A Macroeconomic Analysis of Investment under Public-Private Partnerships and its Policy Implications - the Case of Developing Countries

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ABSTRACT

A MACROECONOMIC ANALYSIS OF INVESTMENT UNDER PUBLIC-PRIVATE PARTNERSHIPS AND ITS POLICY IMPLICATIONS - THE CASE OF DEVELOPING COUNTRIES

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The objective of the present dissertation is to propose a theoretical model of the decision to invest under a Public-Private Partnership (PPP) contract and to test empirically both the determinants of such investment and its economic impact.

The basic theoretical model proposed in the dissertation outlines the conditions for the optimal timing and the scale of monopoly production associated with the decision to invest in a PPP project, in which the two partners fully cooperate. Based on the theory of irreversible investment under uncertainty, it concludes that the optimal decision to invest under a PPP depends negatively on the risk and uncertainty associated with the project, and the real cost of capital, while it could be underpinned when the government tax burden and the associated cost of taxation is high. Two extensions of the theoretical model conclude that PPP arrangements (i) have the potential to diversify risk, when risks

facing the private and the public partners are correlated; (ii) may provide the private partner with the possibility to exit the contract at a later stage should economic conditions deteriorate; through contract renegotiation, explicit or implicit government guarantees, or bailing-out expectations, PPP offer a put option that induces the private partner to undertake the investment more readily or in a larger amount even under higher uncertainty. Together with the findings of the basic model, this results in an ambiguous effect of uncertainty on PPP investment.

The theoretical predictions of what determines the decision to invest under PPP programs, as well as the potential economic impact of PPP investment, are tested empirically for the case of developing countries, using the World Bank database on private participation in infrastructure for the period 1990-2005. This is the largest database of this kind, which uses a consistent methodology across developing countries and time to record investment commitments in four infrastructure sectors: transportation, energy, water and sewerage, and telecommunication.

As regards the determinants of investment under PPP, several predictions of the basic theoretical model are confirmed by the empirical analysis, while the evidence for the others is weaker or difficult to control for empirically. One measure of risk proves to be a robust determinant of PPP investment, that is, the political risk through its component of investment profile risk. Two other measures seem to be significantly associated with the number of PPP infrastructure projects initiated in developing countries over the period 1990-2005, that is, exchange rate uncertainty and uncertainty regarding public investment. Similarly, as indicated by the theoretical model, a higher tax

burden is likely to induce governments to engage in larger PPP programs. Another prediction of the theoretical model—that the nominal lending interest rate is likely to have a negative effect on PPP investment—is weakly confirmed by the empirical model in the whole sample, but it turns more robust in the restricted sample of Latin America and Caribbean (LAC) countries where PPP programs are more developed. Finally, the empirical analysis provides evidence as to other significant determinants of PPP investment, that is: (i) the experience with PPP programs; (ii) the size of the economy; (iii) complementarity with private investment; (iv) external aid; (v) time and regional dummies.

As regards the impact of PPP investment, at a macroeconomic level, larger PPP programs in infrastructure may induce, on balance, higher fiscal risks for governments in developing countries through the attached explicit or implicit contingent liabilities. However, they may also contribute to improving fiscal positions in the future through higher upfront payments to the government or by substituting part of public investment. In several countries of Latin America, private investment in roads may have been a factor associated with higher economic growth since the mid-80s.

The qualitative analysis based on the literature review, as well as the results of the theoretical and empirical models, indicate that, while the experience with PPP in developing countries has been mixed, there is overall more evidence in favor of undertaking PPP investment.

Introduction

As governments throughout the world, be it in developed or developing countries, struggle to improve the provision of public goods, often given tight budget constraints, Public-Private Partnerships (PPP) have been increasingly proposed as a viable solution to this problem.

A PPP is usually defined as a contractual arrangement involving the private sector supply of infrastructure *assets* and *services* that have traditionally been provided by the government (De Bettignies and Ross 2004; IMF 2004; Engel 2005).

Some developed countries, particularly U.K.[1], Australia, and Ireland have now well-established PPP programs. Others, such as Finland, Germany, Greece, Italy, Spain, and Portugal, have developed many PPP projects, although their share in total public investment is still relatively low. The United States (U.S.) has considerable experience with leasing, and more recently with concessions[2] (IMF 2006). The shift towards private financing in infrastructure was made by the U.K. in the 1980s. In the 1990s, many countries followed suit, particularly in Latin America, but also in Southeast Asia, Australia, and Europe (Gomez-Ibanez 2003). Latin American governments, in particular,

[1] According to IMF (2006), the best developed PPP program is Britain's Public Finance Initiative (PFI), currently responsible for about 14 percent of public investment, with projects in key infrastructure areas.
[2] Two relatively recent highway concessions granted in the U.S. (Chicago Skyway for $1.8 billion in 2005 for 99 years and Indiana Turnpike for $3.9 billion in 2006 for 75 years) have attracted considerable interest among specialists and the general public. The sums associated with these transactions exceeded by large margins the pre-sale expectations of policy makers (Source of data: (Fitch Ratings March 2006))

have progressively substituted PPP arrangements, mostly build-operate-and-transfer (BOT) contracts, for traditional government-provided highways during the 1990s (Engel, Fisher et al. 2003).

Compared to other related areas in economics, such as monopoly regulation, incomplete contracting theory, macroeconomics of fiscal policy, the academic literature on the intrinsic relationship between the two different actors—the government and the private sector—in the provision of public goods is much more limited. Engel (2005) calls for a "trend" of systematic research in this area. Similarly, other authors argue that "basic economic theory [would be] extremely helpful in understanding the potential for costs and benefits from these new arrangements" (De Bettignies and Ross 2004).

The current financial and economic crisis, while slowing down the previously high pace of PPP expansion in infrastructure, has brought new policy responses in the form of private-public partnerships, such as the US Treasury program to deal with trouble financial assets during the recent financial turmoil.

In this relatively new area of research, two particular themes have not been investigated, at least not systematically. Both of them are concerned with the issue of *investment* under PPP projects. The first is related to the macroeconomic ***determinants*** of investment under PPP, while the second pertains to the ***impact*** that investment under PPP projects may have at a macroeconomic level, specifically on aggregate public and private investment, fiscal variables, fiscal risk and economic growth.

The present dissertation aims to deal with these research questions both theoretically and empirically.

At the theoretical level, the purpose of the dissertation is to develop a model of PPP investment under uncertainty, explain the macroeconomic determinants of the optimal decision to invest under PPP, and the conditions under which a PPP model would be preferred to either a purely private or a purely public investment model. The decision to invest under a PPP will be modeled as a (partially-) irreversible investment decision under uncertainty, following Dixit and Pindyck (1994) and Abel et al. (1996), and extended to include government participation.

At the empirical level, the purpose of the dissertation is to analyze both the determinants and the impact of investment under PPP in a panel of developing countries for the period 1990-2005.[3]

While the dissertation will also review the main institutional aspects related to the implementation of PPP projects, the research focus will be *on modeling the reasons behind and the impact of PPP investment*. PPP investment is a reality in an increasing number of economies; it is precisely the need to explain what triggers such investment, how it can be modeled, and what impact it may have on output, fiscal variables and growth that motivates this dissertation.

The present dissertation is organized as follows.

The first part introduces the literature review with focus on the intrinsic characteristics of PPP contracts, that is, what distinguishes PPP contracts from purely private or purely public investment contracts. This part outlines the reasons that are found

[3] The analysis is restricted to developing countries due to data limitations and in view of having a higher degree of data homogeneity. The empirical exercise will be primarily based on the World Bank dataset of private participation in infrastructure, which is compiled on the basis of a consistent methodology only for developing countries.

in the literature to lay behind the decision of the private, and respectively, the public agent to invest under a PPP contact. It also contains a review of the institutional and contractual issues that may give rise to fiscal risk (i.e. risk for the government and taxpayer's money) under PPP contracts.

The second part contains the main theoretical model and its extensions, accompanied by an annex with detailed model derivations. This part opens with a review of the theoretical models on PPP, predominantly aiming to capture the optimal contractual form for PPP investment. It continues with a background on the theory of irreversible investment under uncertainty, the backbone of our model for PPP investment. The model introduces first the basic conditions for the optimal decision to invest under a PPP contract. Two model extensions are subsequently developed to take into account the difference in the uncertainty profile for the private and public agent, as well as the possibility to partly reverse the investment as a put option received by the private partner from the government.

Chapter three describes the data: it first gives an overview of the main dataset used in the empirical analysis—the World Bank dataset on private investment in infrastructure—and then introduces other variables of interest and their sources. Descriptive statistics of the main variables are also included.

The main research hypotheses on the determinants of the optimal decision to invest under PPP, as well as the macroeconomic-fiscal effects of such investment decisions are subject to empirical testing in part four. This section includes the description of the empirical methodology, main advantages and shortcomings of various

methods, and comments on the robustness of empirical results. Apart from the determinants of public, private and PPP investment, this section analyzes the impact of PPP programs on aggregate private and public investment, government budget balance, government debt and fiscal risks.

The dissertation concludes by drawing lessons from the interplay between the theoretical and the empirical analyses. Policy recommendations for developing countries aiming to initiate or expand PPP programs are shaped based on the quantitative results of the empirical model and the qualitative results from reviewing the PPP literature.

Chapter I - Literature review

In order to model what determines investment under PPP, and to distinguish it from purely public or purely private investment, it is essential to review:

(i) ***The intrinsic characteristics of PPP projects*—**what distinguishes PPP from other contracts (fully private or fully public). While these characteristics vary across the types of PPP contracts, and separate models would be desirable, only the common characteristics will be modeled theoretically.

(ii) ***The reasons behind each party's involvement in PPP***—what makes each party to enter a PPP contract, versus investing and providing services in the traditional way.

I.1 Intrinsic Characteristics of Public-Private Partnerships

It is generally accepted in the literature that what distinguishes PPPs from other types of infrastructure provision (fully public or fully private) is the special bundling of activities, as well as of interests (risks and returns) between the two parties during the project's life. Three dimensions are particularly relevant for this analysis.

First, as the name suggests, PPPs are essentially contractual partnerships, involving (i) a long-term contract and the private agent's performance of a bundle of activities (mainly design-construction and operation of the asset); (ii) a risk-sharing

arrangement between the government and the private sector; and (iii) some combination of private and government financing of public infrastructure. The contract at the basis of a PPP is a long-term contract, bundling all or the majority of activities during the life-time of the asset, and usually implying (at least some) private project finance for 25 years or longer (Gerrard 2001) to build capacity and deliver services. Yet, even when the project finance is done entirely by the private sector, as in the case of most projects under the U.K. Private Finance Initiative (PFI), the final product's specification is initially set and subsequently monitored by the government. The risk-sharing agreement is essential to structure the right incentives under the contract and to provide cost savings in terms of risk pricing. The optimum allocation of risk, rather than maximizing risk transfer to the private sector, should be the objective of a PPP project; otherwise, the inappropriately transferred risk will be reflected in higher service charges to be paid by the government or directly by end-users (Leahy 2005). Some authors emphasize the need for a team-building approach rather than a commercial supplier-buyer relationship (Smith 2007).

Second, the two contracting parties in a PPP are likely to have different objectives. The public authority and the private operator enter into a partnership with the overlapping objective of achieving a successful project, yet with highly distinct motivations (Aoust, Bennett et al. 2000). The government is often thought of as a very different agent from a private firm, since it is concerned primarily with social welfare rather than just economic profit (Hart 2003).

In practice, the public authority has the following stated objectives in providing infrastructure goods (Gomez-Ibanez 2003)[4]:

A main objective for the government is to promote economic growth and development, or, more generally, to enhance social welfare. The theory of social choice predicts that the government should adopt programs that increase social welfare, meaning "finding those programs that put the society on the highest social indifference curve" (Stiglitz 1999). Overall, governments take into account the potential positive externalities generated by the project, which range from health benefits (such as those associated with water and sewage provision) to environment protection (in railroads, road transportation, power plants etc.) and economic development (infrastructure is viewed as an important factor in promoting regional and national development).

Another broad objective of the government relates to social equity. As pointed out in Gomez-Ibanez (2003), ensuring universal access to a basic level of infrastructure services is considered important for the protection of equal opportunity, often just behind basic education and health. The social choice requires in practice an assessment of the trade-off between efficiency and equity, often involving "a calculation of weighted net benefits, weighing gains and losses to poor more heavily than those to rich, according to the social welfare function" (Stiglitz 1999).

An objective specific to infrastructure goods is consumer's protection against monopoly power. Many infrastructure goods have characteristics of natural monopoly - economies of scale in production, immobility of investment (high sunk costs associated

[4] Adapted from Gomez-Ibanez (2003) classification of the motivations for the government to get involved into infrastructure provision (several factors are aggregated, while others are not included).

with the initial investment), and no alternative supply. Hence, concerns over the exercise of monopoly power on consumers can lead the government either to get involved in the provision of such goods and services or to regulate their prices and quality.

Third, the two partners are usually hypothesized to have different risk profiles, different ability to diversify the project's risk and raise financing.

Since the government can spread the risks among all taxpayers when it undertakes an investment, Arrow and Lind argued that the discount rate to be used in public investments should be the "risk-free" rate reflecting the risk-neutrality of the public sector (Arrow and Lind 1970)[5].

Other authors (Hirshleifer 1964; Bailey and Jensen 1972; Klein 1997) have pointed out that if this argument is accepted then investment decisions will always be biased against private provision. They contend that, leaving aside adjustments due to taxation[6] and incomplete capital markets, the expected value of discount rates for private and public projects should not differ in equilibrium, as the private sector would seek to compensate through higher efficiency, or it should be able to divest itself of risk at market prices.

Grout (2003) investigates the issue of discount rate for PPPs (specifically the PFI type of private provision of services) in comparison with public provision, and argues that even in a world of complete capital markets and no distortionary taxation, it may still be appropriate to use a higher discount rate for the PPP than the public sector equivalent. The difference comes from the different types of cash flows that are being discounted:

[5] Prior work was done by J.K. Arrow (Arrow 1965; Arrow 1966), as cited in (Grout 2003).
[6] An example would be the tax-free bond financing by municipalities in the U.S.

costs versus benefits. Within a PFI project, the government has to fund the present value of the service, while under traditional financing it has to fund the cost of building (e.g. the road)[7].

Based on the above characteristics, from a contractual relationship point of view, ***various types of PPPs*** differ from fully public or fully private contracts. Hence:

In a fully public provision:

- The government keeps full ownership of the infrastructure asset.
- The government builds the asset and offers services by itself (usually, this means through a state-owned company). Alternatively, the government contracts the construction of the infrastructure asset with a private company, and operates the asset by itself or contracts the operation with another company (no bundling of activities).
- The government finances the investment and the provision of services to the public through taxes and public debt. Alternatively, the government pays a private firm for the construction of the asset, and delivers services to the population by itself, free of charge (financed by taxes) or charging unit fees (tolls). If services are contracted with a separate private operator, it pays that company in full for services delivered to the population (contracting-out). Generally, the fixed cost of investment is paid contemporaneously out of taxes and debt, and it is reflected in the government fiscal accounts (affects the fiscal stance) as government investment.

[7] The author shows that the risk characteristics of the two cash flows, as measured by their beta (the weighted covariance between the project cash flow and the market – the aggregate income) are not equivalent. The ratio between beta for cost flows and beta for revenue flows is found to be equal to the ratio between marginal cost and price. Given that the price per unit is expected to be higher than the marginal cost in infrastructure projects, the revenue flow risk, or equivalently the discount rate for PPP projects, is then found to be higher than the cost flow risk, or the discount rate for traditional financing (Grout 2003).

In a full private provision or full divestiture:

- The private company invests in the asset (construction), owns the asset, and operates it by providing services directly to end-users against a fee;
- There is no government intermediation or ownership; there are no payments from the government for either investment in the asset or delivery of services. The delivery of (public utility) services is generally subject to government regulation.
- There is no risk-sharing with the government.

In a public-private partnership, according to PPP types:

- ***Private Financing Initiative (PFI) type:*** The government contracts both the provision and the operation (including maintenance) with *the same private firm,* and pays for services delivered to population (shadow tolls/fees). This allows the government to spread the cost of the asset's construction to future generations. The asset remains under private ownership.
- ***Greenfield projects with transfer of assets (DBOT/BOT):*** The asset is designed and/or built and operated by the private firm, according to some government's specifications, and it is transferred to the government at the end of a long-term contract. The private firm owns the asset initially, provides services directly to the public against a user fee (under government's supervision), and then sells the asset at a residual value to the government. The government can provide shadow payments to the private firm for services delivered to population, or other type of financial support (subsidies, guarantees, etc.). For instance, BOO (Build-Operate-

Own) projects are hybrids that usually benefit of government support, although they do not use shadow-tolls and the asset remain private.

- ***Partial divestiture, public-private joint ventures*** – the government and the private sector can jointly own an asset and operate it by delivering services to population. Such arrangements can be the result of processes of privatization, in which the government does not transfer full ownership on infrastructure assets. Decisions regarding the operation of the asset are made jointly, the objectives of both parties are taken into account, the cost and benefits are shared.
- ***Public-private consortia*** – are similar with the category above, but they are set up specifically to manage the long-term provision of a given public service by negotiating and contracting it with another specialized private company. According to Bennett and Iossa (2006), this is a recent innovation in the U.K. to provide education and health services; the private partner is the dominant partner, but the public partner ensures that profit is not the only objective when a contract is negotiated.
- ***Concession, leases*** – are quasi-sale of government assets to private companies. Such companies (the concessionaire, lessee) will operate the assets, charge direct fees to end-users, and will return the assets to the government at the end of a long-term contract. The government obtains a revenue flow, which will ease its budget constraint upfront. The public will start paying fees for the use of the service (if it was previously provided for "free," financed out of taxes) or will usually be confronted with fee increases (if the government was previously subsidizing the

cost of the service for social reasons). Such arrangements imply only maintenance investment, and/or investment in expanding the facilities.

I.2 Reasons behind each party's involvement in PPP

Starting from the above general characteristics of PPP projects, it is important to investigate the reasons that stand behind each party's involvement in PPP arrangements (some of them still not clarified in the theoretical literature).

I.2 (1) Reasons behind government's involvement in PPP

The most cited economic justification for the government to get involved into PPPs is that they are likely to increase efficiency by aligning the incentives of the parties, and thus enabling the government to provide services at a lower cost than under traditional public delivery (Grout 2003). Various technical reports and theoretical papers cite the private sector's superior efficiency stemming from higher propensity to innovation, advanced management skills, and better-structured incentives when in charge of a bundle of tasks, e.g. the design/construction and the operation of the project (Engel, Fischer et al. 1997; De Bettignies and Ross 2004; Gribbin 2006; IMF 2006). Being also in charge of asset operation, and raising its revenue in this way, the private firm is assumed to expend greater effort during the asset construction phase to ensure delivery on time, avoid asset construction flaws, and ensure better asset quality. This superior efficiency is not always taken as given at the level of policy-making, and it is not the only factor that counts for the government. Hence, according to H.M. Treasury in the U.K., "in assessing where PFI

is appropriate, the Government approach is based on its commitment to efficiency, equity, and accountability"[8].

One cited problem is the trade-off between efficiency and quality, especially when the latter is difficult to monitor (Hart, Shleifer et al. 1997; Hart 2003). Given the inherent difficulties in writing complete contracts, it was shown in theory (Hart 2003) and recommended in practice (IMF 2006) that PPP would be best suited for sectors whose output service quality is easy to specify and monitor, while the asset construction is not. From this point of view, PPPs appear to be particularly well-suited to providing economic infrastructure (IMF 2006). In projects of energy provision, transportation, sewage, water provision, the quality of the service can be easily monitored, while the asset construction can include hidden defaults that become apparent only at later stages. On the other hand, services for which the overall quality is not inherently suited to measurement, such as national defense, public law and order, diplomatic missions, are not candidates for PPP (IMF 2006). It may also be difficult to provide education and some health *services* under PPP[9]. In the UK, there is a clear policy to allow provision of hospital building and maintenance, or student accommodation, against user-fees or shadow payments, but services remain largely with the government, e.g. *clinical services* remain with the National Health Service (Grout 1997). While there are examples of successful PPPs in social sectors, charging for government-supplied social services is not a common practice (IMF 2006), partly due to equity considerations.

[8] H.M. Treasury, The Private Finance Initiative, at: http://www.hm-treasury.gov.uk/documents/public_private_partnerships/ppp_index.cfm

[9] Hart (2003), on the other hand, considers that hospitals may be well suited for PPP, as it may be easier to specify reasonable performance measure for treatment of patients than what a very complex hospital facility should be.

In order to mitigate the trade-off between quality and efficiency, some governments (e.g. U.K under PFI) propose the rule of "value-for-money", which is designed to take into account both cost-effectiveness and the quality of service in selecting a project. However, considerable controversy exists on this issue, mainly due to measurement problems (Grimsey and Lewis 2007), and ex-ante assumptions about risk-sharing that may not materialize in practice due to unexpected events, renegotiations or failure to implement contractual provisions (Edwards and Shaoul 2003; Shaoul, Stafford et al. 2006) .

A review of various studies on contracting-out of government services (only broadly overlapping with PPPs due to the inclusion of short and medium-term contracts, and lower investment commitments, if any), concluded that there were typically substantial time and cost savings compared to traditional provision, while the evidence on quality was less clear cut, partly, due to data problems (Domberger and Rimmer 1994). Various reports of the U.K. National Audit Office (NAO) (e.g. NAO 2003 and NAO 2005) concluded that PFI projects continue to outperform traditionally procured construction projects, in terms of cost and time savings (Leahy 2005).

However, the statistical studies on cost savings, reviewed in Domberger and Rimmer (1994), refer only to developed countries (U.S., Australia, U.K.). Other case studies of failed PPP projects point to cost problems, especially if broader definitions of cost—to include damaged government reputation, additional post-negotiation costs, and enhanced government supervision costs—are taken into account (e.g. Edwards and Shaoul (2003) investigating two cases in the U.K.; Rosenau (1999) in a literature review

drawing primarily on cases in U.S. and U.K.). The evidence from case studies in developing countries is also mixed, with success stories, for example, in Chile, and failures in Mexico (Irwin 2003; Guasch 2004; IMF 2006). A relatively recent and comprehensive World Bank study of private participation in infrastructure (PPI) experience in Latin America (Fay and Morrison 2006) shows that, despite the recent disenchantment with PPI programs, they have in fact generally been beneficial, bringing improved quality and access. The study argues that popular discontent with PPI, as well as private sector reluctance to further engage in PPI in the early 2000s, may have been due to a few well-publicized failures, excessive renegotiations, and poor management of the political economy of reform.

Even in some of the failed projects described in the literature, the reasons for failure are not necessarily related to the intrinsic nature of PPPs. They can range, for example, from technology system failures in the U.K., to the bankruptcy of private road operators in Mexico in 1994 during the financial crisis.

Overall, while the evidence is mixed, there is a stronger support both in theory and in practice for PPP's providing higher efficiency than traditional public contracting, while the evidence is less clear-cut in terms of quality and access.

A second reason behind the government's engagement in PPPs is the relaxation of the budget constraint through private financing of public infrastructure. Hence, PPP projects can support higher investment and growth in countries with tight budget constraints and weak fiscal positions. This corresponds to a substantial risk transfer from the government to the private sector. The gap between infrastructure needs and

government financial resources is usually cited as a problem in both developing and developed countries. This has been the case in PPP programs in Latin America in the 1980s (Engel, Fischer et al. 1997; Estache and Strong 2000; Engel, Fischer et al. 2003); of state PPP programs in the U.S. (as documented by Congressional hearings[10]), and even the United Kingdom private finance initiative (PFI), which has been encouraged by the government wishing to control the public sector borrowing requirement (Grout 1997).

Yet, PPP programs can also trigger fiscal risks (additional *fiscal variability*) especially arising from explicit or implicit guarantees, or contingent liabilities, and fiscal management. It is equally true that such fiscal risks may not characterize all PPP projects. As pointed out in Corbacho and Schwartz (2008, 105), "fiscal risks are more likely to arise when investment projects are of poor quality, the legal and fiscal institutional frameworks for PPPs are weak, and accounting and reporting systems do not transparently disclose the fiscal implications of PPPs." A discussion of fiscal risks associated with PPP investment is presented in the Appendix to this chapter.

At the same time, the complexity of PPP projects and the lack of standards regarding their fiscal accounting and reporting can result in PPPs being used by governments for bypassing public expenditure control (IMF 2004). Drawing from experience in developing countries, Corbacho and Schwartz (2008) reckon that implicit or explicit contingent liabilities arising from PPPs are often not adequately accounted for or disclosed. "There are currently no internationally accepted comprehensive accounting and reporting standards in place for PPPs. Country accounting practices for PPPs differ

[10] See for example the statements in the Congress by Governor of Virginia, T. Kaine, and Governor of Indiana, M. Daniels, as of May 24, 2006.

significantly and are often characterized by fairly lax standards" (2008, 112). Even existing *general* accounting and reporting practices, such as the International Public Sector Accounting Standards (IPSAS) or the International Financial Reporting Standards (IFRS) are not applied across the board (2008, 115). While transparency problems are likely to run higher in developing countries, there are concerns in some developed economies as well. As pointed out in Bloomfield (2006), such concerns can arise not only from poor fiscal regulations and enforcement, but also from intricacies of the *innovative* methods of financing used in long-term PPPs.

In addition, the evidence on government's cost savings over time under PPPs is not so clearly cut when shadow tolls/prices are used as supposed to direct user-fees, or as explained above, broader definitions of costs are used. In a suggestively titled-paper, "Highway Robbery? A Financial Analysis of Design, Build, Finance and Operate (DBFO) in UK Roads", Shaoul, Stafford et al. (2006) question the value-for-money under the first eight DBFO projects in the U.K. roads. The authors infer that the broad costs exceeded by far the potential efficiency gains in terms of delivery within schedule and future maintenance.

A third reason for government adoption of PPP programs is to prepare or advance privatization agendas, when political or public support for full privatization is weak, but the private sector is willing to deliver the good/service. For instance, Newberry and Pallot (2003) and Howell (2007) find PPP as a "logical" or "useful" way towards full privatization in New Zeeland and Mexico.

I.2 (2) Reasons behind the private sector's involvement in PPP

The reasons behind the private sector involvement in PPPs are less extensively analyzed in the literature. Triggered by the obvious reason of ***profit seeking***, a PPP project is also seen by the private partner as ***a venue to share risk with the public partner, and to benefit from government support (share cost)***, especially if compared to complete privatization. The private firm can thus have access to a new market in which the opportunity to invest and gain profit would not be possible due to political barriers to entry or public good-market characteristics. In a PPP, the government usually retains the risks that it can control better, such as political risk, some legal and institutional risk, cost overrun risks due to delays in granting necessary permits, right of way acquisition, or changing legislation, etc. In addition, the government can retain the whole or part of risks that neither party can control, such as geological risk, some environment risk, etc., or risks that the private partner is not willing to take, although it can control them better than the government, such as demand risk.

In general, the literature suggests two principles to guide risk allocation in a PPP contract: (1) each risk should be allocated to the party that is responsible for it or has more control over it; and (2) a risk factor should be allocated to the party that is more able to bear the risk (less risk-averse) (Guasch 2004). However, an optimal allocation of risk requires that these two principles be applied sequentially, that is, the second principle should be applied only for some residual risk that neither party can control and for which neither party is responsible. Otherwise, there will always be an incentive for the private partner to transfer risk back to the government, as a risk-neutral partner or guarantor of

last resort. For its part, the government should not attempt to maximize risk transfer to the private partner. The optimum risk allocation should be the objective of a PPP project; otherwise, the inappropriately transferred risk will be reflected in higher service charges to be paid by the government or directly by end-users (Leahy 2005).

Governments can also provide subsidies or guarantees to private firms to undertake projects in which social benefits exceed private benefits. Although usually loose as a measurement and selection principle, partnerships should give priority to projects that "would benefit society, but would not be privately profitable without a subsidy" (Stiglitz and Wallsten 1999).[11] In analyzing PPP in infrastructure, Engel, Fisher et al. (1997, 2001, 2006) consider PPPs to be the multitude of arrangements between traditional provision and full privatization, that is, projects in which government provides a subsidy to the private provider.

Private contractors, especially in developing countries, often press for generous up-front financial guarantees from the government or for the implicit guarantee that they would be bailed out should the project go into financial distress (Engel, Fischer et al. 1997).

Hence, apart from the ex-ante agreed way of sharing risks, the private partner can implicitly transfer risks back to the public sector, i.e. to taxpayers, with or without politicians' implicit consent. The implicit transfer of risk without politicians consent is the problem of opportunistic behavior, signaled by Williamson in mid-1970s, especially under contract incompleteness and institutional complexity. Williamson (1976) points out

[11] With respect to "research and development partnerships" in a paper analyzing the U.S. experience.

that franchising (concession) reveals difficulties in practice due to uncertainty regarding future events, asymmetric information between the parties and transaction costs (Williamson 1976). This can lead to contract renegotiations in which private firms attempt to extract higher benefits from the government, or simply view it as a "provider of last resort." Such implicit liability arises because governments often still bear the responsibility for service delivery, at least for essential public services (Levin 1999; Rosenau 1999; Edwards and Shaoul 2003). Contract renegotiation under concessions is analyzed in Guasch (2004) and Danau (2007), among others. Guash (2004) investigates about 1000 concession contracts awarded in Latin America and the Caribbean between mid-1980s and 2000 and finds a high incidence of contract renegotiation, mainly initiated by the private partner. Government's opportunistic behavior is also possible through nationalization and/or other actions embedding political risk, such as electoral gains. Danau (2007) proposes a model in which competition for monopoly franchise contracts—through the standard auction procedures—induces firms to report overoptimistic forecasts, whenever they expect renegotiation to occur at a later stage.

