs financed through a few intermediaries will tend to perform better than others.

Another illustration of the lack of commitment or lack of completeness of contracts is the problem arising from 'soft objectives' of the sponsor discussed in detail in Section 3.3. To recall, 'soft objectives' means that the sponsor may find it difficult to commit to a design or to make the initial contract contingent on later changes of design. The importance of external finance in this context is that the financial contract and the allocation of decision rights is a way for the contractor and the sponsor to share the risks associated with the later change in objectives by the sponsor**.**

5. Conclusion

The literature on the theory of contracts and its recent applications to PPPs has some clear implications.

11 Things are more complex since financial markets characterised by a dilution of ownership at the individual firm level are also associated with a higher liquidity of the market, which may enhance the disciplinary role of takeovers. For PPPs, takeovers seem less important and we thus ignore them.

First, PPP contracts enable the partners involved in developing infrastructure projects – whether financing, building or operating – to internalise the various costs associated with the choice of investments or the choice of contracts. For investments, the builder of a project will take into account the maintenance costs of the bridge in a PPP but not necessarily under traditional public sector procurement. For contracts, the builder will anticipate how his contract will affect the negotiation between the sponsor and the operator of the infrastructure under PPP but not necessarily under traditional procurement. For this reason, PPPs seem to be better at providing incentives for life-cycle cost savings; the builder and the operator have the right incentives to minimise life-cycle costs. However, there are concerns that such cost cutting may come at the expense of quality. There is therefore a need for controlling the quality of public services delivered through PPPs.

Second, while cost overruns are often viewed as illustrating the failure of traditional public procurement, we have pointed out that they can be equilibrium phenomena. There are costs associated with trying to make contracts complete and specifying a project in such a way that its characteristics will not change later on. These costs could be related to the difficulty of filtering out exogenous disturbances, like changes in macroeconomic conditions, or to the difficulty of anticipating changes in the objectives of the different parties. There is then a trade-off between the costs of making contracts complete and the benefits of minimising cost overruns, with these benefits resulting from better-specified contracts. Therefore, contract design and choice are also subject to incentive problems, sometimes on the part of the agencies in charge of allocating the public project. As we have pointed out, stiff competition among contractors may help, and opening the markets for public projects is a way to do so. Another option to avoid inefficiencies in the choice of contracts is to compel agencies to provide verifiable evidence on the steps they have followed to design the objectives of the project in a way that anticipates future economic shocks.

There are costs of avoiding cost overruns and of engaging third-party finance in PPPs.

A final lesson from the literature is that the quality of projects reflects both exogenous and endogenous uncertainty and that the purpose of contracts is to disentangle their effects. It is therefore important to identify, and find ways to filter out exogenous disturbances, e.g., by using indexing or – when possible – relative performance evaluation. Although the literature has insisted on the endogenous uncertainty linked to the bundling of property rights in PPPs, we have noted the importance of financial contracting and the use of external finance, which implies transferring financial risk to third parties. Such external financing may have negative effects, which have been emphasised in the corporate finance literature but are surprisingly absent in the economic literature on PPPs. The negative effect of financial contracting – namely that part of the return on effort accrues to outside investors – may also undo whatever beneficial effects arise from bundling the decision rights for building and operating the infrastructure project. That said, external finance may have the benefit of having expert and concentrated investors who will monitor projects. Since we have moreover shown the advantage of debt over equity in limiting underinvestment in effort, this pleads for relying on large, expert creditors when outside investors are relied upon in the context of PPPs.

Annex

The purpose of this Annex is to show that equations (1') and (3') of Box 6 are easier to satisfy than equations (1) and (3).

Consider the level of β such that (1) is binding, that is, $\beta = 1 - 1/(V_1 - V_0)$. This is the maximum level of outside equity compatible with effort e^*. For this β, compute now the level of I such that (3) is binding. This is the maximum 'outside equity funding capacity' compatible with effort e^*. Its level is:

$$I^{equity} = V_0 + (k + e^*)(V_1 - V_0 - 1) - V_0/(V_1 - V_0).$$

As for debt, its level such that (1') is binding is $D = V_1 - 1$ and, for this level, the maximum 'debt funding capacity' (the level of I which makes (3') binding) is:

$$I^{debt} = V_0 + (k + e^*)(V_1 - V_0 - 1),$$

which is higher than I^{equity}. The set of values of I such that (1) and (3) are satisfied is thus a strict subset of the set of values of I such that (1') and (3') are satisfied.

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