The implicit transfer of risk with politicians' tacit consent has been analyzed in a political economy model by Engel et. al (2006). The assumption of a benevolent planner is relaxed so that the government's objective in investing under PPP is to maximize the chances of getting reelected. Infrastructure concessions can be used by political incumbents to anticipate infrastructure spending and thus increase the probability of winning an election. Contract renegotiation allow politicians to replicate the effects of issuing debt, yet without incorporating it into the budget and thus circumventing

Congress approval and opposition review (Engel, Fischer et al. 2006b). In this way, the private partner can benefit from risk-taking by the public sector, as well as from monopoly rents.

I.3 Conclusions

To conclude, the literature on PPP seems to provide some stronger evidence in support of PPP as a way to enhance efficiency and promote investment under tight budget constraints. The evidence on PPP's superiority compared to traditional financing in promoting higher quality, equity and access is less clear-cut. The reasons for the government to get engaged into a PPP project, as opposed to traditional financing, seem to be: (i) enhanced efficiency; (ii) promoting investment while circumventing tight fiscal constraints (including fiscal rules, such as deficit and debt ceilings), and (iii) advancing privatization programs. The reasons for the private partner—summarized in profit maximization—are: (i) risk-sharing (similarly for the government); (ii) accessing markets that would be unavailable without government support; and (iii) potentially, increased room for opportunistic behavior with or without consent from the part of elected officials.

Chapter II – The theoretical model

In chapter two, I first review the existing models of investment under PPP and then propose a new basic model based on Dixit and Pyndick's (1994) theory of irreversible investment under uncertainty. Two model extensions are subsequently introduced. Before introducing the basic model, I give a brief review of the theory of investment under uncertainty. The main conclusion of this part is that the existing models of investment under PPP are scarce and they seek to identify primarily the optimal contractual form of PPP under incomplete contracting. In this dissertation's model, I seek to identify *what determines the decision to invest under a representative PPP contract* (where it is optimal to invest), by incorporating the objective functions, the constraints, and uncertainty of both the government and the private sector.

II.1 Existing models for investment under PPP

Engel, Fischer et al (2001; 2006a), and Engel (2005) present (variations of) a model of PPP financing in infrastructure, as an alternative between traditional financing (no private funds involved) and complete private financing (no government financial support in the form of subsidies/guarantees etc).

The PPP arrangement analyzed is a BOT in road transportation, in which private firms are willing to invest I (assumed to be the same for all firms) in the construction of

the project, operate the road and set the price (tolls) equal to P (constant). The value of the project (net present value of revenue, PVR) will depend on the state of demand Q (uncertain, can be high Q_H, or low Q_L, with probability π_H and π_L) and potential subsidies from the government (also depending on the state of demand: S_H and S_L). After the contract ends, toll revenue goes to the government, assuming that the government is willing to collect tolls from end-users, and can use the tolls to reduce taxes that generate distortions (λ>1 per dollar) in the rest of the economy.

The model attempts to answer two questions: (i) whether private provision of infrastructure is always preferred; and (ii) when private financing is preferred, what is the optimal contract design? To this end, the model is designed as an optimization problem for the planner, that is, to minimize the revenue transferred to the private partner, subject to finding a firm willing to build the project.

$$\underset{T_H T_L}{Min} \sum_{i=H,L} \pi_i \left[(PVR_i + \lambda S_i) - (\lambda - 1)\left(\frac{PQ_i}{r} - PVR_i \right) \right]$$

s.t. $\sum_{i=H,L} \pi_i u_i \left(PVR_i + S_i - I \right) = u(0)$,

where the variable notations are explained above, u() is the utility function of the private agent, assumed to be strictly concave so that the agent is risk-averse. u(0) is the level of utility attained by the private firm if it is not undertaking the project. r is the discount rate, common for the private sector and the planner, and λ is the deadweight loss from taxation (per unit $).

The authors show that the social optimum can be attained when $PVR_i + S_i = I$. Therefore, the road can be financed either only with subsidies (S_i = I), the traditional approach, or only privately PVR_i = I, or with a combination of the two.

Engel et al. (2001, 2005) also posit the so–called "irrelevance result" with respect to public or private financing, i.e. public and private financing are perfect substitutes at the margin, when the government is also able to apply user fees for services delivered to the public. When the road can be financed only privately, Engel et al. (2006) find that the condition $PVR_L = PVR_H$ = I solves the planner's problem, because the private firm is risk averse and it is efficient to insure it completely against any risk. With no subsidies at all, this can be achieved by an auction mechanism that lets firms bid on the expected present value of the project, PVR, under a flexible term contract, i.e. the contract's length is extended when the demand is low and reduced when the demand is high up to the point where the PVR has been entirely collected.

Most of the other formal modeling of PPP deals with inter-connected problems of incomplete contracting, such as the hold up problem and contract renegotiation, and the trade-off between efficiency and quality.

Guash (2004) provides a review of the theory on concession contracts (a form of PPP), showing that most of these relatively recent models[12] focus on incomplete contracts and that ex-ante incentives affect ex-post bargaining. The widely-cited problem of the trade-off between efficiency and quality, especially when the latter is difficult to monitor, is analyzed in Hart, Shleifer et al (1997), Hart (2003), and Bennett and Iossa

[12] Starting with Williamson in the late 80s, many of the other models cited date from the second half of the nineties and early 2000.

(2006), among others. Hart, Shleifer and Vishny provide the formal model of the argument that private provision may be more efficient than the traditional one, but argue that the private contractor's incentive to engage in cost reduction is typically too strong, as it ignores the adverse impact on non-contractible quality.

Hart (2003) adapts this model to PPPs (the PFI type of private service provided to the government) and shows that a PPP-type arrangement is recommendable if the quality of services can be well specified in the initial contract, whereas the quality of the asset that generates the service is difficult to measure and monitor. The reverse holds for the traditional provision, defined as "unbundling" of tasks, where a private contractor builds the asset for the government, but does not operate it. In this model, the private sector internalizes the operation of the project under PPP and has incentives to invest more. However, there are two types of investments for the project operational phase, which correspond to the trade-off between efficiency and quality. The first type, investment "i" is a productive investment that makes the asset more attractive and easier to run. In contrast, the second type, "e" is an investment that reduces total costs and quality ("corner-cut"-type). Hart (2003) finds that under traditional financing a private constructor has incentives not to do any operation-related investments, while under a PPP, it will do both i and e. If quality of service can be controlled, then a PPP is better because the investment in e will not be a problem.

Bennett and Iossa (2006) use an incomplete contract model to compare contracting out by a public sector agency (denoted G—the PFI type of PPP) with the delegation of contracting out to a PPP agent (denoted P)—a joint venture between private

and public sector agents (a cooperative behavior). The PPP maximizes a linear combination of profit and social benefit. Thus, in contrast to Engel et al. (2001, 2006), this model does not consider the case of G implementing user fees in the future, so that the distortive taxation plays a role. In the first best world, in which "i" and "e" were verifiable, the best solution would be obtained under either of the two institutional arrangements (initiated by G or P), and the optimal investment amounts will be chosen to equate marginal social benefit to marginal social cost, appropriately weighted by $1+\theta$, the cost of distortive taxation. Bennett and Iossa (2006) consider then the second-best world in which contracts are incomplete and "i" and "e" unverifiable, and show that the delegation to a PPP may be desirable to curb investment that reduces the cost of provision, but also the social benefit. Their results are also constrained by the shadow cost of public funds, i.e. under centralized contracting, there is overinvestment in quality innovation ($i_G > i^*$), but this declines with the degree of distortion induced by taxation ($di_G/d\theta < 0$).

A literature review has found that Danau (2005) is the only model (at this stage, in an unpublished working paper) of PPP investment based on the Dixit-Pindyck framework of investment under uncertainty, expanded according to Sodal (2001). It models a monopolist's decisions with respect to two options: the time of investment and the scale of service operation. In addition, it analyzes the case where public-private cooperation is necessary to cover (part of) the investment cost and where the accumulation of public funds is costly. It concludes that waiting longer to invest is traded-off against rationing consumers, and sets the conditions for optimum quantity and time of investment.

However, the paper is not concerned with the determinants of investment under PPP and how they differ compared to traditional financing or complete privatization. Moreover, it does not consider risk-sharing approaches or different stochastic processes specific to each partner.

In conclusion, the existing models of why the private sector undertakes PPP are limited, and seek to identify primarily the optimal contractual form of PPP under incomplete contracting. It still remains to identify *what determines the decision to invest under a representative PPP contract* (when it is optimal to invest), and to incorporate the objective functions, the constraints, and uncertainty of both the government and the private sector.

II.2 A background on the theory of irreversible investment under uncertainty

Given that most PPP arrangements refer to the provision of capital goods, investment theory—modeling the decision of an agent to invest—is a starting point to model investment under a public-private partnership. The main investment theories are reviewed in Appendix II.1. A conclusion of the accelerator theory (Keynes, 1936) and macroeconomic models of investment (Samuelson 1939; Hicks 1950; Klein 1950) is that aggregate investment depends on the level or change of output/aggregate demand. In addition, the neoclassical model of investment (Jorgenson 1963; Hall and Jorgenson 1967) posits that the rental cost of capital is also important in determining aggregate private investment.

This chapter focuses on the theory of (partly-) irreversible investment under uncertainty developed by Dixit and Pindyck (1994) based on earlier work by McDonald

and Siegel (1986), Bernanke (1983), Metcalf and Hassett (1993), Pindyck (1988), and others. Further work has been done in Abel, Dixit et al. (1996), Bertola and Caballero (1994), Dixit, Pindyck and Sodal (1999), Sodal (1998; 2001; 2006), etc.

While all main theoretical models of investment may have shortcomings, it is certainly important, especially from the point of view of PPPs, to capture the uncertainty of the decision to invest, and the full opportunity cost of investment due to its inherent irreversibility. Infrastructure projects, in particular, may be well suited for such an analysis given their high specificity. Hence, I will frame our analysis within the theory of (partly-) irreversible investment under uncertainty

Pindyck (1993) stresses that most investment expenditures have two important characteristics. First, these expenditures are broadly irreversible - they involve large sunk costs due to: (i) the fact that capital is industry, firm or project specific; (ii) the "lemon" problem—the resale value of fixed capital is usually well below their purchasing cost, even if new, or simply (iii) government regulations and institutional arrangements, such as capital controls, that make impossible or difficult for investors to sell or relocate their capital. Second, because investment decisions are long term and can be delayed, a firm can wait for new information about the market conditions before committing its resources. Hence, in this model, the ability to delay an investment can affect the decision to invest, which undermines the theoretical foundation of the neoclassical model and invalidates the (micro-level) rule of net present value (Pindyck 1993).

Within this framework, option-pricing methods have been proposed in order to value a firm's investment opportunity and to determine whether the firm should invest. In

the simplest model presented in Dixit and Pindyck (1994)—irreversible investment decision under uncertainty, without entry competition and without costs of exit, based on McDonald and Siegel (1986)—a firm's investment opportunity is equivalent to a perpetual call option. This gives the right, but not the obligation to pay a price—the sunk cost of investment, I—in exchange for a project whose value is V, and which evolves stochastically over time. The value of the option, F(V) is the value of waiting for future information about the project and the opportunity to invest only if V proves sufficiently large. Once an irreversible investment is made, the option to wait is lost, and the value of the option has to be added to the cost of investment. Hence, the cost of investment includes two components: an explicit component—the sunk cost (I)—and an implicit one—the opportunity cost of investing or the value of the option to wait, F(V). The decision rule to invest is then "invest if NPV>0, otherwise do not invest", where NPV (the net present value) is given by the present value of the project, minus the explicit investment cost and the value of option to invest. The problem is to determine at what project value V* it is optimal to invest (pay the sunk cost I and abandon the option of waiting, F(V)), given that V follows a stochastic trend, most often considered to be a geometric Brownian motion. The value V* results from the maximization of the expected payoff from investing, and it depends on several factors, such as:

(i) V* is an increasing function of uncertainty (σ). This means that *an increase in the uncertainty over future values of V determines an increase in V* for a given I, or equivalently, a higher level of future payoff is required to undertake the investment. This would make firms postpone investment.* Conversely, a decline in the uncertainty over

future values of V would make private firms undertake investment I (abandon the option of waiting) more easily.

(ii) V* is an increasing function of the total discount rate, ρ (total cost of capital or total project return; it can be approximated at a macroeconomic level by the average lending interest rate). A higher discount rate makes the expected value of the project lower, and the value of waiting higher.

(iii) V* is a decreasing function of the opportunity cost of waiting (δ). The higher the opportunity cost of waiting (the difference between the total rate of discount and the expected growth rate of the project), the lower the threshold V* and the higher the propensity to invest at present.

Various extensions of the model are presented in Dixit and Pindyck (1994), Abel et al. (1996), Dixit, Pindyck and Sodal (1999) and Sodal (1998; 2001; 2006). If investment is considered partially reversible as in Abel et al. (1996)—the project can be sold or there is a positive scrap value higher than any exit costs E—then there exists a capital gain from exiting the project. In such a case, an increase in the uncertainty of future returns has an ambiguous effect on investment: higher uncertainty increases the value of the call option, which decreases the incentive to invest, but it also increases the value of the put option (option to sell capital in the future), which raises the incentive to invest. The assumption of completely irreversible investment eliminates the put option from the end, and makes the impact of uncertainty on investment always negative.

Darby et al. (1999) extend the model in Dixit and Pindyck (1994) to account for the impact of exchange rate uncertainty on investment, and find that the theory is

ambiguous on whether suppressing exchange rate volatility automatically increases investment (for some industry types it increases investment, but for others it decreases it).

Similarly, ambiguous theoretical results are derived in Caballero (1991), who concludes that under perfect competition and constant returns to scale, there is a positive association between uncertainty and investment, while under decreasing returns to scale or imperfect competition or both, this association becomes negative.

Another extension of the model of irreversible investment, presented in Dixit and Pindyck (1994) based on Metcalf and Hassett (1993), incorporates uncertainty related to government tax policy. Such uncertainty, modeled as a Poisson jump process (e.g. $\lambda_{0,1}$ are the probabilities of granting/removing an investment tax credit), is shown to have an additional detrimental impact on investment (in any state, there is an additional uncertainty induced by the next government move, which tends to postpone investment).

In later works, Sodal (1998; 2001; 2006), Dixit, Pindyck and Sodal (1999) show that the optimal investment has to satisfy a trade-off between a *larger* versus a *later* net benefit, which is analogous with the *price mark-up* versus *quantity* decision of a monopolist facing a downward sloping demand curve. Since the scale of production often results from irreversible investment, Sodal proposes a model in which the firm holds two options: the timing option (when to invest) and the scale option (which quantity to produce to allow a price mark-up over the marginal cost). Depending on the specific assumptions, either option will be more or less relevant—the option to wait prevails when there is high uncertainty and the demand curve is fairly elastic (so the price mark-up is week), while the opposite is true for the option to scale production.

II.3 A proposed model of investment under PPP

II.3 (1) Conditions for the optimal decision of investment under PPP

I consider an entity whose immediate objective function is V(Q, Y), a payoff that would result from making an irreversible investment I to produce an output Q. Such an objective function can be the private value of a project for a firm; the total social utility derived from a project in the case of a benevolent social planner, or a combination of the two in the case of a public-private entity (a PPP).

The realization of the payoff depends on the outcome of a random shift process Y, V(Q, Y) = YV(Q), which is assumed to follow a geometrical Brownian motion:

dY = αYdt + σYdz, where α and σ are parameters and dz is an increment of a Wiener process (dz = $\varepsilon_t \sqrt{dt}$, ε_t ~N(0, 1), a normally distributed random variable with zero mean and standard deviation of 1, and *dt* is an infinitesimally small interval of time[13]). Assuming Q a given output, the current value of the project is known, but future values are lognormally distributed, the more uncertain the further away in time[14].

The entity seeks a rule F(Q, Y) that gives the optimal threshold Y_T^* to invest the amount I at a (future) time T so that to maximize the expected present value of the net payoff.

$$F(Q, Y) = maxE\,(e^{-\rho T}\,[(V(Q, Y_T) - I])$$

[13] The mean of a Wiener process if zero and the variance is dt. This means that the longer the time interval t considered the higher is the variance of a Wiener process, which makes it nonstationary. Correspondingly, the geometrical Brownian motion is a nonstationary process, as well.

[14] The rate of change of Y over a time interval t follows: $dY/Y \sim N(\alpha t;\ \sigma^2 t)$.

The change of logY: $d\log Y \sim N((\alpha - \sigma^2/2)t;\ \sigma^2 t)$.

It follows that dY has a lognormal distribution and $Y(t) \sim \log N(Y_0 e^{\alpha t};\ Y_0 e^{2\alpha t}(e^{\sigma^2 t} - 1))$

See Dixit and Pindyck (1994) for derivations of these formulae.

subject to $dY = \alpha Y dt + \sigma Y dz$, where

E denotes expected value; T is the unknown (future) time when the investment is made; ρ is the discount rate (if the investing agent is assumed to be risk-neutral, ρ is the risk-free interest rate, r). The trend of the growth rate of Y (α) is assumed to be smaller than the discount rate (ρ), otherwise waiting indefinitely longer will always be optimal for a given I, however large the investment may be. Let $\delta = \rho - \alpha$, where $\delta > 0$; in contingent claims terminology, δ would be equivalent with a dividend rate or the difference between the total rate of return and the rate of capital gain.

The optimization problem can be solved using dynamic programming according to Dixit and Pindyck (1994). The full derivation to obtain the condition for the optimal investment trigger is presented in Appendix 1 to this chapter. Thus, the trigger value Y* is given by the solution to the following relationship:

$$\beta_1 V(Q, Y^*) - Y^* V_Y(Q, Y^*) = \beta_1 I \quad \text{(R1)}$$

β_1 is the positive root of the fundamental quadratic,

$$\beta_1 = \frac{1}{2} - \frac{\rho - \delta}{\sigma^2} + \sqrt{\left(\frac{\rho - \delta}{\sigma^2} - \frac{1}{2}\right)^2 + 2\frac{\rho}{\sigma^2}} > 1, \text{ as shown in the appendix;}$$

V_Y is the first derivative of the objective function with respect to the shift variable Y.

Assuming that the value of the payoff (our basic objective function) is a linear function of the shift variable, V=YV(Q), the optimality condition simplifies to:

$\beta_1 Y^* V(Q) - Y^* V(Q) = \beta_1 I \Leftrightarrow$

$$Y^* V(Q) = \frac{\beta_1}{\beta_1 - 1} I \quad \text{(R2)}$$

Therefore, the agent will invest when the random shift variable hits the optimal value Y* and the project payoff exceeds the investment cost I by a wedge factor $w = \frac{\beta_1}{\beta_1 - 1} > 1$.

Any increase in the wedge factor $w(\beta_1)$ will require a higher payoff to undertake the investment, or equivalently, will postpone investment. As summarized in the previous section, in line with Dixit and Pindyck (1994), the following relations hold:

- Ceteris paribus, a higher uncertainty regarding future payoff (σ) raises the wedge factor, and thus postpones investment (see proof in Appendix 1, relation *AR2*);
- A higher discount factor (ρ) has a similar effect of discouraging investment (see proof in Appendix 1, relation *AR3*);
- A higher dividend rate (or opportunity cost of an investment payoff, δ) lowers the wedge and reduces the waiting period towards investment (see proof in Appendix 1, relation *AR4*).

Relation R2 is the core of our model; it includes a generalized form of the objective function Y*V(Q) or V(Q,Y*), which can be transformed to reflect the objective of our economic agents of interest. Hence, for a private firm whose objective is to maximize profits, V(Q, Y) is the total revenue R(Q, P) from selling the production Q minus the operational cost C(Q). If one assumes that the price P follows the geometrical Brownian motion (P~Y) and revenue PQ (Q=1) is obtained in perpetuity so that the total future expected value of the project (with no operational cost) will be $V(Q, P) = \frac{P}{\rho - \alpha} = \frac{P}{\delta}$,

one obtains the basic model of private investment decision (Dixit and Pindyck 1994, pg. 186): $P^* = \frac{\beta_1}{\beta_1 - 1}\delta I$

In the present model of PPP, I consider a social planner who seeks a private firm (assumed to have a monopoly position) to undertake a project whose cost of investment is I and which will produce a quantity Q of goods and services per unit of time. The planner is willing to support part of the investment cost by granting a subsidy S to the private company. Having a long-term balanced budget constraint, the social planner must finance S through taxes θ (S=θ), which will cost society an additional λθ, where λ (λ>1) is the tax-associated dead-weight loss to society (including tax collection cost). In this case, the general form of the objective function under a PPP project, assuming a cooperative behavior between the public and the private agent, can be written as follows:

$$V(Q, Y) = \gamma[U(Q, Y) - R(Q, Y) - (1+\lambda)\theta] + (1-\gamma)[R(Q, Y) - C(Q) + \theta]$$

V(Q, Y) is the aggregated objective function of the two agents and γ is a coefficient ($0 \le \gamma \le 1$) that gives the relative importance of each agent's objective in V.

The total social utility associated with the PPP project, U(Q,Y)—the sum of consumer surplus and firm's revenue U(Q,Y) = CS(Q,Y) + R(Q,Y)—is the flow of utility generated by the output flow Q in perpetuity and triggered by the shift variable Y. If the demand function is D(Q), then $U(Q, Y)=\frac{YU(Q)}{\delta} = Y\frac{\int_0^Q D(q)dq}{\delta}$.

The social planner's objective is to maximize consumer surplus CS(Q, Y): he/she cares about consumers' welfare, as given by the difference between total social utility

associated with the project and the firm-producer's revenue along with the cost of subsidy (the taxes needed to cover the subsidy and the related dead-weight loss to society).

The private producer's objective is to maximize profits $R(Q, Y) + \theta - C(Q)$, where $R(Q, Y)$ is the total revenue from charging users' fee in perpetuity, and it is equal to $YR(Q)/\delta$; θ is the additional amount of revenue received from the public agent at the beginning of the project, as an upfront contribution to the cost of investment if the contract is undertaken together ($\theta = 0$ if $\gamma = 0$); $C(Q)$ is the unit cost of production, assumed to be known so that C does not depend on Y and can be discounted at the free-risk rate ρ, in perpetuity $C(Q)/\rho$.

If $\gamma = 0$, then the contract is purely private. In this case, the project is undertaken solely by the private agent and is entirely financed through user fees with no subsidy ($\theta=0$).

If $\gamma = 1$, then the contract is purely public. If the social planner decides to undertake the project alone, then the total cost of the project will be covered through taxes ($\theta_T+\lambda\theta_T$ is then the *total* tax burden to society necessary to cover the whole cost of the project; $R(Q,Y)=0$).

If $0 < \gamma < 1$, then the two agents will cooperate under a PPP project. If $\gamma = ½$, then the two agents will have equal weight in the aggregate objective function.

The objective function can be further simplified to:

$$V(Q, Y) = \gamma U(Q, Y) + (1-2\gamma)R(Q, Y) + (1 - 2\gamma - \gamma\lambda)\theta - (1-\gamma)C(Q)$$

Replacing the simplified form of the objective function in the general optimal (Y*) threshold condition (R1), it follows that:

$\beta_1 [\gamma Y^*U(Q)/\delta + (1-2\gamma)Y^*R(Q)/\delta + (1 - 2\gamma - \gamma\lambda)\theta - (1-\gamma)C(Q)/\rho] - Y^*[U(Q)/\delta + (1-2\gamma)^*R(Q)/\delta] = \beta_1 I \Leftrightarrow$

$$Y^* [\gamma U(Q) + (1-2\gamma)R(Q)] = \frac{\beta_1}{\beta_1 - 1} \delta[I - (1 - 2\gamma - \gamma\lambda)\theta + (1-\gamma)C(Q)/\rho] \quad \text{(O1)}$$

The expression (O1) gives the optimal (Y*) threshold condition for undertaking our project of interest.

If **$\gamma = 0.5$** (equal shares of the two partners in the objective function of the PPP project)

$$\Rightarrow \tfrac{1}{2} Y^* U(Q) = \tfrac{1}{2} Y^*[CS(Q) + R(Q)] = \frac{\beta_1}{\beta_1 - 1} \delta(I + \tfrac{1}{2}\lambda\theta + \tfrac{1}{2} C(Q)/\rho)$$

In this case, the value embedded in the project is the weighted average between consumer surplus and the private firm's revenue. The two partners share equally the benefits and the costs.

If **$\gamma = 1$** (purely public contract)

$$\Rightarrow Y^*[U(Q) - R(Q)] = Y^*CS(Q) = \frac{\beta_1}{\beta_1 - 1} \delta[I + (1+\lambda)\theta_T)]$$

There is an interest only in maximizing consumer's surplus; there is no subsidy to a private firm, all the cost is borne by the public agent; consumers pay for the project through taxation (plus its associated dead-weight loss), which is used to cover production and operation cost. There is no sharing of cost or benefits.

If **$\gamma = 0$** (purely private contract and no subsidy; $S=\theta=0$)

$$Y^* R(Q) = \frac{\beta_1}{\beta_1 - 1} \delta[I + C(Q)/\rho]$$

There is an interest only in maximizing profits by the private firm; there is no sharing of cost or benefits.

Comparing the cost side of the three optimality conditions, it follows that:

A PPP contract would be preferred to a purely public contract when $C(Q)/\rho < 2\theta_T + \lambda(2\theta_T - \theta)$, that is, when the operating costs incurred by the private partner were lower than twice the total tax burden that had to be raised if the government acted alone plus its associated dead-weight loss to society, reduced by the dead-weight loss associated with the PPP subsidy.

A PPP contract would be preferred to a purely private contract when $\lambda\theta < C(Q)/\rho$, that is, the dead-weight loss associated the PPP subsidy were lower than the operating cost incurred by the private partner.

Combining the two, it results that a PPP contract would be preferred from a cost point of view when the parameters are such that:

$$\lambda\theta < C(Q)/\rho < 2\theta_T(1+\lambda) - \lambda\theta$$

Using comparative statics, the following conclusions can be reached, ceteris paribus:

- The higher the distortionary cost of taxation λ ($\theta_T > \theta$), the more reluctant the social planner will be to make the investment alone, and it will prefer a PPP (a fully private contract will be the most preferred alternative).
- Similarly, the higher the tax burden θ to cover the investment cost entirely under a purely public contract, the more the social planner will prefer a PPP to get the project going (again, a fully private contract would be the preferred alternative from a cost point of view).

- The higher the subsidy to the private agent under a PPP contract, the lower the propensity of the social planner to undertake the project under a PPP.

These results, especially the first one, are worth emphasizing, as they are not widely discussed in the literature. Empirical testing is difficult, but as it will be shown in chapter IV, evidence is found for the second theoretical finding, when the tax burden is proxied by government revenue-to-GDP ratio.

So far, the model assumed that production Q was given (e.g. maximum capacity). As pointed out in Dixit and Pindyck (1994, pg. 289) and later developed more explicitly by Sodal (2001), the production flow Q is also a matter of choice. Sodal (2001) shows that a monopoly can hold at least two options exploiting its market power: one is the option to delay investment (the real option of timing the investment), and the other one is the basic option of scaling the production (optimal Q results from equating marginal benefit with marginal cost, or pricing above marginal cost).

Hence, the agent can first choose the optimal production Q* and then choose the time of investment. As pointed out in Sodal (2001), since the condition regarding the time of investment holds for any scale of production, it also holds for the optimal scale. When the stochastic shift variable is at Y, and $F(Q, Y)$ is the expected present value of the investment opportunity, $F(Q, Y)= e^{-\rho T} [(V(Q, Y_T) - I]$, then the optimal Q (Q*) follows from:

$$\frac{\partial F}{\partial Q} = 0 \text{ (assuming } V(Q) \text{ a concave function of } Q) \Leftrightarrow \frac{\partial V}{\partial Q} = 0 \Leftrightarrow$$

$$\gamma U_Q(Q^*, Y) + (1-2\gamma) R_Q(Q^*, Y) - (1-\gamma)C_Q(Q^*) = 0$$

In terms of elasticities (ε_{UO} is the elasticity of social utility with respect to quantity; ε_{RQ} and ε_{CQ} are the elasticity of private revenue and private operational costs with respect to quantity), this condition translates as:

$$\gamma U(Q^*, Y)\varepsilon_{UO} + (1-2\gamma)\, R(Q^*, Y)\, \varepsilon_{RQ} - (1-\gamma) C(Q^*)\, \varepsilon_{CQ} = 0 \quad \text{(O2)}$$

Hence, O2 gives the optimal condition for scaling the monopoly production (Q*) as a result of the investment decision.

If **$\gamma = 0$** (only private production) =>

$$R_Q(Q^*, Y) = C_Q(Q^*) \Leftrightarrow \frac{R(Q^*, Y)}{C(Q^*)} = \frac{\varepsilon_{CQ}}{\varepsilon_{RQ}}$$

This is simply the condition for private decision on scaling production, i.e. produce where marginal revenue equals marginal cost, or equivalently, the ratio of total private revenue-to-private operational cost equals the inverse of the corresponding elasticity with respect to quantity.

If **$\gamma = 1$** (only public) =>

$$U_Q(Q^*, Y) = R_Q(Q^*, Y) \Leftrightarrow \frac{U(Q^*, Y)}{R(Q^*, Y)} = \frac{\varepsilon_{RQ}}{\varepsilon_{UQ}}$$

If the government does not levy user fees, then it forgoes the revenue R(Q). At the margin, the utility has to equal the marginal revenue.

If **$\gamma = 0.5$** (equal shares of the two partners in the PPP objective function) =>

$$\Rightarrow \tfrac{1}{2}\gamma U_Q(Q^*, Y) - \tfrac{1}{2} C_Q(Q^*) = 0 \Leftrightarrow U_Q(Q^*, Y) = C_Q(Q^*) \Leftrightarrow \frac{U(Q^*, Y)}{C(Q^*)} = \frac{\varepsilon_{CQ}}{\varepsilon_{UQ}}$$

The PPP agent will produce at the scale Q* where marginal utility to the society (total consumer surplus and revenue of the private firm) equals marginal cost of production as incurred by the private partner.

The conclusions of the basic model of investment under PPP can be summarized as follows. Optimality conditions O1 and O2 give the optimal timing of investment (Y*) and the optimal scale of monopoly production (Q*) for the decision to invest in a PPP project. If the two partners have equal shares in the project, then these conditions are:

$$\tfrac{1}{2}Y^* U(Q) = \frac{\beta_1}{\beta_1 - 1}\,\delta(I + \tfrac{1}{2}\lambda\theta + \tfrac{1}{2}C(Q)/\rho) \qquad \textit{(O1)}\ \text{and}$$

$$\frac{U(Q^*,Y)}{C(Q^*)} = \frac{\varepsilon_{CQ}}{\varepsilon_{UQ}} \qquad \textit{(O2)}$$

where the wedge $w(\beta) = \frac{\beta}{\beta - 1} = f((\sigma(+), \rho(+), \alpha(-))$

Hence, the decision to invest under a PPP will depend on the following main factors (I focus on factors that can be extrapolated at a macroeconomic level):

- the uncertainty associated with the project: the higher the uncertainty (macroeconomic, political, financial), the longer the investment in the project will be deferred;
- the discount rate associated with the project: the higher the discount rate, or equivalently a prevailing lending interest rate, the more the investment will be deferred.
- When choosing between undertaking the project as a purely public investment or a PPP, the social planner will compare the tax burden (total tax θ_T, and the associated dead-weight loss to society λ, netted out of the PPP subsidy θ) required

to undertake the project alone with the operational cost to be covered by the private agent under PPP. The PPP investment becomes an increasingly attractive option as θ_T or λ increases.

The actual quantity of goods and services that will be produced following the investment will depend on the shape of the demand curve and cost curve (the elasticities of total social utility and cost with respect to quantity).

II.3 (2) Extensions

So far, I have assumed that the public agent (government) and the private agent are faced with the same stochastic processes. It may be useful to differentiate between the two, e.g. to take into account that macroeconomic uncertainty can affect the two agents differently and that some government actions—independent of the project—can affect the private partner. In the next sub-chapter, some of these considerations are incorporated in the model.

Extension 1 – different stochastic processes for the government and the private firm

Assume that the payoff of the government is a function of the stochastic process Y_G, and the payoff of the private firm is a function of the stochastic process Y_P. The two processes are correlated due to some common macroeconomic shocks or in the sense that private decisions may be influenced by government's decision or vice versa..

$dY_G = \alpha_G Y_G dt + \sigma_G Y_G dz_G$; $dz_G \sim$ increment of a Wiener process

$dY_P = \alpha_P Y_P dt + \sigma_P Y_P dz_P$; $dz_P \sim$ increment of a Wiener process

The two Wiener process increments have equal variances: $E(dz^2_{P;G}) = dt$

The two Wiener process increments are correlated and the covariance is φdt:

$E(dz_P, dz_G) = \varphi dt$ where φ is the coefficient of correlation, if φ = 0, the two processes are uncorrelated.

1) If either the government or the private firm undertakes the project alone, then:

$$Y_G^*V(Q) = \frac{\beta_G}{\beta_G - 1} I ; \quad Y_P^*V(Q) = \frac{\beta_P}{\beta_P - 1} I ;$$

$$\frac{\beta_G}{\beta_G - 1} = f_G((\sigma_G(+), \rho_G(+), \alpha_G(-)); \qquad \frac{\beta_P}{\beta_P - 1} = f_P((\sigma_P(+), \rho_P(+), \alpha_P(-))$$

If according to some conclusions of the literature reviewed, I assume ceteris paribus that:

(i) the government has a smaller rate of discount than the private sector, (reflecting a smaller risk of default due to the power of taxation in line with Arrow (1965; 1966) and the followers), $\rho_G < \rho_P$;

(ii) a government project faces less uncertainty ($\sigma_G < \sigma_P$), i.e. if the service has always been publicly provided and a transfer to the private sector would make users more cautious in using the service,

then a lower investment trigger (Y*) is necessary for the government to undertake the project compared to the private sector ($Y^*_G < Y^*_P$). The private sector will defer the project longer or not undertake it, and public financing project is preferred.

Similarly, if I assume, ceteris paribus, that the private sector is more efficient, i.e.:

(i) the project may have a higher future rate of growth given the same investment ($\alpha_P > \sigma_G$);

(ii) the project will have lower operational costs in the future, $C_P(Q) < C_G(Q)$, which, in terms of the net value of the project, is equivalent to $V_P(Q) > V_G(Q)$,

then a higher investment trigger (Y*) is necessary for the government to undertake the project compared to the private sector ($Y^*_G > Y^*_P$); the government will defer the project or not undertake it, and private financing is preferred. This can be a reason for the public planner to envisage also a PPP project (not only purely private financing).

2) If the project is undertaken in cooperation, then the payoff of the project and the option to invest are functions of two correlated geometrical Brownian motions—$V(Q, Y_G, Y_P)$ and $F(Q, Y_G, Y_P)$. In this case, the boundary between the two regimes: (i) waiting (and keeping the option to invest), and (ii) investing (and getting the project payoff) is a function of two random variables, and an analytical solution of the optimization problem is usually not possible. However, as before, the optimal solution is given by the Bellman equation for $F(Y_G, Y_P)$ and the boundary conditions, as follows:

Bellman equation (detailed derivation is found in Technical Appendix AII.2.):

$$½\,\sigma^2_G Y^2_G\, F''_{GG} + ½\,\sigma^2_P Y^2_P\, F''_{PP} + \varphi\,\sigma_G \sigma_P\, Y_G Y_P\, F''_{GP} + \alpha_G\, Y_G\, F'_G + \alpha_P\, Y_P\, F'_P - \rho F = 0$$

where F''_{GG} *and* F''_{PP} denote the second derivative with respect to Y_G, and respectively, Y_P; F''_{GP} and F''_{PG} are the second partial derivatives, and F'_G F'_P are the first derivatives with respect to Y_G, and respectively, Y_P.

The boundary conditions:

- The value-matching condition: $F(Y_G, Y_P) = V(Q, Y_G, Y_P) - I$
- The smooth-pasting conditions:

$$F'_G(Y_G, Y_P) = V'_G(Q, Y_G, Y_P)$$

$$F'_P(Y_G, Y_P) = V'_P(Q, Y_G, Y_P)$$

The above system (Bellman equation and the boundary conditions) gives the optimal decision regarding investment.

An analytical solution, as presented in Dixit and Pindyck is possible in certain circumstances that can also apply to a PPP-type contract. Hence, if I assume that:

- the private agent bears all investment cost (investment, including any future maintenance and expansion works) and this is subject to uncertainty: Fixed investment cost = $Y_P I$ (Y_P defined above);
- the government will pay for service provision through shadow fees and the project's payoff will be subject to uncertainty facing the government (I consider it as an aggregate of macroeconomic uncertainty, political risk, fiscal risk, risk of sovereign default and demand risk) ⇔ project payoff = $V(Y_G) = Y_G V(Q)$;
- the optimal decision depends on the ratio $y = Y_G/Y_P$, and the value of the option is assumed to be homogenous of degree 1 in y so that $F(V, I) = Y_P f(Y_G/Y_P) = Y_P f(y)$.

Under these conditions, as shown in Dixit and Pindyck (1994, pg. 210-211), the usual dynamic programming for a single random variable y can be applied and the optimal solution is given by the known expression:

$$y^* V(Q) = \frac{\beta_1}{\beta_1 - 1} I \Leftrightarrow (Y_G/Y_P)^* V(Q) = \frac{\beta_1}{\beta_1 - 1} I,$$

β_1 in this case being the positive root of the following fundamental quadratic equation:

$$\tfrac{1}{2} (\sigma^2_G - 2 \varphi \sigma_G \sigma_P + \sigma^2_P)\beta(\beta-1) + (\delta_P - \delta_G)\beta - \delta_P = 0$$

$$\Leftrightarrow \beta_1 = \frac{\delta_G - \delta_P + \sqrt{(\delta_G - \delta_P)^2 - 2\delta_P(\sigma_G^2 - 2\varphi\sigma_G\sigma_P + \sigma_P^2)}}{\sigma_G^2 - 2\varphi\sigma_G\sigma_P + \sigma_P^2} > 1$$

$$\Rightarrow \text{If } \sigma_G \text{ or } \sigma_P \text{ increases} \Rightarrow \beta_1 \text{ decreases and } \frac{\beta_1}{\beta_1 - 1} \text{ increases}$$

$$\Rightarrow \text{If } \varphi \text{ increases} \Rightarrow \beta_1 \text{ increases } (\sigma_G, \sigma_P, \delta_P > 0) \text{ and } \frac{\beta_1}{\beta_1 - 1} \text{ decreases}$$

As before with only one type of uncertainty, an increase in the uncertainty facing either the government (σ_G) or the private firm (σ_P) will reduce β_1, increase the wedge, and therefore, delay investment.

However, a new term, φ, appears now in the optimum solution. Ceteris paribus, as φ increases, β_1 increases, the wedge decreases, and the incentive to wait to invest is lower. This means that a higher covariance between movements in the factors affecting the private partner (the cost of investment IY_P) and those affecting the public partner (the project payoff $V(Q)Y_G$) will stimulate the decision to invest. The covariance between the two Brownian motion (one of the cost of investment and one of the payoff) can be considered a proxy for risk-sharing between the two partners.

If the risk for both partners *(σ_G and σ_P)* rises, the increase in the overall risk of the project may be lower the higher is the covariance (the risk-sharing). According to this model extension, I conclude that a PPP agent may choose more readily to invest than the separate agents acting alone as a result of the capacity for risk-sharing.

Extension 2 – implicit government guarantee/transfer/renegotiation as a put option

So far, the model has assumed irreversibility of the investment decision, which is appropriate for large infrastructure projects. However, in case of PPP projects, experience demonstrates that implicit government guarantees to bail out the private partner or buy-back the private share of the project, as well as contract renegotiations, are not rare occurrences. All these instances can be reflected in our PPP model through a put option given by the public partner to the private partner: the latter has the option but not the obligation to divest the project at the later stage should conditions worsen.

In their model of investment decision under uncertainty with costly reversibility and expansibility, Abel, Dixit et al. (1996) show that an investment decision yields two options: (i) a call option to purchase capital later (delay investment even if the future price will be higher than the current one), and (ii) a put option to resell capital later (reverse the investment even at a future price lower than the current one). Detailed derivation is reworked in the Technical Appendix AII.3.

Hence, the existence of the put option (and the higher its value is) makes the agent to invest now instead of waiting (the option of waiting and deferring investment becomes less valuable). This means that the private agent entering a PPP contracts may speed up the investment process compared to the case of acting alone knowing that it will have the option to disinvest later—this can be done through an explicit government commitment to buy-back, e.g. BOT "Build-Operate-Transfer" or DBOT "Design-Build-Operate-Transfer" types of PPP contracts, or through an implicit government guarantee to bail out

the project in times of financial distress. While in this case, the PPP option may induce more investment, it may also contribute to heightening fiscal risk for the government.

A related implication of this extension is that the effect of uncertainty on PPP investment may be ambiguous (also in line with Darby et al. 1999), or at least, the existence of a put option will reduce the negative impact of uncertainty on investment.

II.4 Conclusions

Several conclusions can be drawn based on our simple theoretical model of PPP investment and its extensions.

First, the optimal timing of investment (Y*) and the scale of monopoly production (Q*) for the decision to invest (I) in a PPP project, in which the two partners cooperate fully (have equal weights in the objective function), are given by the following relations:

$$½Y^*U(Q) = ½\, Y^*[CS(Q)+R(Q)] = \frac{\beta_1}{\beta_1 - 1}\, \delta(I + ½\, \lambda\theta + ½\, C(Q)/\rho) \qquad (O1)$$

where the wedge $w(\beta) = \frac{\beta_1}{\beta_1 - 1} = f((\sigma(+), \rho(+), \alpha(-))$

$$\frac{U(Q^*, Y)}{C(Q^*)} = \frac{\varepsilon_{CQ}}{\varepsilon_{UQ}} \qquad (O2),$$

Hence, the decision to invest under a PPP depends primarily on several factors: (i) the uncertainty associated with the project (σ)—the higher the uncertainty (macroeconomic, political, financial), the longer the project will be deferred; (ii) the discount rate associated with the project (ρ)—the higher the discount rate, or equivalently a prevailing lending interest rate, the longer the investment will be deferred; (iii) the burden of taxation, including the dead-weight loss for society (θ and λ)—the higher the fiscal

burden that would be required for the government to undertake the project alone, the more attractive a PPP option would be.

Second, the expected value of a PPP project is a weighted average of consumer surplus (CS) and private revenue (R), resulting from a cooperative bargaining. With equal shares in the objective function, the two partners in a PPP project equally share the benefits and the costs.

Third, the decision to invest under a PPP project can also be subject to uncertainty specific to the public partner, for instance, uncertainty regarding the government's fiscal position. If the risk for both partners *(σ_G and σ_P)* rises, the increase in the overall risk of the project may be lower the higher the covariance between the two sources of risk (the risk-sharing). Hence, due to the possibility of risk sharing between the partners, a PPP agent may choose more readily to invest than the separate agents acting alone.

Fourth, the investment process may be speeded up under a PPP contract due to another factor, that is, the existence of a readily available put-option or the option of the private partner to disinvest later. This can be done through an explicit government commitment to buy-back, through an implicit government guarantee to bail out the project in times of financial distress, or through contract renegotiation. While in this case, the PPP option may induce more investment, it may also contribute to increasing fiscal risks facing the government.

Chapter III – Data sources and descriptive statistics

III.1 An overview of the World Bank dataset on private investment in infrastructure

The main data source for PPP projects in developing countries is the online World Bank (WB) database on private participation in infrastructure (PPI),[15] which covers four sectors: (i) energy; (ii) telecom; (iii) transportation, and (iv) water and sewerage. Projects are recorded in the dataset based on publicly available sources (the dataset is by no means exhaustive for PPI projects in the developing world), according to a consistent and sound methodology, so that comparisons across countries and time are workable.

According to PPI methodology, "the database records contractual arrangements with and without investments in which private parties assume operating risks [of infrastructure assets] in low- and middle-income countries (as classified by the World Bank)."[16] The projects are classified into four main categories: (i) concessions; (ii) divestiture; (iii) greenfield projects; (iv) management and lease contracts, each of these categories including specific contractual sub-types, as it is shown in table 1 below.

[15] Available at http://ppi.worldbank.org/index.aspx
[16] Available at http://ppi.worldbank.org/resources/ppi_methodology.aspx

Table 1: Types/sub-types of contracts included in the WB database of private investment in infrastructure (PPI)

Types/sub-types of PPI	Description/definition
Concession	**A private entity takes over the management of a project/state-owned enterprise for a given period during which it also assumes significant investment risk.**
Build, rehabilitate, operate, and transfer	A private developer builds an add-on to an existing facility or completes a partially built facility and rehabilitates existing assets, then operates and maintains the facility at its own risk for the contract period.
Rehabilitate, lease or rent, and transfer	A private sponsor rehabilitates an existing facility at its own risk, leases or rents the facility from the government owner, then operates and maintains the facility at its own risk for the contract period.
Rehabilitate, operate, and transfer	A private sponsor rehabilitates an existing facility, then operates and maintains the facility at its own risk for the contract period.
Divestiture	**A private entity buys an equity stake in a state-owned enterprise through an asset sale, public offering, or mass privatization program.**
Full	The government transfers 100% of the equity in the state-owned company to private entities (operator, institutional investors, and the like).
Partial	The government transfers part of the equity in the state-owned company to private entities. The private stake may or may not imply private management of the facility.
Greenfield project	**A private entity or a public-private joint venture builds and operates a new facility for the period specified in the project contract. The facility may return to the public sector at the end of the concession period**
Build, lease, and own	A private sponsor builds a new facility largely at its own risk, transfers ownership to the government, leases the facility from the government and operates it at its own risk, then receives full ownership of the facility at the end of the concession period. The government usually provides revenue guarantees through long-term take-or-pay contracts for bulk supply facilities or minimum traffic revenue guarantees.
Build, own, and operate	A private sponsor builds a new facility at its own risk, then owns and operates the facility at its own risk. The government usually provides revenue guarantees through long-term take-or-pay contracts for bulk supply facilities or minimum traffic revenue guarantees.
Build, own, and transfer	A private sponsor builds a new facility at its own risk, owns and operates the facility at its own risk, then transfers ownership of the facility to the government at the end of the concession period. The government usually provides revenue guarantees through long-term take-or-pay contracts for bulk supply facilities or minimum traffic revenue guarantees.
Merchant	A private sponsor builds a new facility in a liberalized market in which the government provides no revenue guarantees. The private developer assumes construction, operating, and market risk for the project
Management and lease contract	**A private entity takes over the management of a project/state-owned enterprise for a fixed period while ownership and investment decisions remain with the state.**
Management contract	The government pays a private operator to manage the facility. The operational risk remains with the government.
Lease contract	The government leases the assets to a private operator for a fee. The private operator takes on the operational risk.

Source: World Bank

Some types of contracts recorded in the dataset—specifically "full divestiture" and "merchant contracts"—do not fit into the PPP profile, being purely private projects. In the case of full divestiture (privatization) category, the government transfers the ownership of an asset to a private agent, leading in principle to a fully private decision regarding the operation/ownership of the project, and future investment. In the case of merchant contracts, a private agent builds, owns, and operates a new infrastructure facility, for which the government provides no revenue guarantees or other type of financial support. Other projects do not involve public-private investment (investment in new facilities or extension/improvements of existing ones) and would not fit into our model of PPP investment, especially the category of management and lease contracts.

However, most of the projects in the database do involve private investment in public infrastructure facilities, and fit into the general PPP profile under one of the following categories: (i) joint ownership of the project; (ii) investment and operation by the private sector, with residual ownership to the public partner; (iii) ownership and operation by the private sector, with support from the public sector.

PPI projects are included in the database upon reaching financial or contractual closure. While projects are recorded for the period starting with 1986, I will analyze only the period after 1990 as this reduces the likelihood of biases associated with the early period of PPP implementation and with data availability for that period[17]. This approach is also implicitly recommended by the World Bank, as its various descriptive reports refer only to the period after 1990.

[17] Approach taken also in Hammami, Ruhashyankiko et al. (2006).

The database records the PPI counts (number of projects concluded), as well as the investment commitments under PPI contracts, that is, investment made or to be made by the project company under a PPI contract. Total investment commitments are classified in two categories: "investment in physical assets" (to build, expand or modernize existing facilities), which represents capital formation *stricto sensu*, and "payments to the government" (to acquire government-owned assets or the right to provide services in a public utility area). While the latter category does not represent capital formation directly, for the private firm, it is the real measure of its investment spending (the total sunk cost of investment I).

III.2 Descriptive statistics for the PPI dataset

The World Bank database includes 3286 PPI projects in 140 developing countries with financial closure during the period 1990-2005[18]. Total investment for the period 1990-2005 amounts to about USD 1139 billion in real terms[19], out of which 27% are payments to government, and the rest is classified as investment in physical assets (facilities).

Several tabulations/descriptive statistics are presented below.

(a) PPI by region and country

[18] According to online data retrieved as of January 18, 2008.

[19] I have adjusted the nominal amounts available from the WB PPI dataset to constant 2005 USD, using the U.S. CPI (Source of data for the U.S. CPI is Department of Commerce). According to WB PPI methodology, investment is recorded in millions of US dollars in the year of financial closure or year of investment. WB notes and other data analysis formats often used data in real terms adjusted by the U.S. consumer price index. The methodology provides no indication about the exchange rate used in case investment is not expressed in USD. Investment amounts are not adjusted to reflect currency fluctuation over time; they are adjusted only when contractual amounts have changed (part of projects canceled or renegotiated) provided information is publicly available.

Table 2: Number of PPI projects and amount of investment in PPI by regions

Region	Total count	% count of total	Total inv. (USD bill.)	o/w payments to gov. (%)	% inv. of total
East Asia and Pacific	860	26%	205	33%	18%
Europe and Central Asia	684	21%	232	25%	20%
Latin America and the Caribbean	1111	34%	363	27%	32%
Middle East and North Africa	96	3%	49	22%	4%
South Asia	255	8%	93	22%	8%
Sub-Saharan Africa	280	9%	196	25%	17%
Total	**3286**	**100%**	**1138**	**27%**	**100%**

A very preliminary picture of the distribution of PFI projects by region is given in table 2 (data are not normalized to population or GDP). The Latin American and the Caribbean region dominates the other regions in terms of both number of PPI projects and investment (around one third of projects). It is followed by East Asia and Pacific, and Europe and Central Asia regions, very close to each other (the former dominating in terms of number of projects and the latter in terms of investment). The Middle East and North Africa region has the lowest share in total PPI, though partly a reflection of a smaller relative market. Each region has similar shares in total project count and total investment, except for Sub-Saharan Africa, with a much higher share in investment (17%) compared to number of projects (9%), denoting relatively larger projects. The regions have also very similar shares of payments to the government in total investment, with a slightly higher share for East Asia and Pacific.

By country, the distribution of projects is skewed to the right, mainly reflecting differences in the size of the market, but also the concentration of large PPP programs in Latin America. The average number of projects (cumulative for the whole period 1990-2005) per country is 24, while the standard deviation is much larger—about 60. Under

these conditions, the median, which stands at 7 projects per country, is a better measure to reflect the central tendency for private participation in infrastructure in the developing countries for the period 1990-2005. A few outliers contribute to the high variability: China has the largest (absolute) number of PPP projects, 483 for the sixteen year-period, followed by Brazil with 297 projects, Russian Federation with 287 projects, Argentina with 182, India with 172, Mexico 151, Chile with 103 etc.

(b) PPI by sectors:

Table 3: Number of PPI projects and amount of investment in PPI by sectors

Primary sector	Total count	% count of total	Total inv (USD bill.)	%investment of total
Energy	1321	40%	366.7	32%
Telecom	749	23%	542.3	48%
Transport	833	25%	170.4	15%
Water and sewerage	383	12%	59.4	5%
Total	**3286**	**100%**	**1,138.8**	**100%**

Most PPI projects are in the energy sector, while the telecom sector dominates in terms of PPI investment (denoting relatively larger projects). This is most likely due to the fact that services specific to both sectors have good potential for private provision. The infrastructure sector with the smallest number of PPI projects is water and sewerage. At a first glance, this suggests a basic public good profile, with high social externalities and possibly higher propensity for pure government investment. However, it may also reflect non-inclusion of projects in the dataset, given that they are of relatively smaller value (the

sector's share in total PPI investment is lower than in total count), mainly initiated by local governments and less likely to be publicly available.

(c) PPI by infrastructure sector and type/sub-type of arrangement

Table 4: Number of PPI projects by sector and type of PPI

Primary sector/ Type PPI	Concession	Divestiture	Greenfield project	Management and lease contract	Total counts
Energy	71	460	764	26	1321
% by type PPP	5%	35%	58%	2%	100%
Telecom	11	193	540	5	749
% by type PPP	1%	26%	72%	1%	100%
Transport	438	59	281	55	833
% by type PPP	53%	7%	34%	7%	100%
Water and sewerage	160	20	117	86	383
% by type PPP	42%	5%	31%	22%	100%

Overall, the private participation in the energy sector seems to be dominated by greenfield projects, followed by divestiture. The same pattern can be noticed in telecom, this time with a much larger dominance of greenfield projects (72%, the largest among all sectors). Transport, and water and sewerage are dominated by concessions, followed by green field projects. In case of water and sewerage, management and lease contracts also hold a sizable share of all contractual types (22%, by far the largest share compared to all other sectors). This may be again tentatively explained by the higher public good content and social externalities of these sectors, making the government to relinquish less control and keep ownership.

Table 5: Number of PPI projects and investment by type and sub-type of PPI

Type/sub-type PPI	No. projects	% type of total count	Investment (USD bill.)	o/w payment to gov.	% type of total invest
Concession	**680**	**20.7%**	**153.9**	**14%**	**13.5%**
Build, rehabilitate, operate, and transfer	305	9.3%	89.2	8%	7.8%
Rehabilitate, lease or rent, and transfer	36	1.1%	10.8	24%	1.0%
Rehabilitate, operate, and transfer	339	10.3%	53.9	22%	4.7%
Divestiture	**732**	**22.3%**	**438.0**	**54%**	**38.5%**
full	154	4.7%	158.7	36%	13.9%
partial	578	17.6%	279.3	64%	24.5%
Greenfield project	**1702**	**51.8%**	**542.7**	**7%**	**47.7%**
Build, lease, and own	14	0.4%	5.3	0%	0.5%
Build, own, and operate	968	29.5%	355.8	10%	31.2%
Build, own, and transfer	614	18.7%	161.4	2%	14.2%
Merchant	106	3.2%	20.2	0%	1.8%
Management and lease contract	**172**	**5.2%**	**4.1**	**88%**	**0.4%**
Management contract	94	2.9%	0.3	48%	0.03%
Lease contract	78	2.4%	3.8	92%	0.3%
Total	**3286**	**100%**	**1,138.8**	**27%**	**100%**

Overall, greenfield projects seem to be the preferred type of private participation in infrastructure in developing countries, with about half of total projects and amount of investment. The next most common type of PPI is divestiture (22% of projects and an almost double share in investment, 39%). Full privatization and merchant contracts, which can be considered as fully private arrangements, account for about 8% of total number of PPI projects, and 15% of total investment. On the other hand, as mentioned above, management and lease contracts do not involve much of new capital creation,

accounting for only 0.4% of total investment, the bulk of which comes from payments to the government (88%, the highest share among all other types of contracts).

(c) PPI by periods of contract closure (decision to invest)

Table 6: Number of PPI projects and investment in time

Half-decade	% of cumulative count	% of cumulative investment
1990-1994	22%	15%
1995-1999	45%	36%
2000-2004	29%	42%
Total	**95%**	**93%**

Over time (I divided the cumulative 1990-2005 period in three equal periods of 5 years each, thus omitting the year 2005), most PPP contracts (45%) have been concluded in the second part of the '90s, while larger relative deals have been concluded in the first half of the present decade.

III.3 Other variables of interest and data sources

From the World Bank PPI dataset, I obtain a panel data with 140 countries (groups) for a period of maximum 16 years (1990-2005). If a country has no PPI project concluded in a given year, the PFI database does not report that year, therefore I expand the dataset to create a balanced panel, i.e. introduce observations with value zero for each missing year.

Variables that may explain investment under PPP in developing countries have been collected and are listed in table 7 below. These variables are drawn from our theoretical model of PPP investment (risk-related indicators; financial variables; indicators for the government fiscal position), as well as from the literature of aggregate investment (aggregate demand or size of the economy; economic growth rate), with focus on characteristics of developing economies (i.e. heightened importance attributed to sources of financing such as FDI or foreign aid, and institutional issues such as corruption or index of democratic accountability).

Table 7: Potential determinants of investment

Explanatory variables	Description	Source	Availability by country
Lagged dependent variables			
L(1/2).PrivateKf_gdp	Lags of private investment (proxied by private capital formation) as % of GDP. *PrivateKf_gdp* is calculated as the share of private gross fixed capital formation in current local currency units (LCU) to GDP in LCU, both series (yearly data) available from WEO.	IMF, WEO	N=117
L(1/2).PublicKf_gdp	Lags of public investment (proxied by public capital formation) as % of GDP. *PublicKf_gdp* is calculated as the share of public gross fixed capital formation in current local currency units (LCU) to GDP in LCU, both series (yearly data) available from WEO.	IMF, WEO	N=118
L(1/2).PPPinv_gdp	Lags of total investment under PPP projects, yearly data, as available from the World Bank PPI database (full divestiture and merchant contracts are not included).	WB, PPI database	N=128
Market size and economic cycle			
log_GDP_ct	Log of GDP in real terms (constant 2000 USD)	WDI	N=128
log_GDPcap	Log of GDP per capita in purchasing power parity terms	WDI	N=128
realGDPgrowth	Annual growth rate of real GDP calculated as the difference in *log_GDP_ct* in consecutive years	Authors' calculations	
Financing sources of investment/external position			
FDI	Foreign Direct Investment as % of GDP	WB, WDI	N=127
CA_bal	Current Account balance as % of GDP	WB, WDI	N=127
extdebt_GDP	Total external debt as % of GDP	WB, WDI	N=127
log_aid	Log of external aid per capita	WB, WDI	N=128
Indicators of government fiscal position			
gov_tax_gdp	Total revenue of the general consolidated government budget as % if GDP	IMF, WEO	N=114
gov_bal_gdp	Balance of the general consolidated government budget as % if GDP	IMF, WEO	N=114

ppg_debt_gdp	Public and publicly guaranteed debt as % of GDP	WB, WDI	N=127
Financial indicators, real interest rate			
lend_rate	Lending rate (% per annum)	IMF, IFS	N=121
inflation	Inflation Rate (average percentage change in CPI per annum)	WB, WDI	N=128
Volatility/ uncertainty measures			
Calculated for real output, fiscal indicators, lending rate, inflation and exchange rate	Volatility calculated as 3-year moving standard deviation of variable. Uncertainty calculated as 3-year moving standard deviation of residuals from regression of variable over 2 lags and a time trend.	Author's calculation	-
Other measures of sovereign risk: economic, political, institutional risk			
economic_risk	Index of economic risk	ICRG	N=93
financial_risk	Index of financial risk		
political_risk	Index of political risk	ICRG	N=93
corruption	Index of government corruption	ICRG	N=96
law_order	Index of law and order	ICRG	N=96
ethnic_tensions	Index of ethnic tensions	ICRG	N=96
democr_account	Index of government democratic accountability	ICRG	N=96
investment_profile	Index of contractual risk related to investment	ICRG	N=96
Regional dummies	Regional dummies as defined by the WB PPI database: (1) East Asia and Pacific; (2) Europe and Central Asia; (3) Latin America and the Caribbean; (4) Middle East and North Africa; (5) South Asia; (6) Sub-Saharan Africa	WB, PPI database	-
Time dummies	Time dummies for each year for the period 1990-2005		-

The sources of data are the World Development Indicators database (WDI) from the World Bank; the World Economic Outlook (WEO) and International Financial Statistics (IFS) from the International Monetary Fund; and the International Country Risk Guide (ICRG) from the PRS Group. The last data source is used extensively in econometric studies of investment for measures of institutional quality, economic, financial and political risk, due to its large coverage of developing countries starting with mid-1980s and the use of a consistent methodology in time and across countries. All risk indices from ICRG are defined so that a higher value corresponds to a lower risk (when used as explanatory variables in investment equations, this means that a positive regression coefficient will denote a negative impact of risk on investment).

For several variables, such as real output, fiscal indicators, lending rate, inflation and exchange rate, I also calculated measures of volatility and uncertainty. While the two terms are often used inter-changeably, the literature (Ramey and Ramey 1995; Aizenman and Marion 1999) has distinguished between the two methods of calculation. Often, volatility is calculated as standard deviation (over a certain period of time) of a given variable, while uncertainty is calculated as the standard deviation of the residuals from the regression of a variable over its own lags and a time trend (variability unexplained by the past). For the panel with annual data—our main empirical setting—I calculate the volatility and uncertainty measures as 3-year moving standard deviations; I also use a cross-sectional approach by averaging all our variables over the period under study (1990-2005) and calculate the volatility and uncertainty measures as standard deviation over the whole period (a single observation by country).

In addition, I create time and regional dummies that will be employed in the regression analysis to (i) capture the effect of short-term global shocks and control for economic seasonality, and respectively, to (ii) control for regional integration and (regional) spatial interdependence.

In the process of merging the World Bank PPI dataset with the dataset described above, I removed twelve countries (Afghanistan, American Samoa, Cuba, Iraq, Kiribati, Liberia, Myanmar, Somalia, Timor-Leste, West Bank and Gaza, Serbia and Montenegro, and Uzbekistan) due to lack of observations on the macroeconomic variables. Therefore, I obtain a panel dataset with 128 countries and 16 years. However, the risk indicators from the ICRG database are available for only 98 countries, and for some of them,

indicators of government fiscal position are not available. For instance, in the regressions on the determinants of PPP investment in Chapter IV.1(2), the sample includes 77 countries, which are listed in Table 8 below.

Table 8: Countries used in the regressions on the determinants of PPP investment

1	Albania	21	Dominican Republic	41	Mali	61	South Africa
2	Angola	22	Ecuador	42	Mexico	62	Sri Lanka
3	Argentina	23	Egypt	43	Moldova	63	Syrian Arab Rep.
4	Armenia	24	El Salvador	44	Mongolia	64	Tanzania
5	Belize	25	Estonia	45	Morocco	65	Thailand
6	Bolivia	26	Ethiopia	46	Mozambique	66	Togo
7	Bosnia Herzegovina	27	Gambia	47	Nicaragua	67	Trinidad Tobago
8	Botswana	28	Guinea	48	Niger	68	Tunisia
9	Brazil	29	Guyana	49	Nigeria	69	Turkey
10	Bulgaria	30	Haiti	50	Oman	70	Uganda
11	Burkina Faso	31	India	51	Pakistan	71	Ukraine
12	Cameroon	32	Indonesia	52	Panama	72	Uruguay
13	Chile	33	Jordan	53	Paraguay	73	Venezuela
14	China	34	Kasahstan	54	Peru	74	Vietnam
15	Colombia	35	Kenya	55	Philippines	75	Yemen, Rep.
16	Congo, Rep.	36	Lebanon	56	Romania	76	Zambia
17	Costa Rica	37	Lituania	57	Russian Federation	77	Zimbabwe
18	Cote d'Ivoire	38	Madagascar	58	Senegal		
19	Croatia	39	Malawi	59	Sierra Leone		
20	Czech Republic	40	Malaysia	60	Slovak Republic		

Chapter IV - Empirical models and results

IV.1 Determinants of investment: private, public, and PPP

The present chapter aims to investigate the determinants of investment relative to GDP in developing countries at three levels of aggregation: private, public, and private-public partnerships (*PrivateKform_gdp, PublicKform_gdp,* and respectively, *InvPPP_gdp)*. Examining what determines public and private investment in a comprehensive framework is important for a better understanding of the determinants of PPP.

While the theory of irreversible investment under uncertainty is micro based, it has also been applied in empirical studies of aggregate investment. However, as cautioned in Dixit and Pindyck (1994), the theory is not clear about "the effects of uncertainty on the long-run equilibrium values of investment, the investment to output ratio, or the capital to output ratio" (p. 422). On the other hand, Bertola and Caballero (1994), studying the behavior of *aggregate investment* using U.S. private equipment investment, find that aggregate data are broadly consistent with a model in which microeconomic units rationally choose to invest less than implied by a neoclassical model with reversible investment and no uncertainty.

Pindyck and Solimano (1993) uncover a negative association between investment (as percent of GDP) and volatility in the marginal profitability of capital for a panel of 30

developed and developing countries. They use, though, various sources for investment data, and find a stronger relationship among developing countries.

Aizenman and Marion (1999) find a significant negative correlation between various measures of volatility (in monetary, fiscal and real variables) and private investment, even after controlling for various other factors. Yet, the significance vanishes when total investment data (as % of GDP) are used, with public investment being found positively correlated with some measures of volatility. The authors use consistent data for private and public investment for about forty developing countries, but the results obtained from a simple cross-sectional model may be subject to extensive omitted variable bias, model over-fitting given the relatively small sample size, and may not be robust to other specifications.

Despite their ambiguous theoretical result as to the impact of exchange rate uncertainty on investment, in empirical tests on aggregate data, Darby et al. (1999) identify significant negative effects of exchange rate volatility and misalignments on investment in five OECD economies, even after controlling for other variables, such as the real cost of capital and Tobin's Q.

Other studies (Goldberg and Kolstad 1995; Wei 2000; Aizenman and Marion 2004) analyze the effect of uncertainty on foreign direct investment (FDI), with mixed findings. Aizenman and Marion (2004) investigate various types of uncertainty, including uncertainty related to predatory actions by host countries (proxied by sovereign risk measures) and find different responses according to the type of FDI (vertically or horizontally integrated). Wei (2000) analyzes bilateral investment from twelve source

countries to 45 host countries and finds that uncertainty related to corruption in a host country has a detrimental impact on inward FDI.

In this chapter, I use the framework of partly irreversible investment under uncertainty with the following considerations in mind.

First, I analyze the impact of risk —macroeconomic, political and institutional framework-related risk and uncertainty—on investment at a macro level, that is, the aggregate private, public and private-public investment.

Second, I consider a dynamic model in which current investment depends on investment in previous periods. Indeed, by modeling the investment equations in a dynamic framework, I find that all three investment variables are persistent and depend positively on the amount of investment undertaken in the previous years.

Third, I take into account the linkages between the three types of investment, whether substitution/crowding-out or complementarity effects, and account for potential endogeneity issues.

Fourth, I use the real lending interest rate as a proxy for the aggregate cost of capital and the aggregate output or the annual real growth rate in line with the neoclassical investment model and to account for a country position in the business cycle. I control for common international shocks by using yearly dummies and for country characteristics by differencing out country fixed effects;

Fifth, I differentiate between sources of financing, as this is likely to matter for investment in developing countries, e.g. FDI, external aid, and more generally, external financing as proxied by the current account balance;

Finally, as regards the determinants of investment under PPP, according to the basic theoretical model developed in Chapter II, the main factors to control are: volatility and uncertainty measures; real cost of capital; and indicators of government's fiscal position.

Reflecting these considerations, the following basic empirical models are proposed.

$$PrivateKf\_gdp_{ti} = PrivateKf\_gdp_{(t-\tau)i} + PublicKf\_gdp_{t/(t-\tau)i} + PPPinv\_gdp_{t/(t-\tau)i} + uncertainty/volatility/risk\ measures_{(t-\tau)i} + real\ interest\ rate_{t/(t-\tau)i} + financing\ sources_{t/(t-\tau)i} + realGDP\ growth_{t/(t-\tau)i} + common\ shocks_t + fixed\ effects_i + error\ term_{it} \quad [1]$$

$$PublicKf\_gdp_{ti} = PublicKf\_gdp_{(t-\tau)i} + PrivateKf\_gdp_{t/(t-\tau)i} + PPPinv\_gdp_{t/(t-\tau)i} + uncertainty/volatility/risk\ measures_{(t-\tau)i} + real\ interest\ rate_{t/(t-\tau)i} + financing\ sources_{t/(t-\tau)i} + realGDP\ growth_{t/(t-\tau)i} + fiscal\ position_{(t-\tau)i} + common\ shocks_t + fixed\ effects_i + error\ term_{it} \quad [2]$$

$$PPPinv\_gdp_{ti} = PPPinv\_gdp_{(t-\tau)i} + PrivateKf\_gdp_{t/(t-\tau)i} + PublicKf\_gdp_{t/(t-\tau)i} + uncertainty/volatility/risk\ measures_{(t-\tau)i} + real\ interest\ rate_{t/(t-\tau)i} + financing\ sources_{t/(t-\tau)i} + realGDP/growth_{t/(t-\tau)i} + fiscal\ position_{(t-\tau)i} + common\ shocks_t + fixed\ effects_i + error\ term_{it} \quad [3]$$

where t denotes the time period, τ denotes a certain time lag, $t/(t-\tau)$ denotes the fact that I use contemporaneous and/or lagged explanatory variable, i is an index for the country cross-section. The variable abbreviations are those used and described in Table 7, Chapter III.

IV.1 (1) Determinants of aggregate public and private investment

For private and public investment models, I use the generalized method of moments estimators (GMM), namely, the *difference GMM* proposed in Arellano and Bond (1991), and the *system GMM* proposed in Blundell and Bond (1998). They are appropriate for

panels with a large cross-section and a relatively short time series, and thus, our panel dimensions seem broadly adequate. The system GMM estimator (Blundell-Bond) is shown to be superior when the dependent variable is highly persistent (see the technical appendix to this chapter for more details). It has been used to estimate models of dynamic investment under uncertainty (in a panel dataset at U.S. firm level) in Bloom, Bond et al. (2001). I prefer the system GMM estimator given the persistent nature of most of our dependent variables (private and public investment, public debt, etc.) and better goodness-of-fit measures.

Various other models were tested and the robustness of our variables checked. I have first followed Aizenman and Marion (1999) and estimated cross-sectional models by simple ordinary least square (OLS), after averaging the dependent and explanatory variables over the 16-year period of our study, and calculating volatility and uncertainty measures as standard deviation of relevant variables/residuals over the same period. However, the estimation results from such regression models are unstable to changes in the various specifications used. I do not find robust, significant evidence that our fiscal, monetary and financial measures of uncertainty/volatility have a negative impact on private investment, or trigger higher public investment, as found in Aizenman and Marion[20] (1999). The same holds for the ICRG measures of sovereign risk. Several variables, especially political risk components (*corruption*, *law and order*) or uncertainty in financial variables (*interest rate, exchange rate*), are found to be negatively correlated

[20] Aizenman and Marion (1999) tested three measures of volatility (in government consumption as share of GDP; nominal money growth and real exchange rate) separately, and combined in an index.

with aggregate investment, but the correlation proves to be fragile with inclusion/exclusion of other potentially relevant variables.

I then focus on conducting our analysis in the dynamic panel framework, using yearly data. The results of the estimations are presented in the first part of Table 9 for aggregate private investment, and in the second part for aggregate public investment, with the significant and most robust variables retained. I will first discuss the results for the aggregate private and public investment, and then switch to PPP given the rather different nature of the data.

I find that both private and public investment depend positively on the amounts invested in the previous year, while further lags are not significant. As regards the interaction between the two types of aggregate investment, essentially involving the impact of public investment on private investment, the existing empirical literature does not provide a clear evidence: some studies find crowding-out effects, while others find complementarity effects (see literature reviews on the impact of public capital on private inputs and growth in Romp and DeHaan (2005), Kamps (2005), Aschauer (2000), among others).

With the Arellano-Bond/Blundell-Bond techniques,[21] I am able to estimate the regression equations in the presence of potentially endogenous regressors. Hence, I declare the variables *PublicKf_gdp* and *PPPinv_gdp* to be endogenous in the regression equation of *PrivateKf_gdp*, and respectively, *PrivateKf_gdp* and *PPPinv_gdp* to be endogenous for *PublicKf_gdp*. The impact of such endogenous variables is estimated

[21] As implemented in Stata 10 through *xtabond* and *xtdpdsys* routines.

using GMM-type internal instruments, that is, all their lags starting with the second one (L2).

I find contemporaneous crowding-out effects between the aggregate public and private investment, most likely reflecting financing constraints and competition for resources, but lagged complementarity effects, reflecting positive spillovers from one type to another. Yet, the crowding-out effect seems to dominate, both in terms of the economic impact (the estimated coefficient of the contemporaneous variable is higher), and in terms of the statistical significance (the contemporaneous variable is always statistically significant at 1%, while the first lag is significant at best at 5%).

The impact is stronger when the causation runs from *PublicKf_gdp* to *PrivateKf_gdp* (about four to five times larger coefficients than the converse) revealing the fact that private investment is influenced to a higher extent by public investment than the converse[22] (there is potentially also a slower and more subdued response of a politically-related variable, *PublicKf_gdp*, to an economic variable, *PrivateKf_gdp*).

As regards the impact of PPP investment (*PPPinv_gdp)* on the aggregate private investment, I find a positive contemporaneous (only) relation, with the causation apparently working both ways (as shown later, the aggregate private investment has a positive impact on investment under PPP, as well).

The impact of PPP investment on the aggregate private investment partly reflects an accounting relation—at some point in the future, the committed investment in fixed

[22] Granger causality tests cannot be used here as they are implemented (in Stata) only with time series data and not with panel data.

assets under PPP contracts is (primarily) recorded in the national accounts under gross formation of private capital.

The relationship between PPP and public investment turns out to be more complex. I do not find evidence of a contemporaneous relation, but it seems that higher PPP investment in the preceding year is associated with lower purely public investment in the current year. This may indicate a substitution effect—when deciding to expand the PPP investment programs, governments will replace part of the public infrastructure investment with PPP.

The relationship holds even if the estimation takes into account the potential endogeneity of *PPPinv_gdp* and the government budget constraint (by using the fiscal balance and public debt as regressors). In addition, the relationship does not seem to be the result of a reverse causation since *PublicKf_gdp* is not significant in explaining *PPPinv_gdp* across various models to be shown hereafter.

The real lending interest rate (as given by the effect of the nominal lending rate and inflation variables) has a negative impact on public investment, but, surprisingly, such an impact does not remain robustly significant for private investment.[23]

As regards the sources of financing, external aid seems to be significantly positively associated only with public investment, most probably reflecting the channeling of such aid to public infrastructure (the coefficient of the variable *log_aid* is large and remains significant across various specifications). Public investment seems to

[23] The coefficient of the *lending rate* is negative, but its significance drops under various specifications, like the one shown in Table 3.

be significantly financed out of public debt as given by the positive relationship in model m2[24].

Both types of aggregate investment increase as a share of GDP in good economic times: the contemporaneous and lagged growth rate of real GDP have a positive and statistically significant impact on *PrivateKf_gdp* and *PublicKf_gdp.* From this point of view, governments seem to respond to past higher economic growth by increasing public investment (and possibly conducting pro-cyclical fiscal policies).

As regards the impact of risk and uncertainty on investment—the core of our theoretical underpinnings—somewhat surprisingly, the dynamic panel models do not show a strong evidence of a negative significant impact. Our measures of volatility and uncertainty of fiscal, monetary, real output variables are not found statistically robust across various specifications (the evidence of a negative impact on investment is stronger with GLS models, but the significance does not hold with GMM dynamic panel models). Only inflation volatility seems to have a robust negative impact on private investment. Among the economic and political risk variables available from the ICRG database, I find some evidence for the economic risk index, and the component of political risk index related to corruption. However, the impact of the economic risk index on private

[24] As regards other sources of external financing, it is difficult to interpret the persistent impact of the current account balance on private investment, i.e. higher current account (CA) deficits in previous years imply lower gross capital formation. From the external financing perspective, a higher CA deficit means higher external financial inflows, which would imply higher private investment financing, unless most of the external inflows is spent on consumption. A negative impact of the CA deficit on private investment can be interpreted from a risk perspective, that is, larger deficits in developing countries are seen by investors, especially foreign ones, as risky in terms of future inflationary or exchange rate pressures, thus containing or postponing investment. I have also investigated the impact of FDI on both private and public investment. However, CA balance is more robust in various specifications. For instance, including both variables in the regression equation makes the FDI insignificant, while CA balance remains significant.

investment seems to have originated in the economic growth rate, an important factor in the construction of the index: after the introduction of *realGDPgrowth* in the regression equation, the economic risk index becomes insignificant. The *corruption* index remains significant at 10% in both difference and system GMM models, providing some evidence that higher level of corruption in developing countries is associated with a lower ratio of private investment to GDP.[25]

[25] In general, similar results are obtained if I estimated the dynamic models using GLS (generalized least squares) in the presence of AR(1) autocorrelation within panels and heteroskedasticity across panels, with or without regional dummies. Including regional dummies in the GLS models (they are removed in the GMM models through first differencing) does not bring significant changes: the significance and size of regression coefficients remain broadly similar, and the goodness of fit improves only very marginally (by less than a full percentage point).

Table 9: Determinants of aggregate private and public investment

Dependent variable: PrivateKf_gdp

Variables	Difference GMM	System GMM
L.PrivateKf_gdp	0.6546***	0.7099***
PublicKf_gdp	-0.4694***	-0.4052***
L1.PublicKf_gdp	0.2447	0.3182**
PPPinv_gdp	0.0942*	0.1175**
L.CA_bal	0.1488***	0.1295***
L2.CA_bal	0.0824**	0.0683*
Lend_rate	-0.0200	-0.0140
Inflation	0.0022***	0.0021***
realGDPgrowth	0.2019***	0.2199***
L1.realGDPgrowth	0.1127***	0.1435***
Corruption	0.5119*	0.5173*
Inflation_volat	-0.0035**	-0.0033**
Time dummies	Included	Included
_cons	7.4105***	5.0570**
AR test in first differences		
AR(1) (p-value)	0.00	0.00
AR(2) (p-value)	0.36	0.39
AR(3) (p-value)	0.46	0.38
Sargan test of overidentifying restrictions		
chi2(d.f.)	42.7(268)	50.6(307)
p-value	1	1
Goodness of fit measure		
rho sq.	0.69	0.72
No. obs. (NT)	735	826
No. of groups (N)	78	85

Dependent variable: PublicKf_gdp

Variables	Difference GMM	System GMM
L1.PublicKf_gdp	0.3610***	0.4846***
PrivateKf_gdp	-0.1031***	-0.0942***
L.PrivateK_gdp	0.0598**	0.0642**
PPPinv_gdp	0.0177	0.0249
L1.PPPinv_gdp	-0.0675**	-0.0795**
L.CA_bal	0.0283	0.0391*
log_aid	0.3303**	0.6909***
L1.gov_bal_gdp	0.0408*	0.0277
L1.ppg_debt_gdp	-0.0075	0.0057**
lend_rate	-0.0129**	-0.0128**
Inflation	0.0027***	0.0028***
realGDPgrowth	0.0441*	0.0329
L1.realGDPgrowth	0.0498***	0.0487**
Time dummies	Included	Included
_cons	5.0381***	2.0791**
AR test in first differences		
AR(1) (p-value)	0.00	0.00
AR(2) (p-value)	0.13	0.20
AR(3) (p-value)	0.95	0.88
Sargan test of overidentifying restrictions		
chi2(d.f.)	46.4(268)	78.37(307)
p-value	1	1
Goodness of fit measure		
rho sq.	0.59	0.73
No. obs. (NT)	817	927
No. of groups (N)	90	95

Note: The estimation in the first part of Table 9 assumes that variables *PublicK_gdp* and *PPPinv_gdp* are endogenous, while in the second part *PrivateK_gdp* and *PPPinv_gdp* are declared endogenous. The two-step estimation procedure was used with both Arellano-Bond (difference GMM) and Blundell-Bond (system GMM) models to test for: (i) instrument validity using the Sargan test of overidentifying restrictions, and (ii) second and higher order serial correlation in the first-differenced residuals. I cannot reject the null hypotheses for either of the two tests, which makes us more confident in interpreting the estimated coefficients from the one-step procedure with heteroskedasticity-robust standard error (shown in the tables). The goodness of fit measure is calculated as the square of the correlation coefficient between the observed and the predicted values, following Bloom, Bond et al. (2001). The same test specifications are applied to all our dynamic panel models. Significance level (p-values lower or equal to): *10%, **5%, ***1%.

IV.1 (2) Determinants of investment under PPP

As regards the ***investment under PPP*** as percent of GDP, there are two relevant variables available in the World Bank dataset: one is the amount of investment committed by the private partner under a PPP project, i.e. investment in fixed capital assets (*PPPinvfa_gdp*), and the other one is the total amount committed (*PPPinv_gdp*), which includes payments to the government. I present the estimation results for each one as a dependent variable in Table 10 below. The table also includes the estimation results for the determinants of total PPP investment in Latin America and the Caribbean (LAC), the region with the most extensive experience in PPP programs.

Given that PPP investment data represent commitments, mainly reflecting lumpy projects, the dependent variable(s) distribution is concentrated on the value zero (about 60% of observations are zeros). With a non-negative dependent variable, concentrated on zero, the best model specification is Tobit. Results are shown with a pooled Tobit model, a panel random effects Tobit and a GLS model for comparison.[26]

In addition, several values of investment under PPP are extreme. For the sample of 77 countries for which data is available in the regression of PPP investment, the mean of the dependent variable (total PPP investment as % of GDP) is 1.05, while the median is 0.28. Thus, I exclude the observations for which the share of PPP investment per year is larger than 15% of GDP, that is: Bolivia in 1998 and Mozambique in 2003 with 28% of GDP; Panama in 1997 (16% of GDP) and Mali in 2000 (15% of GDP). The value for

[26] I followed the approach taken in Hammami et al. (2006) in terms of the empirical technique.

Bolivia in 1998 is also excluded from the sample of LAC countries (comprising 20 countries), which is used as control for the results with the whole sample.

Table 10: Determinants of PPP investment

Variable	Dependent variable: Total amounts committed under PPP as % of GDP, whole sample			Dependent variable: PPP investment in physical assets as % of GDP, whole sample			Dependent variable: Total amounts committed under PPP as % of GDP in region 3 (LAC)		
	Tobit	**Random Effect Tobit**	**GLS**	**Tobit**	**Random Effect Tobit**	**GLS**	**Tobit**	**Random Effect Tobit**	**GLS**
L1.DV	0.1825***	0.1349***	0.1409***	0.2105***	0.1699***	0.1391***	0.1553***	0.1553***	0.1917***
PublicKf_gdp	-0.0157	0.0176	0.0009	-0.0201	0.0146	0.0023	0.0273	0.0273	-0.0058
PrivateKf_gdp	0.0310**	0.0529***	0.0119**	0.013	0.0337**	0.0096**	0.0425	0.0425	0.0307
lend_rate	-0.0023	0.0002	-0.0022**	-0.0012	0.0007	-0.0012**	-0.0183**	-0.0183**	-0.0067**
inflation	-0.0012	-0.0012	0.0000	-0.0012	-0.001	-0.0001	0.0203*	0.0203*	0.0121**
gov_tax_gdp	0.0264**	0.0241*	0.0124**	0.0210**	0.0200*	0.0081**	0.0453**	0.0453**	0.0241
gov_bal_gdp	-0.0021	0.0003	-0.0069	0.0089	0.0109	-0.0017	-0.0722	-0.0722	-0.027
ppg_debt_gdp	0.0034*	0.0014	-0.0002	0.0021	-0.0004	0.0011	0.0012	0.0012	0.0028
log_GDP_ct	0.2390***	0.2165**	0.0162	0.1886***	0.1536**	0.0520**	0.2981**	0.2981**	0.1275
log_aid	0.2581***	0.2263**	0.0904**	0.1712**	0.1303	0.0766**	0.4559***	0.4559***	0.1709**
investment_profile	0.1332***	0.1184**	0.0413**	0.0743**	0.0484	0.0169	0.2008***	0.2008***	0.1774***
reg2	-0.8333**	-0.5539	-0.2449	-1.0148***	-0.7615*	-0.5445**	-	-	-
reg3	-0.2722	0.0385	-0.075	-0.5280**	-0.2247	-0.2242	-	-	-
reg4	-1.7868***	-1.4049***	-0.8803***	-1.6311***	-1.2654***	-0.8509***	-	-	-
reg5	-0.6044	-0.3086	-0.4966**	-0.6312*	-0.3393	-0.5901***	-	-	-
reg6	-1.5714***	-1.2125**	-0.7411***	-1.4092***	-1.0441***	-0.7884***	-	-	-
Time dummies	Included	Included	Included	Included	Included	Included	Included	Included	Included
_cons	-9.8659***	-10.0811***	-0.6069	-7.2509***	-7.0722***	-1.1411	-13.4437***	-13.4437***	-5.6523**
AR(1) test			0.1957			0.2017			
Goodness of fit measure									
rho sq.	0.17	0.16	0.20	0.19	0.17	0.21	0.25	0.25	0.27
LL	-1400	-1400	-	-1200	-1200	-	-410	-410	
AIC	3000	2900	-	2400	2400	-	874	876	.
BIC	3100	3100	-	2500	2500	-	964	970	.
No. obs. (NT)	819	819	819	819	819	819	238	238	238
No. of groups (N)	Not panel	Panel (77)	Panel (77)	Not panel	Panel (77)	Panel (77)	Not panel	Panel (20)	Panel (20)

Significance level (p-values lower or equal to): *10%, **5%, ***1%. reg2 is Europe and Central Asia; reg3 is Latin America & Caribbean; reg4 is Middle East and North Africa; reg5 is South Asia; reg6 is Sub-Saharan Africa. The omitted dummy is reg1, East Asia and Pacific.

The following conclusions can be drawn based on this analysis. First, I find a dynamic component in PPP investment as well, with (only) the first lag highly statistically significant across all models.[27] Using the lagged PPP investment as a proxy for experience with PPP programs, I can conclude that countries are more likely to implement larger PPP investment the more experienced they are with such programs.

Second, the share of PPP investment in GDP is likely to depend on the size of the market/economy, as proxied by the real GDP taken in natural log (*log_gdp_ct*). The bigger the market/economy, the larger the PPP program is likely to be.

Third, among our measures of risk and uncertainty, political risk proves to be the most robust among various specifications—countries with higher political risk, as assessed by ICRG, tend to have smaller PPP investment programs relative to their GDP. Yet, when I use the disaggregated components of political risk, only the investment profile risk (retained in Table 10) turns out to be highly statistically significant and robust. No other component—corruption, law and order, democracy index—remain robustly significant when used separately. Similarly, the other risk components, which proved significant in explaining private investment (economic risk, corruption and inflation volatility) do not prove to be robust in explaining investment under PPP.

Given the importance of investment profile risk in explaining PPP commitments, the variable needs to be described in more detail. As stated in the ICRG methodology,

[27] I cannot use the dynamic panel models (difference and system GMM) in the case of PPP investment due to the special nature of data. Using a lagged dependent variable with the Tobit model is likely to induce correlation in the error term, but excluding it leads to omitted variable bias and overlooking an important conclusion. The fact that the first lag is highly significant across all models suggests that I should keep it in the regression equation.

this component comprises several factors affecting the risk to investment that are not covered by other political risk components, nor are they covered by economic or financial risk. It includes an assessment of political-institutional aspects related to investment contract enforcement, namely: (i) contract viability or expropriation; (ii) profits repatriation, and (iii) payment delays. Countries scoring higher on this index (being assessed as having a lower risk) are likely to have larger PPP investment. This is an indication that private partners entering long-term investment contracts with the government are particularly cautious about political risk, insofar as the integrity of their investment is concerned. No other measure of risk or uncertainty is found statistically significant in explaining investment under PPP. Only *uncertainty of the government budget balance* proves to be significant in the Tobit models, but it does not remain very robust at the inclusion/exclusion of various other variables.

Fourth, as regards potential complementarity/ crowding-out effects with purely public or private investment, as already mentioned, I find evidence of complementarity with private investment. Aggregate private investment is positively related to PPP investment in the whole sample, i.e. the share of PPP investment in GDP grows when the share of private investment grows as well (yet, this relationship does not remain statistically significant in the sample of LAC countries). The impact of the aggregate public capital on PPP investment is not found statistically significant. As already discussed, it seems that larger PPP programs have a substitution effect on public investment in later years, while the converse does not hold on average in the whole sample.

Fifth, according to the theoretical model of PPP investment proposed in Chapter II, I find that a higher tax burden, as proxied by government revenue as a share of GDP, is likely to induce governments to engage in larger PPP programs. This means that the higher the existing tax burden (or by combination with the budget constraint, the higher the overall government spending), the more difficult governments find to further raise taxes to cover for additional infrastructure spending. Instead, they are more likely to prefer the PPP investment alternative. This relationship is even better explained econometrically if I use a quadratic form for the tax-to-GDP ratio (that is, we add the term *gov_tax_gdp* squared in the regression equation). For the whole sample,[28] we obtain a concave relation: the coefficient of the squared term is negative and statistical significant at 5% confidence level (β=0.0019; p-value = 0.022), and the coefficient of the linear term remains positive and is significant at 1% (β=0.1349; p-value = 0.006); the significance of other explanatory variables does not change. The quadratic relation implies that, given a certain level of existing taxation, increasing the tax burden is likely to be associated with larger PPP programs. However, after a certain high tax threshold is reached, raising even more the tax burden may also negatively affect the PPP investment, most likely by affecting the private partner propensity to invest.

The other indicators of a government fiscal burden, such as the general budget balance or the public and publicly guaranteed debt (lagged or contemporaneous), are not found significant in explaining investment under PPP.[29]

[28] The squared *gov_tax_gdp* variable is not significant in the LAC sample.

[29] This is in contrast to Hammami et al. (2006) who conclude that PPP tend to be more common in countries where governments suffer from heavy debt burdens. There are several major differences between our study and Hammami et al. with respect to the determinants of PPP investment: (i) our sample size is

Sixth, the nominal lending interest rate is found to have a negative and statistically significant effect on PPP investment (as predicted by the theoretical model) only in GLS models, and not in the preferred Tobit models. However, it turns statistically significant when the restricted sample of LAC countries is used. Associated with the impact of inflation, real lending interest rates seem to induce less PPP investment in the LAC region, as predicted by the theoretical model.

Finally, other explanatory variables that are robust across various specifications are external aid (*log_aid*), and the year dummy variables. External aid is positively associated with PPP programs, possibly reflecting support from international financial institutions and other donors for infrastructure programs. The year dummies are highly statistically significant, capturing the lumpy nature of PPP committed investment, and possibly indicating that PPP investment programs vary with cycle, or with the political calendar. The regional dummies capture regional fixed effects, that is, various economic, cultural, political linkages between countries within a region that are not controlled for in the empirical model. Several are statistically significant across various specifications, particularly reflecting a much more limited experience with PPP programs in Middle East and Africa, and a broader experience in Latin America, Eastern Europe and East Asia.

The determinants of investment under PPP can also be investigated from another angle, that is, the frequency of undertaking PPP projects. This approach comes closer to the basic theory of investment under uncertainty, which models the decision to invest or

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almost double (total number of observation, NT, is about 800, compared to theirs 450, resulting from a longer time series 1990-2005 compared to 1990-2003, 77 countries compared to 70, and use of variables with less missing value); (ii) the quality of our dataset is better due to recent adjustments operated by the World Bank; (iii) I use a stricter definition of PPP investment, excluding fully private contracts; (iv) I look at both investment in real assets and total PPP investment, the latter including payments to the government.

postpone investment. To this end, I will use as the dependent variable our count variable of PPP projects (total number of PPI projects excluding full privatization and merchant contracts). For count variables, the most adequate empirical model is negative binomial, the Poisson model being rejected due to the discrepancy between the unconditional mean and variance of our dependent variable. A technical discussion of the empirical models for count variables is presented in the Appendix to this chapter. Since count data models assume that events are independent in time, dynamic panel models cannot be used, and I estimate the model as cross-sectional by averaging the variables over our period of analysis (1990-2005).

The dependent variable is the total number of PPP projects concluded over that period. Since China is the country with the most PPP projects (483 compared to a median of 7 projects by country), followed by Brazil with 297 projects and the Russian Federation with 284 projects, I also show the results with the sample excluding these countries.

Table 11 summarizes the results: m1 is a negative binomial (NB) model using the same variables as in Table 10 (plus two more volatility variables consistently found significant); m2 adds the squared term of the tax burden (previously found significant) and excludes the three extreme outliers; m3 is similar with m2, but estimated using Poisson (shown for comparison only since it is rejected by post-estimation tests).

Table 11: Determinants of PPP project count

Variable	m1 Negative Binomial (NB)	m2 NB (sample excl. China, Brazil, Russia)	m3 Poisson (sample excl. China, Brazil, Russia)
PrivateKf_gdp_avg	-0.0215*	-0.0125	-0.0053
PublicKf_gdp_avg	0.0037	0.0011	0.0081
lend_rate_avg	-0.0014*	-0.0006	-0.0013
inflation_avg	0.0003	-0.0001	0.0003
gov_tax_gdp_avg	-0.0138	-0.0058	0.0057
gov_tax_gdp_avg_sq	-	-0.0002	-0.0002
ppg_debt_gdp_avg	0.0074	-	-
gov_bal_gdp_avg	0.0013	-	-
log_GDP_ct_avg	0.7880***	0.6634***	0.7035***
log_aid_avg	0.1964*	0.1367	0.2049*
inv_profil_avg	0.0685	0.1099**	0.1176*
ex_rate_uncert	-0.0003***	-0.0002**	-0.0002**
publicKf_uncert	0.0472**	0.0442*	0.0381
reg2	-0.273	-0.4928	-0.7154**
reg3	-0.2861	-0.3165	-0.2076
reg4	-1.3989***	-1.3709***	-1.5012***
reg5	-0.2684	-0.1629	0.05
reg6	-0.7383***	-0.7696***	-0.8269***
_cons	-15.7329***	-13.0791***	-14.7058***
Post-estimation statistics			
goodness of fit chi-2 test			Poisson rejected
alpha	0.1433**	0.1102**	
Log pseudolikelihood	-252	-230	-274
AIC	542	496	581
BIC	587	537	621
N	**77**	**75**	**75**

Note: Significance level (p-values lower or equal to): *10%, **5%, ***1%.
The variables are the same as described in Table 7, Chapter II. The suffix *_avg* indicates that the variables are expressed as averages over the period of the analysis (1990-2005). The variable *gov_tax_gdp_avg_sq* is the squared term of the variable *gov_tax_gdp_avg*. The variables *ex_rate_uncert* (exchange rate uncertainty) and *publicKf_uncert* (public capital uncertainty) are calculated as the standard deviation by country, over the period 1990-2005, of residuals from regression of the respective annual variable over its two immediate past lags and a time trend. reg2 is Europe and Central Asia; reg3 is Latin America & Caribbean; reg4 is Middle East and North Africa; reg5 is South Asia; reg6 is Sub-Saharan Africa. The omitted dummy is reg1, East Asia and Pacific.
The fact that the parameter alpha is significantly different from zero in the m1 and m2 models, and the result of the goodness of fit chi-2 test, indicate that the Poisson model is rejected and the negative binomial models are preferred.

With count data, the evidence on the determinants of PPP programs is less clear, partly because of a much smaller sample size and lower data variation originating only from the cross-sectional dimension of data.

The most important determinant of PPP project count seems to be the size of the market/economy (this result is also triggered by the fact that the count variable is expressed in absolute terms, while the PPP investment was expressed in relative terms to a country's GDP). Larger foreign aid still proves to be important in financing more PPP projects although its significance is weaker than before (it drops below 10% when the three outliers are excluded).

As regards the measures of risk and uncertainty, two variables turn now to be robust across various specifications. While the exchange rate uncertainty seems to be associated with fewer PPP projects over the period 1990-2005, higher uncertainty regarding public investment seems to induce more PPP projects, most likely accounting for a substitution effect between the two. The investment profile index that was found significant in explaining PPP investment seems again to play a role in explaining the number of projects when China and Russia (Brazil does not seem to influence so much the change in its significance) are excluded from the sample. These two countries have large PPP programs despite ranking below the median of the investment profile index.

IV.2 Impact of PPP investment programs

With respect to the impact of PPP investment on the aggregate private and public investment, fiscal stance and output, I focus the empirical analysis on the large Latin American (LA) countries.

The reasons are threefold. First, this is the region with the largest and most mature PPP programs. It was a pioneer among developing countries in opening its infrastructure sector to private sector participation, by introducing regulations to delegate infrastructure financing and management, and thus attracting about half of the developing world's PPI between 1990 and 2003 (Fay and Morrison 2006). The other regions have relatively less developed PPP programs for potentially unveiling any significant productive effects. Second, the variable PPP investment and its sub-components are not centered on the value zero (only 14 observations or about 17% of total are zeros, compared to 60% for the whole sample)[30]. Third, the area is much more homogenous in terms of economic, cultural and institutional values.

The sample includes seven LA countries (Argentina, Bolivia, Brazil, Chile, Colombia, Mexico and Peru) for twelve-year period (1990-2001). I limited the dimensions of the panel to these seven countries and the period 1990-2001 after having merged our dataset with the one provided in Calderon and Serven (2004). This dataset includes data on private investment in various infrastructure sectors that I shall use in the analysis. I kept the restricted sample for comparison purposes and because data quality in these countries is higher. Yet, I have also conducted the regressions with the full sample and other regional sub-samples (Europe and Central Asia, Eastern Asia, and all available countries in Latin America and the Caribbean), and I shall discuss the results accordingly.

[30] The observations of the variable *PPPinvest_gdp* are still skewed to the right due to an extreme outlier, that is, the value for Bolivia in the year 1998 (28.1% of GDP, while the maximum value excluding this outlier is 8.2% of GDP). I also estimated all our models excluding this outlier, but the conclusions do not change (in general, I obtain higher p-values for the PPP variables, but still below the regular significance thresholds).

The basic empirical model to be used is the dynamic panel model. Given the limited number of cross-sectional units, the bias-corrected LSDV dynamic panel estimator (Bruno 2005a) will be used (to be henceforth called *xtlsdvc*[31]). This is the corrected fixed effects (or least squares dummy variable, LSDV) estimator for estimation and inference in dynamic unbalanced panel models with a small number of individuals (see more details in the technical appendix to this chapter). Arrelano-Bond (Difference GMM) or Blundell-Bond (System GMM) models are the standard dynamic panel models (fixed effects are also eliminated through first differencing), but they are more adequate for panels with many cross-sectional units, which is not the case of our restricted LA sample. Therefore, I shall show the regression results also with the GMM models for comparison, but consider *xtlsdvc* the most appropriate model and draw the conclusions thereafter.

I first re-analyze the impact of PPP programs on the aggregate private and public investment with the LA sample, then I investigate the impact on the government fiscal balance, public and publicly guaranteed debt, fiscal risks, and finally the impact on economic growth.

IV.2 (1) Impact on aggregate private and public investment

I first estimate the determinants of aggregate public and private investment in the sample of Latin American economies by including investment under PPP as explanatory variables, that is, total PPP investment (*PPPinv_gdp*); PPP investment in fixed assets

[31] According to the Stata command for this model

(*PPPinvfa_gdp*) and payments to the government under PPP contracts (*PPPgov_pay_gdp*), all variables as shares of GDP.

Table 12.a. below shows the results for the aggregate private investment, using four models: m1 is a bias-corrected LSDV model (*xtlsdvc*) using *PPPinv_gdp* as an explanatory variable; m2 is a *xtlsdvc* model using the two sub-components of the variable *PPPinv_gdp*; m3 is a difference GMM model using the aggregate PPP investment, and m4 is a System GMM using the sub-components. I show all these models for comparison because of the dynamic nature of our dependent variable, but the *xtlsdvc* models are preferred.

Table 12.b. shows the results for the aggregate public investment. Because I do not find a dynamic model appropriate in this case (the first lag of our dependent variable, *PublicKf_gdp* is not significant in the *xtlsdvc* model), I show only results with the *xtlsdvc* and the fixed effects (FE) models, the latter being preferred.

Table 12: Impact of PPP investment on aggregate investment

12.1. On aggregate private investment

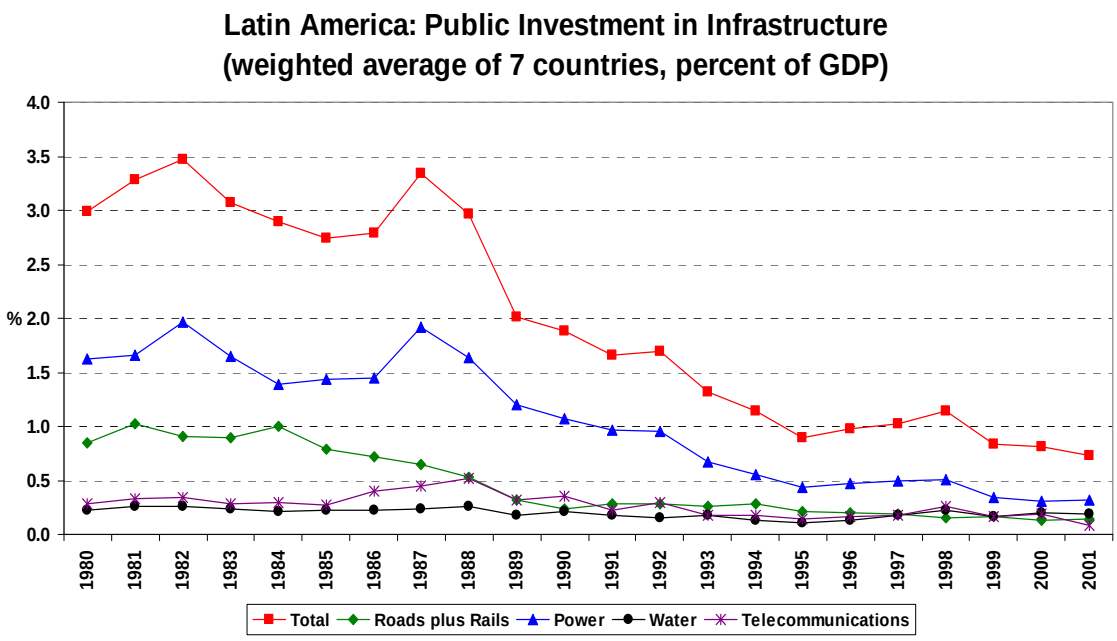
Variable	m1 xtlsdvc	m2 xtlsdvc	m3 Difference GMM	m4 System GMM
L1.PrivateKf_gdp	0.5043***	0.5030***	0.4571***	0.4545***
PublicKf_gdp	-1.6225***	-1.5356***	-1.6433***	-1.2180***
PPPinv_gdp	0.1183***	-	0.1186***	-
PPPinvfa_gdp	-	0.1321***	-	0.1001***
PPPgov_pay_gdp	-	-0.1371	-	-0.1598
lend_rate	-0.0358***	-0.0348***	-0.0361***	-0.0407***
Inflation	0.1127***	0.1113***	0.1119***	0.1370***
L1.ppg_debt_gdp	0.0607**	0.0629**	0.0544**	-0.0332
realGDP_growth rate	0.1540***	0.1577***	0.1500***	0.2363***
CA_gdp	-0.5071***	-0.5141***	-0.5286***	-0.4261***
economic_risk	0.1962***	0.1846***	0.2050***	0.2295***
Corruption	0.4946*	0.4774*	0.4911*	0.3501
inflation_volat	-0.0038***	-0.0040***	-0.0037***	-0.0052***
_cons	-	-	3.4574*	1.2061
Time dummies	Included	Included	Included	Included
AR test in first differences				
AR(1) (p-value)	-	-	0.0329	0.0188
AR(2) (p-value)	-	-	0.2982	0.5174
AR(3) (p-value)			0.5598	0.0737
Sargan test of overidentifying restrictions				
chi2(d.f.)	-	-	41.5 (40)	50.4 (48)
p-value	-	-	0.4057	0.3806
Goodness of fit measure				
rho square	0.773	0.774	0.766	0.938
No. obs. (NT)	68	68	61	68
No. of groups (N)	7	7	7	7

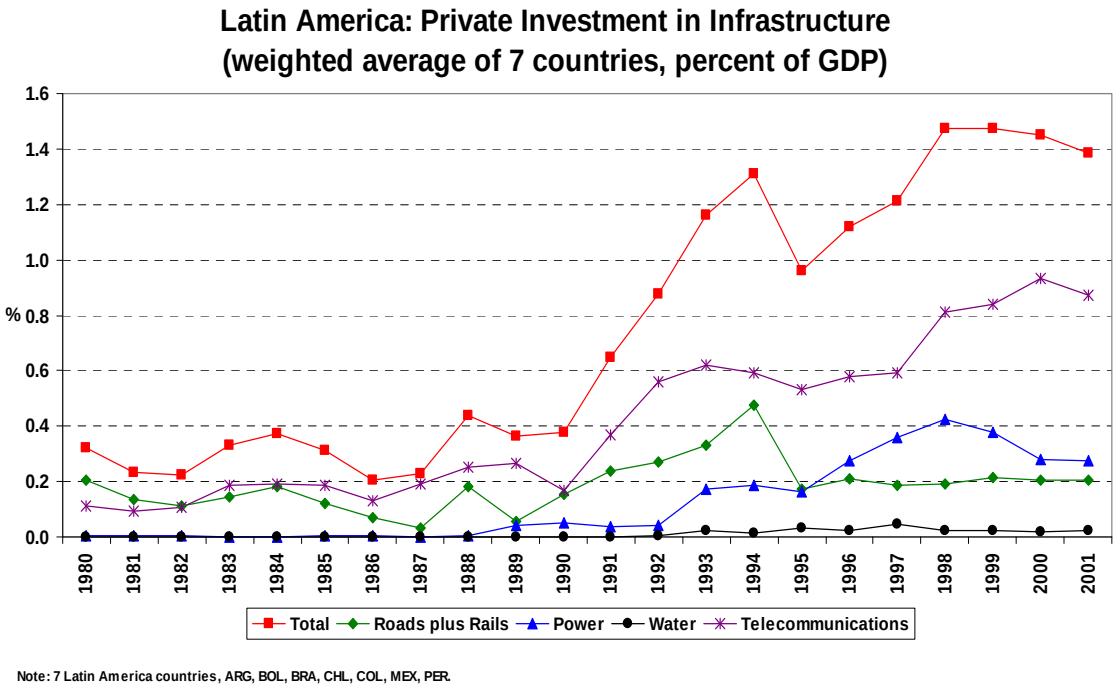
Significance level (p-values lower or equal to): *10%, **5%, ***1%.

12.2. On aggregate public investment

Variable	m1 xtlsdvc	m2 FE
L1.PublicKf_gdp	-0.0404	-
PrivateKf_gdp	-0.1548***	-0.1597***
L1.PrivateKf_gdp	0.0276	0.0347
PPPinv_gdp	0.0090	0.0114
L1.PPPinv_gdp	-0.0009	-0.0013
L1.ppg_debt_gdp	0.0014	0.0026
L1.gov_bal_gdp	0.1468***	0.1470***
lend_rate	0.0055	0.0058
inflation	-0.0095	-0.0101
log_aid	-0.1563	-0.156
CA_gdp	-0.0862***	-0.0849***
realGDP_growth rate	0.0203	0.023
democracy	-0.2288**	-0.2204**
gov_bal_uncertainty	-0.1167*	-0.1159*
pubcons_uncertainty	0.5134***	0.5087**
_cons		6.1938***
Time dummies	Included	Included
Goodness of fit measure		
rho square	0.48	0.58
R-square (within/overall)		0.77/0.58
No. obs. (NT)	63	63
No. of groups (N)	7	7

The impact of our variables of interest—*PPPinv_gdp* and its sub-components—is highlighted across all models. I find that investment under PPP in our LA countries is positively related to the aggregate private investment and, contrary to the results for the whole sample, there is no significant crowding-out impact on the aggregate public investment. The latter result is rather surprising given that a preliminary inspection of data shows that several LA countries with the largest PPP programs are also among the ones with a very small share of public investment in GDP, indicating a potential substitution effect between the two types of investment. For instance, Argentina, Brazil, and Chile are among the lowest 15 ranked countries in the whole sample (of 118 countries for which data is available) in terms of public investment (1.8% of GDP, 2.2%, and respectively, 2.7% of GDP compared to a sample average of 7.1% of GDP for the period 1990-2005). At the same time, they are among the countries with the largest PPP programs: Brazil is ranked number 2 in terms of absolute number of projects with 297, Argentina number 4 with 182 projects, and Chile number 7 with 103 projects. In relative terms—PPP investment as percent of GDP—they are among the 20 highest ranked among the developing economies included in the World Bank dataset. In addition, data from Calderon and Serven (2004) also broadly indicate a substitution trend between public and private investment in infrastructure in the seven LA countries used in our analysis (see Figure 1 below for a longer period of time, 1980-2001). This trend is only indicative for the substitution effect between public and PPP investment, since some of the private investment shown in the second graph accounts for purely private investment (especially in telecom).





Source: Serven (2005) based on data from Calderon and Serven (2004)

Figure 1: Public and private investment in infrastructure in LA countries

Some explanations of why the substitution effect between PPP investment and aggregate public investment does not prove to be significant in the LA sample are: (i) this relation is indirectly captured by the government budget constraint (explained below); (ii) the infrastructure gap has not been closed in these countries, i.e. the growth of private participation in infrastructure has not matched the decline in public infrastructure investment, as it can be noticed in Figure 1 above and pointed out in Calderon and Serven (2004) and Fay and Morrison (2006); (iii) even in the likely case of a substitution trend in the infrastructure sector, this trend may not be observed in our data with the aggregate investment (which includes fixed public capital formation in other sectors as well).

As regards the impact of PPP investment on aggregate private investment (found in model m1), as expected, this is explained in m2 entirely by the sub-component of PPP investment in fixed assets—only the variable *PPPinvfa_gdp* is significant, while the variable *PPPgov_pay_gdp* is not. Similar results are obtained with the GMM models, in which the variable *PPPinvfa_gdp* remains statistically significant even when modeled as an endogenous regressor.

The models I use in this chapter for the aggregate public and private investment are broadly similar with those in the preceding chapter. I also find now a contemporaneous substitution effect between the aggregate public and private investment, but the complementarity effect given by the first lag is not significant any longer for any of the two variables. Corruption and inflation volatility seem to have a negative impact on private investment in the LA sample, as well.

As regards the fiscal variables, there is strong evidence that LA governments tend to cut their public investment as a fiscal restraint measure—higher deficits in the preceding year[32] or higher uncertainty about the fiscal stance are associated with lower current public investment. This result is in line with various World Bank studies (Serven 2005; Fay and Morrison 2006) showing that one of the main reasons for the decline in public infrastructure investment in the LA countries during the late 80s and 90s has been the adoption of fiscal austerity programs forced by the region's macroeconomic crises. This has been coupled with the paradigm of promoting more private participation in infrastructure by delegating infrastructure financing and management to the private sector.

The economic growth rate is no longer significant in determining a higher ratio of public investment-to-GDP in the LA countries (and thus, there is less of an indication of pro-cyclical fiscal policy). It remains, though, highly significant in inducing private investment. The impact of the current account (CA) balance on both type of investment is negative for these countries: larger CA deficits, or equivalently larger external inflows (borrowing abroad and FDI), are associated with higher private and public investment.

Several variables, especially risk-related, that did not prove to be significant or robust for the whole sample turn out now to be robust across our models. Thus, higher economic risk remains significant in lowering the amount of private investment even after controlling for the real GDP growth rate. The democracy index turns now significant in explaining public investment, but with a rather surprising sign: less democratic LA regimes seem to implement higher public investment works. This could

[32] Conversely, higher budget surpluses in the previous year are associated with higher public investment (as given by the positive sign of the estimated coefficient for *L1.gov_bal_gdp*).

be evidence of populism. As already pointed out above, higher uncertainty regarding the fiscal balance induces more cuts into public investment, while higher uncertainty regarding public consumption has a positive impact on investment, most likely through the substitution effect triggered by lower government consumption. In addition, the stock of public and publicly guaranteed debt in the preceding year seems to be significant in raising current private investment, possibly reflecting the role of government guarantees in promoting private projects in the LA group.

IV.2 (2) Impact on government budget balance

I propose the following dynamic model for the determination of the government budget balance (as percent of GDP):

Gov. balance = f(Gov. balance $_{previous\ years}$*; PPP investment and gov. payments; Gov. debt; CA balance; inflation; GDP growth rate and GDP uncertainty; institutional variables; common shocks)*

I thus assume that, in setting its budget balance, the government takes into account: (i) its fiscal stance in the previous years (given that only a relatively smaller part of budget expenditure are discretionary), (ii) its public debt stock, (iii) the growth rate of GDP and GDP uncertainty reflecting the response to the economic cycle through a (counter-) cyclical fiscal policy, (iv) and macroeconomic targets that fiscal policy can address such as the CA balance and inflation. Institutional variables likely to shape the political process of budget approval, such as the level of corruption, democracy, law and order are also included. Our variable of interest is investment under PPP programs, which is integrated in the empirical model using its two sub-components—PPP investment and payments to government.

Various sub-components of the variables mentioned above, especially elements of budget expenditure financing (e.g. external debt, external aid) have also been tested, but they do not turn significant in any model. I have also experimented with various lags of the variables. For the target variables, CA balance and inflation, I have used either the first lag, or the first lead to capture the possibility of governments having adaptive or forward-looking expectation (in the latter case assuming perfect foresight). The results of the estimations are presented in Table 13 below.

Table 13: Impact of PPP investment on government budget balance

Variable	m1 xtlsdvc	m2 xtlsdvc	m3 Difference GMM
L1.gov_bal_gdp	0.6498***	0.4949***	0.5075***
L1.ppg_debt_gdp	0.0481	0.0398	0.0454
L1.CA_bal (F1.CA in m2)	0.0916	-0.2504**	0.0957*
L1.inflation (F1.infl in m2)	-0.0015**	0.0016**	-0.0015***
L1.gdp_growth	0.1308**	0.0398	0.1333**
log_gdp_uncertainty	-6.2106	-4.9984	-6.8491
PPPinvfa_gdp	-0.0079	-0.0628	0.0037
PPPgov_pay_gdp	-0.2675	-0.2555	-0.2923**
L1.PPPgov_pay_gdp	0.1126	0.1756	0.0806
L2.PPPgov_pay_gdp	0.3745*	0.5552***	0.3882**
law_order	0.3044	-0.2174	0.3966
Democracy	0.1362	0.1355	0.213
Corruption	0.279	0.7342*	0.3277
_cons			-6.5950**
Time dummies	Included	Included	Included
AR test in first differences			
AR(1) (p-value)	-	-	0.0457
AR(2) (p-value)	-	-	0.1358
AR(2) (p-value)	-	-	0.2759
Sargan test of overidentifying restrictions			
chi2(d.f.)	-	-	40.3 (41)
p-value	-	-	0.4998
Goodness of fit measure			
rho square	0.72	0.56	0.68
No. obs. (NT)	70	63	63
No. of groups (N)	7	7	7

Note: In m3, *PPPgov_pay_gdp* is declared endogenous.
Significance level (p-values lower or equal to): *10%, **5%, ***1%.

The first two models are *xtlsdvc* (m1 uses the first lag of the variables CA balance and inflation as regressors, while m2 uses the first lead); model m3 is difference GMM. I find evidence of persistence in the budget balance—a higher deficit in the preceding year (the second lag is not significant) implies a rise in the deficit in the current year—so that a dynamic model is appropriate.

With respect to our main question—the impact of PPP programs on fiscal balance—I find evidence that payments to governments under PPP programs[33] are eventually likely to improve future fiscal balances. Hence, the second lag of PPP proceeds is found statistically significant across models, including under the more appropriate bias-corrected LSDV models (at 10% in model m1 and 1% confidence level in model m2).[34] The fact that only a *two-year lagged* value of the PPP component is significant may be evidence that it takes some time until the PPP commitment to pay becomes an actual payment that feeds through the budget.

Another region for which *PPPgov_pay_gdp* turns to be significant in reducing future budget deficits is East Asia and Pacific (region 1), while no significant impact is unveiled in the whole sample of developing economies. Surprisingly, *PPPgov_pay_gdp* is not found significant in explaining government budget balances across countries in region 2, Europe and Central Asia, which is the region with the largest average annual PPP payments to governments (while the mean of the variable *PPPgov_pay_gdp* for the

[33] Exclude proceeds from full privatization and merchant contracts

[34] In model m3, with the variable *PPPgov_pay_gdp* declared endogenous, I find a negative contemporaneous effect of PPP payments on the budget balance, but this is smaller than the positive effect of lag 2, so that the cumulative impact is positive. The first two models are preferred due to the low dimension of the cross-section.

whole sample is 0.20, the mean for region 2 is 0.35, followed by region 3, LAC, with 0.31).

Investment in fixed assets under PPP projects is not found significant in determining current or future government balance in the *xtlsdvc* models (only *PPPinvfa_gdp* is shown in Table 13, but no other lag is significant).

With respect to the impact of other regressors, the public and publicly guaranteed debt in the previous year is not found statistically significant in any models (the same applies for further lags or for the contemporaneous effect). Institutional variables do not turn significant either for the period under analysis. There is evidence that a higher GDP growth rate in the preceding year leads to lower budget deficits in the current year. This may be the work of automatic stabilizers or the conduct of discretionary counter-cyclical fiscal policy during the period 1990-2001. Similarly, a higher perceived inflation in the future leads to slight tightening of the fiscal stance (higher budget surplus) at present. However, higher inflation in the previous year tends to lead to slightly higher current budget deficits.

IV.2 (3) Impact on government debt

Next, I analyze the impact of PPP programs (investment and payment to the government) for the public and publicly guaranteed debt, all variables being in GDP terms.[35] I propose the following dynamic model for the government debt:

[35] When I refer to these variables in the text, I understand them as shares of GDP.

Gov. debt = f(Gov. debt $_{previous\ years}$; PPP investment and gov. payments; public capital formation; gov. budget balance; CA balance; lending rate; inflation rate; economic growth rate; institutional variables; common shocks and specific economic risks)

I posit that the government debt stock depends on: (i) the previous year's stock of debt; (ii) the government budget balance; (iii) our variable of interest—investment under PPP with its two sub-components (investment and payments to the government), as well as the purely public capital formation; (iv) external financing requirement as given by the current account balance; (v) lending interest rate and the inflation rate; (vi) institutional variables (corruption, democracy, law and order).

As expected, given the stock nature of the dependent variable, I find a high persistence in the dynamic model, and therefore I will present the results for the LA sample with the bias-corrected LSDV model, and system GMM (in this case, clearly preferred to difference GMM). Under the first model (m1, *xtlsdvc*), I obtain a slightly explosive debt path with the coefficient of the first autoregressive term higher than 1, hence model m2 is preferred. Table 14 summarizes the results: 14.1 for the seven LA countries and 14.2 for the whole sample.

Table 14: Impact of PPP investment on public and publicly guaranteed debt

14.1. LA countries

Variable	m1 xtlsdvc	m2 System GMM
L1.ppg_debt_gdp	1.1406***	0.9861***
L2.ppg_debt_gdp	-0.0669	-0.0917
L1.lend_rate	0.0565**	0.0607***
L1.inflation	-0.1267***	-0.1347***
L1.CA_gdp	-0.4929**	-0.4494***
L1.gov_bal_gdp	-1.3072***	-1.1467***
realGDP_growth rate	-0.5826***	-0.5667***
PublicKf_gdp	2.0768*	1.2262***
L1.PublicKf_gdp	1.6598*	0.5493
PPPinvfa_gdp	0.1034	0.0405
L1.PPPinvfa_gdp	0.0846	-0.0367
PPPgov_pay_gdp	-1.6110***	-1.1117***
L1.PPPgov_pay_gdp	-0.9663**	-0.7610***
_cons		-9.8805***
Time dummies	Included	Included
AR test in first differences		
AR(1) (p-value)	-	0.0466
AR(2) (p-value)	-	0.1909
AR(2) (p-value)	-	0.1137
Sargan test of overidentifying restrictions		
chi2(d.f.)	-	39.9(42)
p-value	-	0.57
Goodness of fit measure		
rho sq.	0.88	0.97
No. obs. (NT)	61	61
No. of groups (N)	7	7

14.2. The whole sample

Variable	m1 System GMM	m2 System GMM
L1.ppg_debt_gdp	0.9513***	0.9465***
L2.ppg_debt_gdp	-0.0768**	-0.0782**
lend_rate	0.0314	0.0459
Inflation	-0.0114***	-0.0118***
FDI	-0.1690***	-0.1586***
gov_bal_gdp	-0.5502**	-0.5597***
realGDP_growth rate	-0.7518***	-0.7175***
PublicKf_gdp	0.9864**	0.9079**
PPPinv_gdp	0.3294	-
L1.PPPinv_gdp	0.3105**	-
L2.PPPinv_gdp	0.4619	-
PPPinvfa_gdp	-	0.3515
L1.PPPinvfa_gdp	-	0.202
L2.PPPinvfa_gdp	-	0.6623
PPPgov_pay_gdp	-	0.0216
L1.PPPgov_pay_gdp	-	0.2183
L2.PPPgov_pay_gdp	-	-0.4875*
_cons	1.1974	1.8355
Time dummies	Included	Included
AR test in first differences		
AR(1) (p-value)	0.0000	0.0000
AR(2) (p-value)	0.1648	0.1941
AR(3) (p-value)	0.5492	0.5926
Sargan test of overidentifying restrictions		
chi2(d.f.)	75.7(202)	75.3(305)
p-value	1.00	1.00
Goodness of fit measure		
rho sq.	0.97	0.97
No. obs. (NT)	1040	1040
No. of groups (N)	98	98

Significance level (p-values lower or equal to): *10%, **5%, ***1%.

As regards the LA sample, in both models, payments to the government under PPP programs (*PPPgov_pay_gdp*)—both contemporaneous and lagged one year[36]—are

[36] The second lag is not statistically significant

significant in reducing the stock of public and publicly guaranteed debt. The variable has a strong statistical significance (at 1% confidence level) and a large economic impact (the combined size of the coefficient is over 1.8 in m2). As in the case of government budget balance, investment in fixed assets under PPP programs (*PPPinvfa_gdp*), as well as total PPP investment including payments to the government (*PPPinv_gdp*), is not found statistically significant in reducing the stock of public debt. Jointly with the evidence on the budget balance, it seems that larger PPP programs, particularly larger payments to the government by private partners, are likely to ease the future government fiscal position (budget deficit and public debt burden) in the LA countries under analysis.

For the whole sample (Table 13.2), I find somewhat contrary evidence that total PPP investment in the previous year (only the first lag is statistically significant) may in fact contribute to higher public debt in the future.[37] Yet, when I use the disaggregated components, the significance disappears and I find again (only at 10% significance level) that payments to the government under PPP programs, lagged two years, are likely to reduce the stock of debt in the future. The difference between the results with the whole sample and with the LA sample may indicate that PPP programs have a positive impact on the government debt only when they are sufficiently large and developed, as in the LA countries. For instance, when I restrict the whole sample only to those observations for which *PPPinv_total* is larger than 3% of GDP (52 countries or 116 observations), total

[37] The significance remains even when *PPPinv_gdp* is declared endogenous and is thus instrumented through GMM-type instruments starting from lag 2 (L2) in the difference equation and the first difference (LD) in the level equation.

PPP investment lagged two years becomes again statistically significant in reducing the stock of public and publicly guaranteed debt.

With respect to the impact of other variables on public debt, I obtain broadly similar results for the whole sample and the LA sample. In general, the models' goodness-of-fit measures are very high, mostly reflecting the high persistence of the dependent variable.

As expected, a higher budget surplus contributes significantly to reducing the stock of public debt in both samples. When I account for the component of public expenditures that is of interest for this analysis, I find that higher public capital expenditures in the previous years add up significantly to the government debt.

The external financing requirement is also reflected in the stock of public debt. A higher current account surplus in the LA sample in the previous year is associated with a lower stock of public debt in the current year (the contemporaneous effect is not statistically significant). For the whole sample, FDI proves more highly significant: higher external inflows in the form of FDI are associated with lowering public debt, most likely by lowering the guaranteed external debt or through currency revaluation (higher FDI, as well as higher current account surpluses, are expected to be associated with domestic currency appreciation in the developing countries under study).

As expected, a higher economic growth rate contributes to lowering the share of public debt in GDP. Our institutional and political economy variables do not seem to have a robust impact in this model-specifications (not shown in Table 14).

IV.2 (4) Impact on fiscal risks

As presented in Chapter I, the technical literature hints at concerns about the fiscal risks associated with PPP programs, especially stemming from contingent liabilities and investment management. In investigating the impact of PPP investment programs on fiscal risks in developing countries, I seek to answer the following questions (partly determined by the availability of data in the PPI dataset):

(i) Are governments more likely to grant guarantees and other forms of financial support to PPP projects in preference to fully private infrastructure projects?

(ii) Are PPP infrastructure contracts more likely than purely private contracts to run into difficulties (get canceled or distressed)? Which is the PPP type that has confronted most financial difficulties?

(iii) What is the econometric impact of PPP investment on our measures of fiscal volatility and uncertainty?

Q(i): Are governments more likely to grant guarantees and other forms of financial support to PPP projects in preference to fully private infrastructure projects?

The evidence from the World Bank PPI database regarding fiscal support extended by governments in developing countries to private infrastructure partners is mixed. It is likely that public disclosure of this type of information is limited, especially if support is provided under guarantees and other contingent liabilities that do not involve immediate government payments. Therefore, the dataset may underestimate the number of projects with such government support. For most of these projects, the *amount* of government

support (committed or already extended) is not available; only *the type* of support is recorded.

Table 15: Number of projects with committed government support by type of PPP

Type of government support	Concessions	Greenfield*	Management/ Lease	Total by type of support	% type of support in total
Payment Guarantee	3	18	0	21	12%
Revenue Guarantee	20	15	0	35	20%
Exchange Rate Guarantee	0	1	1	2	1%
Interest Rate Guarantee	0	1	0	1	1%
Debt Guarantee	2	1	0	3	2%
Fixed government payments	69	25	11	105	60%
Variable government payments	2	5	0	7	4%
Total	96	66	12	174	100%

Source of data: The World Bank PPI database and author's calculations
* excludes Merchant contracts

Only 174 projects, or 4.6% of the total of about 3,800 PPI projects with financial closure between 1990 and 2006,[38] are recorded with committed (contractual) government support in the form of guarantees (payment guarantee, revenue guarantee, exchange rate guarantee, interest rate guarantee, debt guarantee, and other variable government payments) and fixed government payments.

By type of PPP, according to the WB PPI dataset (see Table 15 for details), most government support goes to concessions (55% of the total supported projects), followed by greenfield projects, out of which, BOT-type projects account for 34% of the total supported projects.

[38] At the time of this analysis (Report retrieved on April 24, 2008), data for 2006 have also become available, and I have included this year as well.

By sector (table not shown), the highest absolute number of government-supported projects is in transportation (80), followed by water and sewerage (75), and energy (19), while telecom is recorded with only one supported project. However, in relative terms (relative to the total number of projects in each sector), the water and sewerage sector dominates by far, followed by transportation and, with a much lower share, by energy.

Among the various types of government support, *fixed payments* account for about 60% of the supported projects. These are mostly upfront subsidies that do not normally involve fiscal variability or constitute fiscal risk in our definition. However, as mentioned before, the number of projects supported by explicit government guarantees may be under-estimated in the WB PPI dataset due to lack of transparency in government data. For instance, the World Bank methodology acknowledges that, in greenfield projects, mostly BOT, "The government usually provides revenue guarantees through long-term take-or-pay contracts for bulk supply facilities or minimum traffic revenue guarantees," but only about 3% of all greenfield contracts are recorded with government guarantees. *Revenue guarantees* (20%) and *payment guarantees* (12% of total supported projects) are the next most frequent types of government support after *fixed payments*.

On the other hand, none of the purely private contracts, such as full divestiture and merchant contracts, is recorded with government support. The partial divestiture contracts (joint ventures) are not documented with government support in the World Bank PPI dataset either.

The conclusions from this preliminary data analysis are that: (i) governments tend to provide some (more) fiscal support for PPP projects as opposed to purely private infrastructure projects; (ii) governments tend to provide more fiscal support to the infrastructure sectors regarded as social targets with lower private benefits, such as water and transportation, as opposed to energy and telecom; (iii) only 40% of the number of projects recorded with government support involve contingent liabilities (mostly revenue guarantees) and thus incur fiscal risks; (iv) data on government support, especially guarantees, are likely to be underestimated in the WB PPI dataset due to lack of transparency.

The perception from various case studies and technical reports (Engel, Fischer et al. 1997; IMF 2006; Corbacho and Schwartz 2008) is that fiscal risks are important when considering PPPs for infrastructure provision. Engel, Fischer, and Galetovic (1997) point out that private contractors, especially in developing countries, often press for generous up-front financial guarantees from the government. Moreover, some investors may presume the existence of implicit guarantees, that is, expect to be bailed out should the project go into financial distress.

Q(ii): Are PPP infrastructure contracts more likely than purely private contracts to run into difficulties (get canceled or distressed)? Which is the PPP type that has confronted most financial difficulties?

The World Bank dataset for private participation in infrastructure also records canceled or distressed contracts. According to the PPI methodology, contracts are recorded as *canceled* when the private party has exited the contract by (i) "selling or

transferring its economic interest back to the government … or removing all management and personnel from the project …, before fulfilling the contract terms"; (ii) "ceasing operation, service provision, or construction for 15 percent or more of the license or concession period, following the revocation of the license or repudiation of the contract, or sponsor."

Projects are deemed *distressed* when "the government or the operator has either requested contract termination or are in international arbitration." As acknowledged in the methodological notes to the World Bank PPI dataset, the number of distressed projects tends to be underestimated because most arbitration bodies do not disclose information about cases, an exemption being the International Centre for Settlement of Investment Disputes (ICSID).

Both purely private contracts and PPP-type contracts have confronted difficulties, but relatively more PPPs have been canceled. While 234 projects with financial closure between 1990 and 2006 are recorded as canceled or distressed (that is 6% of the total), only 18% of these projects are purely private—full divestiture or merchant contracts. However, this is also likely to reflect the lower share of purely private projects in the total number of projects included in the database. Indeed, both categories—purely private and PPPs (in a stricter or looser definition, the latter excluding partial divestitures, management and lease contracts)—have the same proportion of canceled or distressed projects, about 6%. Nonetheless, already canceled projects are relatively more frequent in the case of PPPs (about 80% of problem cases and 5% of total PPP count) than in the

case of purely private projects (about 50% of problem cases and 3% of total private count). See Table 16 below for more details.

Table 16: Count of canceled and distressed PPI projects

Type of contract	Count canceled plus distressed projects	Count canceled projects	All PPI projects count	% canceled plus distressed in total PPI count	% canceled in total PPI count
	1	**2**	**3**	**4=1/3**	**5=2/3**
Strictly private contracts total	**43**	**23**	**715**	**6%**	**3%**
Full divestiture	17	2	167	10%	1%
Merchant	26	21	548	5%	4%
Public-private					
Partial divestiture	31	19	596	5%	3%
Concessions	65	50	853	8%	6%
Greenfield contracts, excl. merchant	79	72	1415	6%	5%
Management and lease contract	16	15	214	7%	7%
Total broadly PPP contracts (all public-private)	**191**	**156**	**3,078**	**6%**	**5%**
Total strictly PPP (concession and greenfield, excl. merchant)	***144***	***122***	**2,268**	**6%**	**5%**
All projects	234	179	3,793	6%	5%

Source: The World Bank PPI dataset and author's calculations

In terms of investment, a larger share of investment under PPPs has been canceled or distressed (10% of broadly defined PPP projects and 12% of concession and BOT-type contracts) compared to investment under purely private contracts (4% of full divestiture and merchant contracts). See table 17 for details. By comparison with count data, PPP projects that failed, or are distressed, are relatively larger in investment terms than purely private contracts with the same status. By type of PPI, *concessions* dominate in terms of

the amount of canceled and distressed investment (in both absolute terms—USD 26,781 million or 32% of total canceled and distressed investment—and relative terms—18% of total investment under concession projects).

Table 17: Investment commitments under canceled and distressed PPI projects

Type of contract	Investment commitments in canceled plus distressed projects (mill. USD)	% type in total canceled/ distressed	Investment commitments all projects (mill. USD)	% canceled/ distressed in total by type
	1.	**2=1/sum1**	**3**	**4 = 1/3**
Strictly private contracts total	**16,392**	**19%**	**397,574**	**4%**
Full divestiture	10,929	13%	140,127	8%
Merchant	5,464	6%	257,447	2%
Public-private				
Partial divestiture	16,867	20%	267,426	6%
Concessions	26,781	32%	147,570	18%
Greenfield contracts, excl. merchant	24,719	29%	274,082	9%
Management and lease contract	10	0.01%	4,599	0.2%
Total broadly PPP contracts (all public-private)	**68,377**	**81%**	**693,677**	**10%**
Total strictly PPP (concession and greenfield, excl. merchant)	***51,500***	**61%**	**421,652**	**12%**
All projects	84,769	100%	1,091,251	8%

Source: The World Bank PPI dataset and author's calculations

Problems in dealing with private investment in infrastructure are not confined to a single region. However, Latin America and the Caribbean, the most experienced in terms of PPP programs in the developing world (i.e., dominant in terms of the number and size of PPP projects) also record the largest share of canceled and distressed projects (9% of

its total, the same as Sub-Saharan Africa, and followed by East Asia and Pacific with 6%). Of the canceled projects, about 50% were financially concluded in the period 1990-1995, and most of them were PPP projects in transportation, that is, road concessions and BOT programs affected by the Mexican crisis (see Table 18).

Table 18: Canceled and distressed projects by region

Regions	Count canceled projects	Count canceled plus distressed projects	% region in total canceled/ distressed	All PPI projects count	% canceled plus distressed in total PPI count
	1	**2**	**3=2/sum2**	**4**	**5=2/4**
East Asia and Pacific	63	64	27%	1,080	6%
Europe and Central Asia	20	21	9%	740	3%
Latin America and the Caribbean	58	110	47%	1,202	9%
Middle East and North Africa	6	6	3%	110	5%
South Asia	4	4	2%	329	1%
Sub-Saharan Africa	28	29	12%	332	9%
All regions	**179**	**234**	**100%**	**3,793**	**6%**

Source: The World Bank PPI dataset and author's calculations

The conclusions from this preliminary data analysis can be outlined as follows: (i) while both purely private contracts and PPP-type contracts have confronted difficulties, relatively more PPPs have been canceled; (ii) *concessions* seem to have been the sub-type of PPP confronting most economic and financial distress (this is not to suggest that the type of contract *per se* was necessarily the cause of distress); (iii) most cancelled and distressed contracts, both in absolute and relative terms, were recorded in Latin-America

and the Caribbean, the region with the most extensive experience with PPP among the developing countries.

Q(iii): Which is the econometric impact of PPP investment on our measures of fiscal volatility and uncertainty?

To answer this question, I use as a dependent variable our (three-year moving) measures of volatility and uncertainty related to two fiscal indicators: general consolidated budget expenditure and budget balance. I analyze the impact of PPP investment (aggregate and by components) on these variables for the whole sample, as well as in Latin America and other regional samples. The proposed dynamic econometric model[39] is as follows:

Fiscal risk = f(Fiscal risk $_{previous\ years}$; PPP investment and gov. payments; gov. budget balance; gov. debt; inflation rate; institutional variables; common shocks)

The results are shown in Table 19 below: Table 19.1 is for the whole sample, while Table 19.2 summarizes the results for regional samples. In 19.1, m1 models government expenditure volatility, m2 government expenditure uncertainty, m3 government balance volatility and m4 government balance uncertainty. In table 19.2, all regional models have government expenditure volatility as the dependent variable (this was the variable found most strongly associated with PPP investment).

[39] The literature on the *determinants* of fiscal volatility is very scarce (most studies analyze the *impact* of fiscal volatility on investment or growth). I found two working papers dealing with this topic for Latin American economies: Gavin and Perotti (1998) and Bertin-Levecq (2000), the latter being an empirical extension of the former. Fiscal risk is hypothesized to depend on: (i) shocks: external shocks to the economy and changes in real GDP; (ii) structural factors, such as the level of financial development, access to international capital markets, and the composition of fiscal revenue or expenditure; (iii) political variables. Bertin-Levecq (2000) finds that political instability, the composition of the budget and the level of financial development affect fiscal volatility, but only the composition of the budget seems to be robust. I do not find the composition of government expenditure or FDI significant.

All models are dynamic, with fiscal risk measures depending positively on levels in the previous year (the second lag is also included in order to mitigate the problem of autocorrelation in our AR test). In Table 19.1, I show the results with system GMM models, in which the two PPP investment components (the aggregate was not found statistically significant) are declared endogenous. Even with this specification, there is still a risk of reverse causation, since in our theoretical model, PPP investment depends on fiscal risk. However, as resulted from the previous investigation, I did not find evidence of a significant impact of our fiscal risk variables on PPP investment.[40]

[40] Even in a System GMM model having PPP investment as the dependent variable, the fiscal risk variables are not found statistically significant (for instance, *government expenditure volatility* has a positive, though insignificant coefficient).

Table 19: Impact of PPP investment on fiscal risk

Table 19.1. The whole sample

Variable	m1 gov exp volatility	m2 gov exp uncertainty	m3 budget balance volatility	m4 budget balance uncertainty
L1.DV	0.5113***	0.7664***	0.3559***	0.5589***
L2.DV	-0.0493	-0.1450**	-0.0416	-0.0719*
PPPgov_pay_gdp	0.0039	-0.0193	0.0168	0.0156
PPPinvfa_gdp	0.0159	-0.0561**	-0.0595***	-0.0289
L1.PPPgov_pay_gdp	0.0668*	0.0261	0.0298	0.008
L1.PPPinvfa_gdp	-0.0336***	-0.0372*	-0.0125	-0.0178
L1.gov_bal_gdp	-0.0822***	-0.0874**	-0.1049***	-0.0221
ppg_debt_gdp	0.0130***	0.0086*	0.0053	0.0135**
realGDP_growth rate	-0.0456***	-0.0682**	-0.0144	-0.0374*
inflation	0.0020*	0.002	0.0026*	0.0035
corruption	-0.2168*	-0.1486	-0.0042	-0.1033
_cons	0.8092*	0.4967*	0.4641	0.3129
Time dummies	Included	Included	Included	Included
AR test in first differences				
AR(1) (p-value)	0.0001	0.0003	0.0001	0.0001
AR(2) (p-value)	0.2337	0.152	0.636	0.4323
AR(3) (p-value)	0.2935	0.1296	0.1043	0.0072
Sargan test of overidentifying restrictions				
chi2(d.f.)	55.0(285)	60.1(264)	59.3(285)	61.2(264)
p-value	1.0	1.0	1.0	1.0
Goodness of fit measure				
rho sq.	0.52	0.70	0.45	0.58
No. obs. (NT)	948	876	948	876
No. of groups (N)	84	84	84	84

Table 19.2. Regional samples (DV = gov. exp. volatility)

m1 Latin America; System GMM	m2 Europe and Central Asia; System GMM	m3 East Asia and Pacific; System GMM	m4 East Asia and Pacific; xtlsdvc
0.3902***	0.2110**	0.3005***	0.3441**
-0.1879**	-0.0744	0.0273	-
0.0543	0.0725**	0.4559***	0.3265
-0.0154	0.0207	0.0086	0.0006
-0.0883	0.0389	0.6282***	0.5951**
-0.0088**	-0.0610	-0.1023**	-0.0826
0.0935*	-0.1381***	-0.0276	-0.0103
-0.001	0.0058	0.0098**	0.0128*
-0.0658***	0.0274	-0.0215	0.0078
0.0015***	0.0015**	0.0083	0.004
-0.1138	-0.2846	0.3057	0.2275
1.9979	1.8565***	-0.6204	-
Included	Included	Included	Included
0.1561	0.0173	0.0905	
0.2504	0.6700	0.0698	
0.1711	0.5300	0.0530	
50.2(55)	185.4(170)	102.9(89)	
0.66	0.2000	0.1500	
0.61	0.47	0.48	0.54
56	175	83	89
7	19	7	7

Note: The models in Table 19.1 and 19.2 are estimated with *System GMM*, except for the models m4 in Table 19.2, which is estimated with *xtlsdvc*. In all System GMM models, the variables *PPPgov_pay_gdp* and *PPPinvfa_gdp* are declared endogenous. The sample in Table 19.1 excludes Croatia, for which two extreme outliers in terms of *government expenditure volatility* were found (however, the results do not differ substantially).

This allows us to interpret more confidently the results in Table 19. For the whole sample, I find some evidence that higher investment in fixed assets under PPP (*PPPinvfa_gdp*), contemporaneously or lagged one year, may lower the volatility and uncertainty in government expenditure, as well as the volatility of the budget balance (no significance is found in the case of budget balance uncertainty). The results hold if I restrict the sample to the large PPP programs (total PPP investment exceeding one, two or three percent of GDP). Intuitively, this may be the case when public expenditure for investment works is very volatile, and by substituting part of it, higher investment under PPP reduces this volatility. However, the result may simply hide the impact of other institutional factors, which are not reflected in the variables I control for, and which changed over the period of our analysis (and, thus, were not eliminated through first differencing). Hence, countries with larger PPP investment programs may have had more stable administration and therefore have confronted less fiscal volatility.

Contrary to the above result, I find that higher payments to the government under PPP programs may increase government expenditure volatility. Corroborated with the impact on the budget balance from a previous sub-chapter, this result implies that higher payments to the government under PPP programs are likely to reduce the budget deficits, but potentially to induce more volatility in government expenditure given the one-off profile of most of such payments. The evidence is weaker (significant only at 10% level) for the whole sample, but stronger (at least 5% level) for the regional samples of Europe/Central Asia and especially East Asia/Pacific (see Table 19.2). East Asia and Pacific is the only region for which I find similar results with both *system GMM* and the

(preferred) *xtlsdvc* model. For the other regions shown in Table 19.2, including for our target group of Latin American (LA) countries, the PPP investment variables are not significant under the *xtlsdvc* models, which makes these results problematic.

As regards the other potential determinants of fiscal risk, I find that a higher *government budget deficit* in the previous year or a higher current *stock of public debt* is associated with more fiscal volatility and uncertainty in the current year. On the contrary, a *higher economic growth rate* is associated with lower fiscal volatility and uncertainty. Overall, our institutional and political system measures were not found significant; only corruption is shown since it proved to have a weak significant impact (at 10% level)—a lower level of corruption may be supportive for reducing the volatility in government expenditures.

To conclude, the analysis in this sub-chapter suggests that the evidence of the impact of PPP programs on fiscal volatility and uncertainty is mixed.

On the one hand, the simple inspection of the World Bank data shows that there is no great fiscal risk on average associated with PPP programs: a very limited number of PPP projects involve *explicit* government guarantees that could trigger fiscal risk (yet, this does not eliminate the risk associated with *implicit* PPP guarantees). The econometric analysis also shows that higher investment in fixed assets under PPP programs may actually contribute to reducing fiscal volatility and uncertainty.

On the other hand, although both purely private contracts and PPP-type contracts have confronted difficulties, relatively more PPPs have been canceled according to the World Bank PPI dataset. Such incidents are likely to be accompanied by government

bailout programs, such as Mexico's PPP program in the '80s, and increased fiscal volatility and uncertainty. Various technical papers and case studies also indicate that PPP programs may incur considerable fiscal risks, especially when the institutional framework is not properly in place and in times of financial and economic turmoil. In addition, the econometric analysis brings some evidence that payments to the government under PPP programs, despite contributing to lowering budget deficits in the future, may also induce more volatility in future government expenditure. This piece of evidence is found for the whole sample of developing countries, but it is particularly strong for the region of East Asia and Pacific, with some support also revealed for Europe and Central Asia.

IV.2 (5) Impact on GDP growth rate

In view of modeling the economic growth rate (annual growth rate of GDP per capita in purchasing power parity terms), I propose a typical convergence model (Barro and Sala-i-Martin 1990; 1992; Mankiw, Romer et al. 1992), expanded to incorporate an additional type of capital formation, that is, investment under PPP:

GDP growth rate = f(initial GDP/capita; PPP investment; Private capital formation, Public capital formation; Population growth rate; government tax burden; Institutional variables; common shocks and specific financial risk).

Hence, the annual growth rate of real GDP per capita is hypothesized to depend on (i) the initial level of GDP per capita (a negative statistically significant coefficient would be an indication of convergence in output per capita across the seven Latin-American economies for the period 1990-2001); (ii) the three types of investment: private,

public, and investment under PPP; (iii) the population growth rate; (iv) the government's tax burden; (iv) institutional factors, such as corruption, democracy, law and order; (v) common shocks and the financial risk index to capture the occurrence of financial crises.

I do not find evidence of a significant impact of PPP investment on economic growth in our restricted sample of seven Latin-American countries during the period 1990-2001.[41] However, aggregate private or public investment (as % of GDP) are not found significant either, pointing out to the fact that it may be difficult to unveil growth effects for a relatively short period of time. The most significant variable in explaining economic growth (rate of growth of real GDP per capita in period t+1 compared to period t) is the initial level of real GDP per capita (at time t). The negative coefficient across all FE models is a preliminary indication for a process of convergence in output per capita during the period 1990-2001 among the seven LA countries. None of the institutional and political economy variables was found robustly significant in determining economic growth (consequently, not shown in the tables).

In order to check for potential growth effects that may occur with long lags (and to increase precision of our estimates), I expand the model to incorporate public and private investment spending in infrastructure over the period 1980-2001, totals and disaggregated into five sectors: roads, railways, electricity, water, and telecommunications. These variables are from Calderon and Serven (2004) and represent actual investment spending; a large part of the private investment spending in each sector,

[41] I used a FE model and a dynamic bias-corrected LSDV model that incorporated the three types of aggregate investment (private, public and PPP). The investment variables turn insignificant in both models.

with the possible exception of telecommunications, is likely to fall under our definition of public-private partnerships.[42]

To mitigate the problem of endogeneity, particularly the reverse causation, I construct the dependent variable as the 5-year forward annual growth rate, that is, the moving average growth rate over a 5-year interval, covering the period 1985-2005, while all explanatory variables are measured at the starting point of each interval (i.e., yearly for the period 1980-2000). I thus increase significantly our sample size (from 84 maximum number of observations before to 147 observations in the extended time-dimension sample).

I first use aggregate measures for the explanatory variables, that is, total public and private *infrastructure* investment spending, and later I disaggregate them by sectoral components. I note that the shares of public and private fixed capital formation in GDP (i.e., incorporating all investment in the economy not only in infrastructure) are not found significant for growth in the extended sample either. However, when I replace them with the private, and respectively, the public rate of saving in GDP, I find a significantly positive impact of private saving on economic growth. While this is in line with the neoclassical growth model for a closed economy, it is still puzzling why only private saving and not private investment rates are found significant for growth in these countries.

The results with the aggregated measures are presented in Table 20 below: m1 is a fixed effects (FE) model; m2 is dynamic bias-corrected LSDV model, while m3 and m4

[42] I do not have information regarding the contractual details, but most of these contracts must involve both private and public participation (including partial divestiture, which I consider a type of PPP).

are 2-SLS (two stage-least squares) panel models with fixed effects (country dummy variables included), m4 estimated through GMM.

Table 20: Impact of investment spending in private infrastructure on economic growth

Variable	m1 FE	m2 xtlsdvc	m3 IV_2SLS	m4 IV_GMM
L1.GDPcap_growth_5yf	-	0.7193***	-	-
ln_GDPcap	-15.0913***	-6.5578***	-17.9848***	-18.1623***
infrs_public_gdp	-0.0824	0.0901	-0.4359	-0.1804
infrs_private_gdp	0.5551**	0.4840**	0.9290***	0.7911***
saving_public_gdp	0.0913*	-0.0503	0.0721	-0.0142
saving_private_gdp	0.1177***	0.0316	0.1100**	0.0852**
gov_tax_gdp	-0.0047	0.0111	-0.0051	0.0084
pop_growth	-0.1526	-0.3003	-1.2137**	-1.2137**
_cons	127.9755***	-	168.5415***	170.3936***
Country dummies (6)	(by default)	(by default)	Included	Included
Time dummies (20)	Included	Included	Included	Included
Goodness of fit measure				
R-square within	0.66	-	-	-
rho square	-	0.23	0.79	0.81
No. obs. (NT)	144	139	126	112
No. of groups (N)	7	7	7	7
Variables instrumented			Infrs_priv_gdp Saving_pub_gdp Saving_priv_gdp	Infrs_priv_gdp Saving_pub_gdp Saving_priv_gdp
Instruments			L(1/3)	L(1/5)
Instrument relevance test (Shea partial R2)				
Infrs_priv_gdp			0.41	0.48
Saving_pub_gdp			0.38	0.46
Saving_priv_gdp			0.55	0.60
Hansen J statistic (overidentification test of all instruments):				
chi2(d.f.)			4.997(6)	9.040(12)
p-value			0.5442	0.6995

Note: The dependent variable is *GDPcap_growth_5yf* (5-year forward moving average of the economic growth rate). *L1.GDPcap_growth_5yf* denotes the first lag of the dependent variable. The variables i*nfrs_public_gdp* and i*nfrs_private_gdp* denote the aggregate public and, respectively, private investment spending in infrastructure as % of GDP (variables from Calderon and Serven 2004). s*aving_public_gdp* and s*aving_private_gdp* denote the rate of national public, and respectively, private saving to GDP. The variable g*ov_tax_gdp* denotes the share of general government revenue as percent of GDP, used as a proxy for the tax burden on growth. *pop_growth* denotes the annual growth rate of population.
In models m3 and m4, the estimates are robust to heteroskedasticity and autocorrelation.

I am primarily interested in the impact on growth of the variable i*nfrs_private_gdp* (private investment spending in infrastructure as percent of GDP), the most closely associated with investment under PPP.[43] In the FE model, I find evidence that the aggregate private and public saving rate, as well as the private investment in infrastructure, are significantly and positively associated with future growth (the public saving rate is significant only at 90% confidence level). In the dynamic model m2, only private investment in infrastructure is significant in determining a higher growth rate.

In order to control more adequately for the impact of these variables on growth, and to avoid further problems of endogeneity, I instrument them through their lags (the first three lags in model m3 with IV, and the first five lags in model m4 with IV-GMM). Although I constructed the dependent variable as a 5-year forward lag, there is still a potential for reverse causation through positive autocorrelation. The estimates in m3 and m4 tackle this problem from two angles: first, by using instruments for the variables of interest (and which turn significant in the FE model), and second, by using statistics robust to arbitrary autocorrelation.[44]

When instrumented, the impact of the variable *infrs_private_gdp* on growth becomes higher (the point estimate increases from 0.55 in m2 to 0.8-0.9 in m3 and m4 and the significance rises (from 95% confidence level to 99%). On the contrary, the variable public saving loses its significance (previously significant at 90% confidence level), while private saving stays significant only at 95% level (versus 99% before) and its coefficient declines compared to m1, especially in m4.

[43] Especially in sectors like transportation and water, which will be analyzed later.
[44] See the command ivreg2 for estimates efficient for arbitrary autocorrelation and heteroskedasticity.

Overall, the conclusion from the models with aggregated data is that private investment in infrastructure proves to be significant in determining higher economic growth in the future. The variable remains robust across the models used, especially in the dynamic panel model, in which the two other related variables lose significance.

I now switch to disaggregated data on private and public investment spending in infrastructure, by looking at five sectors: roads, railways, electricity, water, and telecommunications. Table 21 shows the results employing the same models as above.

With disaggregated data, the only investment variable that proves significant and positive across all models (including in the dynamic LSDV model or when instrumented through its lags) is private investment in roads (*roads_priv*), the most likely to be predominantly undertaken under PPP projects. This may explain why, when private investment in roads is instrumented, public investment in the same sector becomes significantly negative, most likely capturing a substitution effect—if private investment under PPP boosted growth, and substituted public investment spending, then the subsequent decline in the later would be associated with higher GDP growth.

Another variable that proves fairly robust (it loses significance only in the dynamic model m2) is private investment in telecommunications (*telecom_priv*, also with a positive impact on growth), but this type of investment is usually undertaken under purely private contracts.

Table 21: Impact on economic growth of investment in private infrastructure by sector

Variable	m1 FE	m2 xtlsdvc	m3 IV_2SLS	m4 IV_GMM
L1.GDPcap_growth_5yf		0.7397***		
ln_GDPcap	-18.4180***	-8.0498***	-20.5031***	-21.9152***
roads_pub	-1.2229	0.7003	-1.8746**	-1.6259***
roads_priv	2.6146**	1.9826**	2.8301***	2.8035***
rail_pub	0.2002	0.5871	1.1537	2.4247***
rail_priv	0.7600	0.2684	-0.299	-4.3770***
electricity_pub	-0.0562	0.0511	-0.238	0.0494
electricity_priv	0.1042	0.1977	0.0847	-0.2756
water_pub	-0.0764	-1.4001	-2.974	-0.3662
water_priv	-0.8894	-1.0959	-0.98	-1.7725**
telecom_pub	0.0832	-0.2313	0	-0.9949**
telecom_priv	1.7385**	0.6097	2.7595***	2.5053***
saving_pub_gdp	0.1511**	-0.0311	0.0296	-0.0201
savings_priv_gdp	0.1625***	0.0456	0.098	0.0487
gov_tax_gdp	0.0048	0.0185	-0.0002	-0.0327
pop_growth	-0.1291	0.112	-0.4654	-0.6216**
_cons	155.9506***	-	190.5261***	205.7385***
Country dummies (6)	(by default)	(by default)	Included	Included
Time dummies (20)	Included	Included	Included	Included
Goodness of fit measure				
R-square within	0.69			
rho square	-	0.16	0.82	0.88
No. obs. (NT)	144	139	126	112
No. of groups (N)	7	7	7	7
Variables instrumented			roads_priv telecom_priv savings_pub savings_priv	roads_priv telecom_priv savings_pub savings_priv
Instruments			L(1/3)	L(1/5)
Instrument relevance test (Shea partial R2)				
roads_priv			0.64	0.64
telecom_priv			0.30	0.33
savings_pub			0.19	0.32
savings_priv			0.38	0.50
Hansen J statistic (overidentification test of all instruments):				
chi2(d.f.)			11.845(8)	21.262(16)
p-value			0.1582	0.1687

Note: The Models are the same as in Table 15. The investment spending variables are by sector (the sector name is shown as a prefix in the variable's name; _pub denotes public and _priv denotes private) and are all calculated as % of GDP. The other variables are the same as in table 20. In m3 and m4, the investment/saving variables that are instrumented are those found significant in the FE model (m1).

Overall, the conclusion from the growth models is that, over a sufficiently long period of time, private investment spending in infrastructure has had a positive impact on growth in Latin America. Across the disaggregated components, private investment in roads—mostly undertaken under PPP projects—proves to be the most important source for the additional boost in economic growth.

Another robust conclusion emerging from the growth models is that there has been a process of economic convergence among the seven Latin-American countries under study, as shown by the negative coefficient of the initial level of GDP per capita (the so-called β-convergence[45]).

IV.3 Conclusions

In this chapter, I have analyzed empirically *the determinants* of investment under PPP programs (and of the decision to invest under such programs), as well as *the impact* that PPP investment may have on the aggregate public and private investment, the government budget balance and its debt, fiscal risks, and the economic growth rate.

Before drawing our conclusions, several relevant clarifications need to be reiterated.

First, the data on investment under PPP, which I normalized in GDP terms, represent commitments, and not necessarily amounts effectively spent. Yet, such data are periodically revised by the World Bank to exclude amounts that are canceled, which makes me more confident in making the assumption that committed amounts will be

[45] The term β-convergence denotes a negative relationship between the growth rate of GDP per capita and the initial level of income per capita (see Barro 1991; Barro and Sala-i-Martin 1992; Sala-i-Martin 1996).

effectively spent. Even without making this loosely grounded assumption, the contractual commitment itself to invest in infrastructure projects under PPP is likely to reflect the investment behavior of both governments and their private partners. The issue becomes more problematic in terms of the impact of PPP investment; in this case, using lagged values of PPP investment, as done in the preceding chapter, is more likely to unveil the PPP impact on, let's say, fiscal variables.

Second, in order to determine more accurately the determinants and impact of *PPP* investment, I exclude purely private contracts—full privatization and merchant contracts—from the World Bank database of private investment in infrastructure used in this analysis.

Third, in terms of the impact of PPP investment, I use predominantly a restricted sample of Latin American countries, whose PPP programs are more developed than in the rest of the world. Most often, the impact found for these countries is not uncovered for the sample as a whole or is found only when I restrict the sample to those observations with large PPP projects. This means that generalizations are hard to make, but there are some lessons to be drawn for countries with large PPP programs.

Fourth, I look only at aggregate investment commitments in four infrastructure sectors: transportation, energy, water and sewerage, and telecommunication. While PPP investment in other sectors (e.g. provision of fixed assets in the health and education sectors) may also be important in some countries and help relieve the budget constraint, infrastructure is likely to represent the bulk of PPP investment.

As regards the determinants of investment under PPP, the following conclusions can be drawn. Several predictions of the theoretical model proposed in Chapter II are confirmed by the empirical analysis while the evidence for others is weaker or difficult to control empirically.

First, among our measures of risk and uncertainty, political risk proves to be the most robust among various specifications—countries with higher political risk tend to have smaller PPP investment programs relative to their GDP. When the disaggregated components of political risk are used, only the investment profile—denoting risks related to contract viability or expropriation—turns out to be highly statistically significant and robust. Two other measures seem to be significantly associated with the number of PPP infrastructure projects initiated in developing countries over the period 1990-2005. Thus, exchange rate uncertainty seems to entail the financial conclusion of fewer PPP projects, while higher uncertainty regarding public investment seems to induce more PPP projects, most likely accounting for a substitution effect between the two. Other measures of risk and uncertainty—the core of our theoretical model of (partly-) irreversible investment decision under uncertainty—do not prove to be robust in explaining investment under PPP projects. This may be explained in line with our two theoretical model extensions: the impact of risk on PPP investment may be ambiguous due to: (i) a potential for risk-sharing between the partners in a PPP; and/or (ii) the explicit or implicit put option that the private partner is likely to benefit at the expense of the public partner, i.e. that the latter may take over the contract obligations should economic or financial conditions deteriorate.

Second, I also find that a higher tax burden, up to a certain threshold, is likely to induce governments to engage in larger PPP programs. This means that the higher the existing tax burden (or by combination with the budget constraint, the higher the overall government spending), the more difficult governments find to further raise taxes to cover additional infrastructure spending. Instead, they are more likely to prefer the PPP investment alternative.

Third, another prediction of the theoretical model—that the nominal lending interest rate is likely to have a negative effect on PPP investment—is weakly confirmed by the empirical model in the whole sample (only with GLS models, and not the preferred Tobit models). It turns more robust in the restricted sample of Latin America and Caribbean (LAC) countries.

Fourth, among other significant determinants of PPP investment, it seems that experience with such programs is likely to induce more investment in the future.

Fifth, one of the most robust variables in explaining PPP investment and the frequency of undertaking PPP projects is the size of the market/economy. The larger a country's GDP, the larger the share of PPP investment in GDP, or the (absolute) count of PPP projects.

Sixth, I also find a strong evidence of complementarity with private investment. Aggregate private investment is positively related to PPP investment, i.e. the share of PPP investment in GDP grows when the share of private investment grows as well. Purely public investment does not seem to have a significant impact on PPP.

Finally, external aid is positively associated with PPP programs, possibly reflecting support from international financial institutions and other donors for infrastructure programs. The year dummies are highly statistically significant, capturing the lumpy nature of PPP committed investment. With respect to regional dummies, which capture regional fixed effects, the significance of some across various specifications, reflects a much more limited experience with PPP programs in the Middle East and Africa.

As regards the impact of investment under PPP, the following conclusions can be been drawn.

First, higher PPP investment is likely to raise the aggregate private investment. This partly reflects an accounting relation, that is, the fact that these commitments will be mostly reflected in the national accounts under private formation of gross capital. The evidence of double causation shows the high complementarity between the two: that PPP investment will grow in general when private investment grows (even after controlling for other factors, such as the economic growth rate). The relationship holds for the whole sample of developing countries, as well as for the benchmark sample of seven large Latin American (LA) countries: Argentina, Bolivia, Brazil, Chile, Colombia, Mexico and Peru. As regards the public capital formation, the relationship with PPP investment turns out to be more complex, tentatively pointing out to a substitution effect. Hence, for the whole sample, it appears that higher PPP investment is associated with lower purely public investment in the future. This may indicate that when deciding to expand the PPP investment programs, governments will replace part of the public infrastructure

investment with PPP. Yet, the relationship does not hold in the LA sample, despite preliminary evidence that several countries with the largest PPP programs (Argentina, Chile, Brazil) are also among the ones with the lowest share of public investment in GDP.

Second, larger PPP programs in the LA countries, especially through higher payments to the government, are likely to ease future fiscal positions, i.e. both the governments' budget balance and the public and publicly guaranteed debt. Such a relationship is weakened (for the public debt) or does not hold (for the budget balance) in the whole sample of developing countries, but there is some evidence that restricting the sample to large PPP programs tends to restore the positive impact of PPP programs on the fiscal stance.

Third, the empirical evidence on the role of PPP programs on fiscal risk is mixed. However, corroborated with the qualitative evidence from a review of other relevant studies, it leads to the conclusion that larger PPP programs may lead to higher fiscal risk, especially if compared to purely private infrastructure projects.

Finally, and possibly the most important goal for governments to undertake PPP investment programs, is their potential role for spurring economic growth. Given the relatively short period of time of up to sixteen years of our analysis, I do not find a significant impact of PPP investment on the economic growth rate, either in the LA sample or in the whole sample of developing countries. However, no significant impact is detected for the aggregate private or public investment either, which points out to difficulties in unveiling any significant result for a relatively short period of time. When I extend the sample period to 1980-2005, and use instead actual investment spending data

from Calderon and Serven (2004), I find that private investment in infrastructure has had, on average, a positive impact on growth in the LA countries under analysis. This impact has mainly originated from private investment in roads—a component undertaken mostly under PPP programs.

Chapter V - Conclusions, policy recommendations and areas for further research

This chapter contains the main conclusions from the theoretical model and the empirical analysis, outlines policy recommendations drawn based on the quantitative results, as well as the qualitative analysis from the literature review, and proposes areas for further research.

The contribution of the present dissertation to the literature on PPP is to propose a theoretical model of the decision to invest under a PPP contract and to test empirically both the determinants of such investment and its economic impact.

The proposed basic theoretical model, based on the theory of irreversible investment under uncertainty, concludes that the optimal decision to invest under a PPP depends negatively on the risk and uncertainty associated with the project, and the real cost of capital, while it could be facilitated when the government tax burden and the associated cost of taxation is high.

PPP arrangements have the potential for risk sharing: the basic theoretical model shows that when the two partners have equal shares in the investment objective function, then they will tend to share equally the benefits and the costs. With a benevolent social planner, the benefit from a PPP investment project will be the weighted average of consumer surplus and private firm revenue. The potential for risk sharing under a PPP

results also from a theoretical model extension in which the two partners are assumed to have different risk profiles. However, the overall risk of the project is shown to decrease with the covariance between the two individual risks, which acts as a proxy for risk sharing.

The private partner's decision to invest under a PPP may also be influenced by the possibility to exit the contract at a later stage should the economic and financial conditions deteriorate. This possibility can be offered explicitly or implicitly by the public partner through several types of PPP contractual arrangements (e.g. DBOT/BOT), government guarantees, contract-renegotiations, past or expected bailing out operations. A second extension of the dissertation's theoretical model captures this case through a put option at the disposal of the private sector in line with the theory of partly-irreversible investment under uncertainty. The existence of a put option may induce the private partner to undertake the investment more readily or in a larger amount even under a higher uncertainty. Corroborated with the findings of the basic model, this results in an ambiguous effect of uncertainty on investment.

The theoretical predictions of what determines the decision to invest under PPP programs, as well as the potential economic impact of PPP investment, are tested empirically using the World Bank database on private participation in infrastructure in developing countries for the period 1990-2005. This is the largest database of this kind, which uses a consistent methodology across countries and time to record investment commitments in four infrastructure sectors: transportation, energy, water and sewerage, and telecommunication.

As regards the determinants of investment under PPP, several predictions of the basic theoretical model are confirmed by the empirical analysis, while the evidence for the others is weaker or difficult to control for empirically (the latter especially for the results of the two model extensions).

First, among the employed measures of risk and uncertainty, political risk through its component of investment profile risk, proves to be the most robust among various specifications. Countries rated at risk in enforcing contract viability or resorting to investment expropriations tend to have smaller PPP investment programs relative to their GDP. Two other measures seem to be significantly associated with the number of PPP infrastructure projects initiated in developing countries over the period 1990-2005. Thus, exchange rate uncertainty seems to entail the financial conclusion of fewer PPP projects, while higher uncertainty regarding public investment seems to induce more PPP projects, most likely accounting for a substitution effect between the two. Other measures of risk and uncertainty—the core of the theoretical model of (partly-) irreversible investment decision under uncertainty—do not prove to be robust in explaining investment under PPP projects. This may be explained in line with the dissertation's theoretical model extensions. The impact of risk on PPP investment may be ambiguous due to: (i) a potential for risk-sharing between the partners in a PPP; and/or (ii) the explicit or implicit put option that the private partner is likely to benefit at the expense of the public partner, i.e. that the latter may take over the contract obligations should economic or financial conditions deteriorate.

Second, a higher tax burden, up to a certain threshold, is likely to induce governments to engage in larger PPP programs. This means that the higher the existing tax burden (or by combination with the budget constraint, the higher the overall government spending), the more difficult governments find to further raise taxes to cover for additional infrastructure spending. Instead, they are more likely to prefer the PPP investment alternative.

Third, another prediction of the theoretical model—that the nominal lending interest rate is likely to have a negative effect on PPP investment—is weakly confirmed by the empirical model in the whole sample. It turns more robust in the restricted sample of Latin America and Caribbean (LAC) countries.

Finally, the empirical analysis provides evidence of other significant determinants of PPP investment, that is: (i) the experience with such programs, which is likely to induce more investment in the future; (ii) the size of the market/economy—the larger a country's GDP, the larger the share of PPP investment in GDP, or the (absolute) count of PPP projects; (iii) complementarity with private investment—aggregate private investment is positively related to PPP investment, i.e. the share of PPP investment in GDP grows when the share of private investment grows as well; (iv) external aid—positively associated with PPP programs, possibly reflects support from international financial institutions and other donors for infrastructure programs; and (v) the year dummies, capturing the lumpy nature of PPP committed investment, and regional dummies, capturing regional fixed effects.

As regards the impact of investment under PPP, the analysis is focused on seven Latin American (LA) countries (Argentina, Bolivia, Brazil, Chile, Colombia, Mexico and Peru) that have implemented large PPP investment programs. Robustness across other regions or the whole sample of developing countries has also been checked, but generalizations can be made only in limited cases.

First, concerning the relationship with the other types of investment, complementarity with aggregate private investment is found for the whole sample of developing countries, as well as for the benchmark group of LA countries. The relationship between PPP investment and aggregate public investment turns out to be more complex, tentatively pointing out to a substitution effect. In general, there is some evidence that aggregate public and private investment tend to crowd-out each other in our sample of developing countries. Some indirect evidence for a substitution effect between aggregate public investment and PPP investment is that governments tend to implement fiscal restraint programs by cutting public investment and potentially encouraging more private participation in infrastructure. This seems to have been the case in the LA benchmark group for 1990-2001 and there is some evidence, albeit weaker, also for the whole group of developing countries.

Second, larger PPP programs in the LA countries, especially through higher payments to the government, are likely to ease future fiscal positions, i.e. both the governments' budget balance and the public and publicly guaranteed debt. Such a relationship is weakened (for the public debt) or does not hold (for the budget balance) in the whole sample of developing countries, but there is some evidence that restricting the

sample to large PPP programs tends to restore the positive impact of PPP programs on the fiscal stance.

Third, the evidence of the impact of PPP programs on fiscal risk, i.e. fiscal volatility and uncertainty, is mixed. However, corroborated with the qualitative evidence from a review of other relevant studies, it leads to the conclusion that larger PPP programs may lead to higher fiscal risk, especially if compared to purely private infrastructure projects. On the one hand, the simple inspection of the World Bank PPI database shows that there is no great fiscal risk on average associated with PPP programs: a very limited number of PPP projects involve *explicit* government guarantees that could trigger fiscal risk (yet, this does not eliminate the risk associated with *implicit* PPP guarantees). The econometric analysis also shows that higher investment in fixed assets under PPP programs may actually contribute to reducing fiscal volatility and uncertainty. On the other hand, although both purely private contracts and PPP-type contracts have confronted difficulties, relatively more PPPs have been canceled according to the World Bank PPI dataset. Such incidents are likely to be accompanied by government bailout programs, such as Mexico's PPP program in the '80s. Various technical papers and case studies also indicate that PPP programs may incur considerable fiscal risks, especially when the institutional framework is not properly in place and in times of financial and economic turmoil. In addition, the econometric analysis brings some evidence that payments to the government under PPP programs, despite contributing to lowering budget deficits in the future, may also induce more volatility in future government expenditure. This piece of evidence is found for the whole sample of developing

countries, but it is particularly strong for the region of East Asia and Pacific, with some support also revealed for Europe and Central Asia.

Finally, and possibly the most important goal for governments to undertake PPP investment programs, is their potential role for spurring economic growth. Such an impact is found for the benchmark sample of seven LA countries when the period is extended to 1980-2005 and data on actual private investment spending in infrastructure is used. The positive effect on growth seems to have originated mainly from private investment in roads—a component undertaken mostly under PPP programs.

Policy recommendations

The qualitative analysis based on the literature review, as well as the results of the theoretical and empirical models, indicate that while the experience with PPP in developing countries has been mixed, there is overall more evidence in favor of undertaking PPP investment.

Private participation in infrastructure can lead to higher efficiency in service provision, better quality[46] (especially if quality delivery standards are well specified by the responsible government agencies), and increased coverage (especially in case of government that confronted tight budget constraints and thus were unable to expand infrastructure investment). At a macroeconomic level, a part that has been investigated under the dissertation's empirical analysis, larger PPP programs in infrastructure may induce, on balance, higher fiscal risks for governments in developing countries through the attached explicit or implicit contingent liabilities. However, they may also contribute

[46] The quality vs. efficiency debate has been studied in the literature on private participation in infrastructure, but it is not the object of the empirical analysis in the present dissertation.

to improving fiscal positions in the future through higher upfront payments to the government or by substituting part of public investment. In several countries of Latin America, private investment in roads may have been a factor associated with higher economic growth since the mid-80s.

Taking into account the potential of PPP investment programs, several policy recommendations can be outlined based on the analysis in this dissertation:

First, PPP programs should be developed or expanded after a sufficient preparatory work has been done in terms of institutional building and regulatory framework. One of the main determinants of PPP investment in our sample of developing countries was found to be the investor's profile risk index, part of the larger political risk index. The conclusion from the empirical analysis was that countries at a lower risk in terms of contract enforcement, investment expropriation and nationalization tended to have larger PPP programs. Consequently, government should pay attention to improving investor's climate, ensuring a regulatory level-playing field, and avoiding opportunistic behavior towards their private partners (e.g. avoid contract infringement, for instance by breaching contractual clauses with respect to the agreed tariff increases, or retort to forced investment take-over etc.). In terms of institution building, an enforceable legal framework for PPP contracting and operations, as well as the establishment of an external department (e.g., a specialized PPP division in the Ministry of Finance), separate from the PPP implementation agency, should be prerequisites for starting or expanding PPP programs in infrastructure. As pointed out in Irwin (2003, 34), decision-making "should involve not only people who have an interest in the benefits (in achieving the

objective) but also those who have an interest in minimizing costs." This process implies an upfront (as well as sequential) investment in personnel training and institution building, and, if feasible, the diffusion of expertise from central to subnational governments. Although difficult, such a task should not be avoided, especially given that good practice in some countries (Chile, South Africa, the state of Victoria in Australia, U.K. etc.) can serve as instructive examples.

Second, as pointed out in the theoretical model, investment under a PPP contract may be a way to share risk between the two partners, and thus, possibly to mitigate the overall risk facing the project. At the same time, each party may attempt to act opportunistically and transfer risk to the other partner (the private partner by taking the put option offered by the government under the explicit or implicit government guarantees). In this respect, as indicated in the literature reviewed in the present dissertation, PPP contracting should be based on setting realistic objectives and sharing equitably the risks between the two partners. This means that each partner should take over the risks that it can better control and should not attempt to maximize the transfer of risk to the other partner. To this end, the government needs to design a clear and comprehensive tender specification for the PPP project to permit the selection of a well-experienced constructor-operator with adequate financial backing and good track record. Clear quality standards and penalties for quality shortfalls need be stipulated in the contract and the private partner required to provide insurance-backed guarantees for project completion. The contract needs also to clearly specify ex-ante the trigger clauses for renegotiation in case the profitability of the project is affected by events under the

control of the government, such as changes in the legislative and regulatory framework; exchange rate regime; or major economic policy changes.

Third, PPPs have the potential to offer governments an approach for alleviating fiscal constraints associated with the provision or improvement of infrastructure. Private funds can thus be used to narrow the financing gap that exists in many countries between infrastructure needs and available public funds. In this way, PPPs may promote infrastructure development and spur economic growth, particularly when fiscal policy alone has limited scope for action due to tight budget constraints and weak fiscal stance. However, the complexity of PPP projects, the lack of standards regarding their fiscal accounting and reporting, corrupt practices, and often insufficient institutional capacity for such complex tasks, can trigger additional *fiscal variability* compared to traditional financing or full privatization. Such risks are more likely to arise when the regulatory and fiscal institutional frameworks are weak, and accounting and reporting systems do not transparently disclose the fiscal implications of PPPs.

More transparency in PPP operations as a first step, followed by sound budget programming rules as a second step, should help contain negative fiscal surprises. This would require governments to include reports on PPP status in their budget documents (as partly done in Hungary and the U.K.), to be made available to both legislators and the wider public, and start valuing contingent liabilities in view of capturing at least some of their potential fiscal impact. Corbacho and Schwartz (2008) and Irwin (2003) provide the examples of Chile and Colombia (and most recently the preparatory work that is done in Peru) to value contingent liabilities using option methods and Monte-Carlo simulations.

Such actions would "force" the government to consider more seriously the future cost of PPP projects to the taxpayer, and limit the scope of fiscal opportunism. Yet, they also require strong political will and usually broad coalition support.

Until international norms for PPP accounting and reporting are approved, existing international accounting standards should be used more extensively. For instance, Australian governments report according to locally modified International Financial Reporting Standards (IFRS) that, although not providing explicit norms for PPP, tend to require government recognition of liabilities for at least some PPP projects (Irwin 2008).

In extending public funds to private partners, such as in greenfield projects, which are likely to give rise to higher risks due to the novelty of operation, governments should consider strict limits to such payments, to contain the potential for moral hazard and opportunistic behavior from the private partner. Fixed availability payments or subsidies at the beginning of the operating period, strictly limited to a certain period and amount, should be considered first. As pointed out in Brixi and Schick (2002), budgetary subsidies or direct government loans would sometimes be more effective and less expensive than extending government guarantees.

Fourth, a factor that in the empirical analysis proved to be robustly associated with PPP investment and the number of PPP projects was foreign aid. This association may reveal the fact that part of the foreign aid, possibly from international financial institutions (IFIs), is directed to infrastructure building. Part of it may also reflect technical assistance from IFIs for institutional-building related to PPP programs. Governments in developing countries should try to tap to the extent possible such

technical assistance and benefit from IFI's cross-country expertise with PPP program development.

Areas for further research

Several areas of the empirical analysis may be expanded especially if some data shortcoming may be corrected and availability improved.

First, and primordially with respect to the impact of PPP investment, the present dissertation covers only PPP in infrastructure, and specifically the transportation, energy, water and sewerage, and telecom sectors. While PPP investment in other sectors (e.g. provision of fixed assets in the health and education sectors) may also be important in some countries (e.g. help relieve the budget constraint or promote economic growth), infrastructure is likely to represent the bulk of PPP investment. Expanding sectoral coverage could be the subject of further work, especially if the analysis is extended to developed countries (where such programs are more frequent, as examplified by the UK's PFI infrastructure projects in health and education).

Second, and related to the above, the dissertation has focused on the empirical determinants and the impact of PPP investment in developing countries, mainly taking advantage of the comprehensive and consistent methodology in data collection by the World Bank PPI Initiative.[47] Further work could focus on a separate analysis for the developed economies provided data is consistently collected and processed according to a common methodology.

[47] In the empirical analysis on the determinants and impact of *PPP* investment, I exclude purely private contracts—full privatization and merchant contracts—from the World Bank database of private investment in infrastructure.

Third, a shortcoming of our data, especially with respect to the *impact* of PPP investment, is that it refers to commitments and not necessarily amounts effectively spent. Yet, such data are periodically revised by the World Bank to exclude amount that are canceled, which provides more confidence in making the assumption that committed amounts will be effectively spent. Even without making this assumption, the contractual commitment itself to invest in infrastructure projects under PPP may be what triggers the future behavior of both governments and their private partners. In addition, using lagged values of PPP commitments (as done in the empirical analysis) is more likely to unveil the PPP impact on current economic variables. Yet, research into the efficiency of implementation, especially the potential for corruption that siphons off money or compromises design/quality, as well as ways to deal with it, are likely to be among the most important areas of future research.

Appendix to Chapter I

A discussion of fiscal risks associated with PPP programs

All infrastructure projects, irrespective of their ownership structure and financing, face common risks during the lifetime of the project. These risks can be classified according to the phase of the project lifetime (see Aoust, Bennett et al. 2000) as: (i) risks arising during the design-construction phase, such as technical risks, availability risk, economic and financial risks (interest rate, exchange rate, inflation risk); (ii) operational risks, such as demand risks, as well as economic and financial risks, and (iii) permanent or indirect risk, that is, risk of force majeure, environmental risk, macroeconomic risk, general legal and institutional related risk, etc.

I hereby focus on fiscal risks, or PPP-related risks that could add additional burden or induce more volatility to the government fiscal stance. I classify fiscal risks into two sub-categories: contingent liability risk and fiscal investment risk.

Contingent liability risk is the variability in fiscal expenditure induced by future uncertain events, most frequently encountered under the use of government guarantees. It is an indirect risk, with the fiscal variability being triggered by factors related to the project to which the guarantee is extended. According to the IMF (2006), guarantees are a common feature of PPP contracts worldwide. Traditional procurement, on the other hand, involves full government payment for asset construction, that is, direct liabilities recorded in the budget and public debt. Due to the fact that the private partner finances (at least

partly) the asset construction and operation under a PPP, it is arguably easier for the government to justify moving public investment off the budget, and public debt off the government balance sheet, in spite of continuing to bear explicit or implicit fiscal risk. Moreover, the *partnership* behind this type of arrangement could, in principle, justify provision of government guarantees more easily than with fully private contracts.

In addition to explicit government liabilities—those agreed ex-ante in contractual forms between the government and the private partner—implicit guarantees (without an agreed contractual obligation) are also likely to give rise to fiscal risks. Bail-out expectations may be compounded by the notion that the government has to serve as a "provider of last resort" to maintain service delivery, at least for essential public services (see Levin 1999; Rosenau 1999; Edwards and Shaoul 2003). For example, the large bail out of road concession projects in Mexico in the early 1990s should serve as a reminder for governments to be prudent in respect to implicit fiscal guarantees. The difficulties that the toll road concessions had already confronted since late 1980s were exacerbated by the 1994 currency crisis in Mexico. The government decided to bail out the projects when interest rates rose more than 100 percent a year for most projects. New toll-road financings (e.g. Tepic-Guadalajara) were canceled at the last minute because of the onset of the crisis (Ruster 1997). According to the World Bank PPI dataset, out of 37 projects with private participation concluded in Mexico during 1990-1995 (25 BOT, 10 concessions, and 2 management and lease contracts), 16 projects (14 BOT and 2 concessions) were canceled (private partner exited the contract).

In the late 1990s, after the East Asian financial crisis, government debt in Malaysia, Thailand, Indonesia, and as far away as in Pakistan, increased substantially after unexpected defaults on government guarantees issued to promote private participation in infrastructure added to the overall fiscal stress (Brixi and Schick 2002; Mody 2002).

Several papers discuss the possibility of PPPs being used to circumvent budget and debt rules despite the government bearing most of the risk. (Engel, Fischer et al. 2006b). Government planners should remember that PPP contracts in public infrastructure are still a tool of fiscal policy and have an impact on aggregate demand. With or without contingent liabilities attached, PPPs can complicate the management of fiscal policy as a macro-stabilization tool. For instance, under conditions of high aggregate demand, high capital inflows, and inflationary pressures, shifting traditional capital expenditure from the public to the private sector (and thereby reducing the budget deficit) could compound domestic demand pressures, while creating the (misleading) impression of stabilizing fiscal policy. Domestic demand pressures could even intensify if current expenditures are substituted in the budget for capital expenditures.

Fiscal risks and budget management can be complicated by contingent liabilities due to transparency problems, which arise from lack of fiscal accounting and reporting standards. As pointed out in Bloomfield (2006), such concerns can arise not only from poor fiscal regulations and enforcement, but also from intricacies of the *innovative* methods of financing used in long-term PPPs. For instance, Bloomfield (2006) provides examples of PPPs in the U.S. public utilities sector (e.g., water) that have confronted

serious legal and fiscal problems resulting from deregulation and lack of transparency. Innovative PPP financing and contracting at local government levels have sometimes been found incompatible with municipal procurement laws, thus benefiting from waivers on competitive tender, and/or bypassing public debt monitoring and other fiscal transparency requirements.

Fiscal investment or fiscal management risk. Concessions of road infrastructure can provide large up-front funding for the government, as shown by the recent U.S. experience with the Chicago Skyway and Indiana Toll Road. Even if amounts are less spectacular than in these projects, the way the money is allocated and spent can induce variability, and thus risk, in the financial position of both the government and the concessionaire. Large up-front payments from the private partner to the government can have two impacts on government debt ratings. In principle, a prevalent impact, stemming from the time value of money—a dollar received today is worth more than a dollar tomorrow— would be an upgrading of the government fiscal position and risk outlook. However, there is a need to match investment decisions made today with long-term sustainability of public infrastructure, especially in the case of public transportation systems (the government will not receive any revenues from the project during the entire duration of the concession). If this matching is not achieved, then this type of arrangement is likely to have a negative impact on the government's risk assessment. Fitch Ratings, for instance, considers the choice of high up-front payments as a risk to the government's fiscal position, as it may limit its flexibility to meet future transportation needs. Yet, Fitch positively assesses arrangements that generate large up-front payments

"if proceeds are invested in comparable long-term assets that provide lasting economic benefits" (Fitch Ratings March 2006, 4). Conversely, it will view negatively "the use of proceeds for short-term operating needs of the government" (March 2006, 4). The credit ratings assigned to government debt and to the project, itself, can influence financial parameters in case of refinancing.

Appendices to Chapter II

AII.1. Summary of other strands of literature on aggregate investment

As mentioned in Chapter II.2, given that most PPP arrangements refer to the provision of capital goods, investment theory is an important area for the set-up of a macroeconomic model incorporating PPP characteristics. This Appendix reviews the theoretical investment literature that preceded the theory of investment under uncertainty[48]. It emphasizes the private sector decision to invest.

Historically, the economic literature has focused primarily on explaining the determinants of private investment and its role for capital accumulation and long-term economic growth. Alternatively, macroeconomic models have incorporated total investment in the equation of aggregate demand to study the impact on short-term stabilization and output.

According to some authors[49], ***Keynes (1936)*** was the "first [to] call attention to the existence of an independent investment decision in the economy […]". In the "General Theory," Keynes referred specifically to the decision of private entrepreneurs to accumulate capital, which depended on the expected "marginal efficiency of capital" (the "investment demand schedule") relative to the "current rate of interest" (reflecting the supply of loanable funds). Although less acknowledged, Keynes pointed out the importance of uncertainty and expectations in determining investment decisions. "The

[48] This section expands on reviews by Fisher (1953) and Serven and Solimano (1993).
[49] Serven and Solimano (1993, pg 12).

marginal efficiency of capital is here defined in terms of the *expectations* of yield and of the *current* supply price of the capital asset. It depends on the rate of return expected to be obtainable on money if it were invested in a *newly* produced asset; not on the historical result of what an investment has yielded on its original cost […]" (italics in original).[50] However, as pointed out in a 1953 review of the treatment of investment in macroeconomic models (Fisher 1953), in the simplified formal Keynesian models investment was broadly considered exogenous.

After Keynes, the evolution of investment theory was linked to simple macroeconomic models, mainly based on the ***accelerator theory*** (Serven and Solimano 1993). Fisher (1953) reviews the early development of endogenous models of investment, such as Samuelson (1939), Hicks (1950) and Klein (1950), which considered aggregate real investment at time t (I_t) to be induced by the *change* (sometimes by the *level*) of aggregate real output ($Y_{t/t-1}$) or other variable, such as consumption ($C_{t/t-1}$), through an "accelerator coefficient" (β):

change-induced investment: $I_t = \beta (Y_{t-1} - Y_{t-2})$ [1]

$I_t = \beta (C_t - C_{t-1})$ [2], or

level-induced investment: $I_t = \beta_1 Y_{t-1} + \beta_2 Y_{t-2}$ [3],

where β is the accelerator coefficient (Fisher 1953).

The accelerator theory, making investment a linear proportion of the change in output, was popular due to its simplicity, but ignored forward-looking expectations (or assumed that the future is behaving like the past) and the price of capital.

[50] "The inducement to invest depends partly on the investment demand schedule and partly on the rate of interest" (Keynes 1936, pg. 137).

The neoclassical theory of optimal capital was used by Jorgenson (1963) and Hall and Jorgenson (1971) to derive and test empirically a model of behavioral investment that depended on the level of output and the user cost or rental cost of capital (determined as a combination of the real interest rate and depreciation). The optimal capital stock (K*) is that level of K, which maximizes net worth (the integral of discounted net revenue), subject to a standard neoclassical production function and the motion law of capital.

$K^* = \gamma \frac{pQ}{c}$, where pQ is the nominal output (in a Cobb-Douglas production function), γ is the output elasticity with respect to capital, and c is the price or user cost of capital (derived from the optimization as a combination of the real interest rate and depreciation)

After K* is determined, investment (I) is derived from the motion law of capital as:

$I = w(L)[K^*_t - K^*_{t-1}] + \delta K_t$, where w(L) is the proportion of projects completed, L a lag operator, K* is the optimal or desired capital stock and K is the actual capital stock, δ is the depreciation rate (Jorgenson 1963; Hall and Jorgenson 1967).

The neoclassical model has been criticized on the grounds of its assumption of fixed or static expectations about prices (in Jorgenson (1963) model, all prices, including the interest rate, are taken as fixed), taken as inappropriate for essentially forward-looking investment decisions (Serven and Solimano 1993).

Tobin's q model (1969) posits that "the rate of investment – the speed at which investors wish to increase the capital stock – should be related, if anything, to q, the value of capital relative to its replacement cost" (Tobin 1969, pg. 21).

Tobin's q is usually interpreted as a *marginal* rate - the ratio between the increase in the value of a firm as a result of the installation of *an additional unit* of capital (the stock market valuation of such an additional unit), and its replacement cost (the acquisition price of the capital good). In a simplified version (e.g. the textbook model presented in Blanchard, 2003) and in empirical studies, the *average* q is taken to matter for investment decision, i.e. the relationship between the market value of one unit of capital *already in place* and the purchase price of an additional unit of capital. Hence, a firm will invest as long as its stock price (an indicator for the firm of how much the market values each unit of capital already in place) exceeds the purchasing price of an additional unit of capital.

Using U.S. data[51], changes in the average "q" lagged one year were found to follow very closely changes in current investment (Blanchard 2003). At firm level, studies such as Leahy and Whited (1996) and Bulan (2005) find that Tobin-q is positive and statistically significant in investment regressions (although its economic effect is found to be lower than some measures of uncertainty). Some studies find that Tobin's q exhibit only low explanatory power, but others reviewed in Bulan (2005) have sought to explain such results as either measurement error in the q variable, or non-linearity of the investment function.

The calculation of Tobin-q as an average, and not as a marginal value, is found to be problematic for several reasons: (i) marginal q and average q will systematically differ

[51] Blanchard (2003) presents the steps in calculating Tobin-q: (1) Calculate the total value of U.S. corporations as assessed by financial markets, i.e. the sum of the stock market value plus the total value of bond outstanding; (2) Calculate the value of the capital stock of U.S. corporations at replacement cost; (3) Divide the two variables, which gives the (average) Tobin-q.

if firms enjoy economies of scale or market power; (ii) the assumption of increasing marginal installation costs underlying the theory may not be appropriate given that many investments are done in stages, and once a basic structure was established, it may be cheaper to install additional capital; (iii) adding or removing one unit of capital may not have the same cost; sometimes, disinvestment is more costly than positive investment, due to the partly or completely irreversible nature of investment (Serven and Solimano 1993).

The shadow price of existing capital goods as given by the stock market (numerator in the average q) is equivalent, under rational expectations, to total future discounted profits, plus the residual value. Hence, investment is taken to depend positively on the expected present value of future profits per unit of capital (Π_t^e), which in turn depends negatively on the rental cost of capital (the sum of the real interest rate and the depreciate rate) (Blanchard 2003).

$I_t = I\ (\Pi_t^e(r_t + \delta))$

Blanchard points out that one striking empirical fact about changes in investment is that it follows very closely the fluctuations in *current* profit (e.g. the case of the U.S. data series for 1960-2000). Although the theory predicts that both current profits and investment are correlated with future expected profits, some economists[52] found that current profits (Π_t) appeared to affect investment even after controlling for measures of expected present values of profits, so that the above equation can be rewritten as:

[52] Lamont (1997) studied the response of investment to changes in profitability (the expected present value of profits) and cash flows (taken as a proxy for the current profit). His approach in isolating the effects of the two factors was to identify the times when cash flows and profitability moved in different directions and see what happened then with investment. He found that current cash flow matters in the investment decision (based on Blanchard, 2003).

$I_t = I\ (\Pi_t^e(r_t + \delta),\ \Pi_t)$

The fact that investors seem to give a sizable weight in their decisions to short-term profitability and, ultimately, short-term output fluctuation, led many authors to question the validity of forward-looking rational expectations, and bring-in the hypothesis of ***myopic investors, within the framework of behavioral economics and finance.*** Starting from the concept of bounded rationality, introduced by Herbert Simon in the mid-1950s[53], a large body of literature has focused on the cognitive processes of choice (e.g. choice to invest) and the limits not only to agents' access to information, but also to their attention to information. The role of attention allocation in finance, suggesting that individuals may simplify complex decisions by neglecting long-term information was found in works by Huberman and Regev (2001), Barber and Odean (2005), DellaVigna and Pollet (2005), etc. Although this literature refers primarily to individual investors' financial decisions, it is also of some relevance for real investment decisions, especially in the context of the Tobin-q theory, which links real investment with capital markets.

[53] Simon (1948) "Administrative behavior; a study of decision-making processes in administrative organization", and subsequent editions. The ideas of choice simplification by not taking into account all available alternatives, and of environment adaptation in decision making were developed in (Simon 1955) and (Simon 1956).

AII.2. Derivation of the basic model based on Dixit and Pindyck (1994)

- Maximize the expected payoff from investing:
  $F(Y) = max\ E\ [(V_T(Y, Q) - I)\ e^{-\rho T}]$, *Q is given* $(Q=\overline{Q})$
  subject to $dY = \alpha Y dt + \sigma Y dz$
  Let $\delta = \rho - \alpha$, where $\delta>0$

- The Bellman equation of dynamic programming:
  $\rho F(Q, Y)dt = E[dF(Q, Y)]$.

  The optimization problem can be solved using dynamic programming: the agent breaks the decision into the immediate future and a continuation period. Because the investment opportunity yields no payoff flow until the time T when the investment I is made, the Bellman fundamental equation of dynamic programming can be written as above.
  In contingent claims terminology, this means that (absent a dividend) the total return on the investment opportunity over a time interval dt—$\rho F(Q, Y)dt$—must equal in equilibrium the expected capital gain—$E[dF(Q, Y)]$.
  The part F(Q) is deterministic, is decided by the agent based on current information. I assume that the agent has already decided on quantity Q so that $F(Q, Y) = F(\overline{Q}, Y) = F(Y)$. In short, the Belllman equation can be written: $\rho F = (1/dt)E(dF)$

- I use Ito's Lemma to obtain an expression for dF(Y), given that Y~geometrical Brownian motion (gbm)
  $\boldsymbol{dF = F_Y dY + \frac{1}{2} F_{YY}(dY)^2}$
  Substitute dY into the above equation => $dF = F_Y(\alpha Y dt + \sigma Y dz) + \frac{1}{2} F_{YY}(\alpha Y dt + \sigma Y dz)^2$
  Taking into account that the mean of the Wiener process is zero E(dz) = 0; $dz^2 = dt$, and all dt terms at power larger than 1 vanish more quickly than dt when dt -> 0 =>
  $E(dF) = \alpha F_Y Y dt + \frac{1}{2} F_{YY} \sigma^2 Y^2 dt$

- Substituting for E(dF), the Bellman equation becomes:
  $\rho F = \alpha F_Y Y + \frac{1}{2} F_{YY} \sigma^2 Y^2$ *(the time derivative is netted out)* ⇔
  $\frac{1}{2} \sigma^2 F_{YY} Y^2 + \alpha F_Y Y - \rho F = 0$; $\alpha = \rho - \delta$
  Therefore, the Bellman equation becomes the following differential equation that must be satisfied by F(Y):
  $\boldsymbol{\frac{1}{2} \sigma^2 Y^2 F_{YY} + (\rho - \delta) Y F_Y - \rho F = 0}$

- In addition, F(Y) must satisfy simultaneously three ***boundary conditions***, where the boundary (given by Y*) separates the two regimes: (i) waiting and keeping the option to invest F(Y*), and (ii) investing and thus obtaining the value of the project V(Q,Y*) and paying I.
  (1) F(0)=0 *(if Y ->0, it will stay at 0 and the option to invest has no value)*
  (2) F(Y*) = V(Q, Y*) - I

Condition 2 is the value-matching condition that "matches" the two regimes, or equalizes the two functions in Y, at the boundary. It means that upon investing, the payoff from the option will be V(Q, Y*) – I. Equivalently, the optimal value of the project V(Q, Y*) equals the full cost of investing at present—the direct cost I and the opportunity cost of investing or the value of waiting F(Y*).

(3) $F_Y(Y^*) = V_Y(Q, Y^*)$

Condition 3 is the "smooth-pasting" condition, which requires that the two functions meet tangentially at Y*, i.e. the derivatives of the two functions, F(Y) and V(Q, Y) – I =YV(Q) – I, with respect to Y are equal when evaluated at Y*. As explained in Dixit and Pindyck (1994), in investment terminology, this condition implies that the transition to the new regime has to be continuous and smooth at the critical point Y*, otherwise an investor could do better by exercising it at a different point.

- To find F(V), I must solve the Bellman equation subject to the boundary conditions.
  - To satisfy condition (1), the solution must take the form: $\boldsymbol{F(Y) = AY^{\beta 1}}$, where A is a constant to be determined and β1>1 is a known constant that depends on the values of parameters σ, ρ, δ of the differential equation
  - The remaining two conditions can be used to solve for A and Y*
    $AY^{*\beta 1} = V(Q, Y^*) - I$ (2) and $A\beta_1 Y^{\beta 1 - 1} = V_Y(Q, Y^*)$ (3).
  - Hence, the trigger value Y* is given by the relation:
    $\boldsymbol{\beta_1 V(Q, Y^*) - Y^* V_Y(Q, Y^*) = \beta_1 I}$

    As I assumed that the value of the payoff (our basic objective function) is a linear function of the shift variable Y (V=YV(Q)), the optimality condition simplifies to:

    $\beta_1 Y^* V(Q) - Y^* V(Q) = \beta_1 I \Leftrightarrow Y^* V(Q) = \frac{\beta_1}{\beta_1 - 1} I$ **(AR1)**

    From condition (3) and result R1 => $A = 1/(\beta_1 Y^{\beta 1 - 1}) = \frac{(\beta_1 - 1)^{\beta_1 - 1}}{\beta_1^{\beta_1} I^{\beta_1 - 1}}$
  - Therefore, the agent will invest when the random shift variable hits the optimal value Y* and the project payoff exceeds the investment cost I by a wedge factor $w = \frac{\beta_1}{\beta_1 - 1} > 1$
  - The wedge factor w is a decreasing and convex function of β_1
    $dw/d\beta_1 = -1/(\beta_1 - 1)^2 < 0$ for any β_1 and $d^2V/d\beta_1^2 = 2/(\beta 1 - 1)^3 > 0$ given that $\beta_1 > 1$.

- To determine the value of β_1, I return to the Bellman equation:
  $\frac{1}{2}\sigma^2 Y^2 F_{YY} + (\rho - \delta) Y F_Y - \rho F == 0$
  - $F_Y(Y) = A\beta Y^{\beta - 1}$
  - $F_{YY}(V) = A\beta(\beta - 1) Y^{\beta - 2}$

  $\Leftrightarrow$ $\frac{1}{2} A\beta(\beta - 1)\sigma^2 Y^\beta + (\rho - \delta) A\beta Y^\beta - \rho A Y^\beta = 0 \mid A Y^\beta$

  $\Leftrightarrow$ $\frac{1}{2}\sigma^2\beta(\beta - 1) + (\rho - \delta)\beta - \rho = 0$ $\Leftrightarrow$ *a quadratic equation in β = the fundamental quadratic (convex function, $\frac{1}{2}\sigma^2 > 0$)*

$\Leftrightarrow$ *½ $\sigma^2\beta^2$ + ($\rho - \delta$ − ½ σ^2) β - ρ = 0*

- *The fundamental quadratic has the following roots:*

$$\beta_1 = \frac{1}{2} - \frac{\rho-\delta}{\sigma^2} + \sqrt{\left(\frac{\rho-\delta}{\sigma^2} - \frac{1}{2}\right)^2 + 2\frac{\rho}{\sigma^2}} > 1$$

$$\beta_2 = \frac{1}{2} - \frac{\rho-\delta}{\sigma^2} - \sqrt{\left(\frac{\rho-\delta}{\sigma^2} - \frac{1}{2}\right)^2 + 2\frac{\rho}{\sigma^2}} < 0$$

Going one step back to the general solution, the Bellman equation could be written:
$F(V) = A_1 Y^{\beta 1} + A_2 Y^{\beta 2}$
However, in our case, the boundary condition 1, F(0) = 0, implies that A_2 has to be 0 (β_2 is negative, so Y must have been different from zero, otherwise, at zero, the option value would be infinite) $\Leftrightarrow$

$F(Y) = AY^{\beta 1}$ and $Y^*V = \frac{\beta_1}{\beta_1 - 1} I$, where $\beta_1 = \frac{1}{2} - \frac{\rho-\delta}{\sigma^2} + \sqrt{\left(\frac{\rho-\delta}{\sigma^2} - \frac{1}{2}\right)^2 + 2\frac{\rho}{\sigma^2}} > 1$

Next, I show the impact of changes in parameters on β_1, and implicitly, on the wedge factor and on the optimal payoff (the maximized basic objective function), Y*V.

- ***β_1 is a decreasing function of σ,*** $\frac{\partial \beta_1}{\partial \sigma} < 0 \Leftrightarrow \frac{\partial w}{\partial \sigma} > 0$ **(AR2)**

Impact of uncertainty (σ): *An increase in the uncertainty over future values of Y determines a decrease of β_1 $\Leftrightarrow$ an increase in the wedge w $\Leftrightarrow$ an increase in Y*V for a given I (higher level of future payoff required to undertake the investment).*

- *Either show $\frac{\partial \beta_1}{\partial \sigma} < 0$ directly or indirectly by getting the total differential of the fundamental quadratic function (noted Qf)*
  $Qf(\beta_1) = 0 \mid d \Leftrightarrow dQf(\beta_1(\sigma)) = 0$

$$dQf(\beta_1, \sigma) = \frac{\partial Qf}{\partial \beta_1} d\beta_1 + \frac{\partial Qf}{\partial \sigma} d\sigma = \frac{\partial Qf}{\partial \beta_1}\frac{\partial \beta_1}{\partial \sigma} + \frac{\partial Qf}{\partial \sigma} = 0$$

($d\sigma = 1 = \frac{\partial \sigma}{\partial \sigma}$, σ does not depend on other variable)

$\frac{\partial Qf}{\partial \sigma} = \sigma\beta(\beta-1) > 0$ for $\beta > 1$; $\frac{\partial Qf}{\partial \beta_1} > 0$ the larger root is in the increasing part of the convex function => $\frac{\partial \beta_1}{\partial \sigma}$ must be <0

- ***β_1 is a decreasing function of ρ (μ, the total discount rate)*** $\frac{\partial \beta_1}{\partial \rho} < 0 \Leftrightarrow \frac{\partial w}{\partial \rho} > 0$

= the same proof with $\frac{\partial Qf}{\partial \rho} = \beta_1 - 1 > 0$ **(AR3)**

- ***β_1 is an increasing function of δ*** *(the difference between the total discount rate and the expected growth rate of the project payoff V)* $\frac{\partial \beta_1}{\partial \delta} > 0 \Leftrightarrow \frac{\partial w}{\partial \delta} < 0$

= the same proof with $\frac{\partial Qf}{\partial \delta} = -\beta_1 < 0$ **(AR4)**

AII.3. Technical details for Extension 1 of the theoretical model

The Bellman equation for correlated geometrical motions:

$dY_G = \alpha_G Y_G dt + \sigma_G Y_G dz_G$; $z_G \sim$ Wiener process
$dY_P = \alpha_P Y_P dt + \sigma_P Y_P dz_P$; $z_P \sim$ Wiener process
$E(dz^2_{P;G}) = dt$ (variances of an increment of each Wiener processes)
$E(dz_{P;} dz_G) = \varphi dt$ (correlated Wiener processes are correlated and the covariance is ηdt, where φ is the coefficient of correlation, $0 < \varphi < 1$).

The Bellman equation:
$\rho F(Y_{P;} Y_G) = E[dF(Y_{P;} Y_G)]$

Expanding using Ito's lemma $\Leftrightarrow dF = dY_G F'_G + dY_P F'_P + ½(dY_G)^2 F''_{GG} + ½(dY_P)^2 F''_{PP} + ½ d Y_G dY_P F''_{GP} + ½ d Y_G dY_P F''_{PG}$,

Taking into account that $E(dz) = 0$; $dz^2 = dt$, $dz_G dz_P = \varphi dt$, $F''_{GP} = F''_{PG}$, and all dt terms at power larger than 1 vanish more quickly than dt when $dt \to 0$ =>

$E[dF(Y_{P;} Y_G)] = (½ \sigma^2_G Y^2_G F''_{GG} + ½ \sigma^2_P Y^2_P F''_{PP} + \varphi \sigma_G \sigma_P Y_G Y_P F''_{GP} + \alpha_G Y_G F'_G + \alpha_P Y_P F'_P)dt$ $\Leftrightarrow$ The Bellman equation becomes:
$½ \sigma^2_G Y^2_G F''_{GG} + ½ \sigma^2_P Y^2_P F''_{PP} + \varphi \sigma_G \sigma_P Y_G Y_P F''_{GP} + \alpha_G Y_G F'_G + \alpha_P Y_P F'_P - \rho F = 0$

AII.4. Technical details for Extension 2 of the theoretical model

The derivation of the model of partial irreversible investment under uncertainty according with Abel et al. (1996):

In a two-period framework, in which the second-period returns depend on the stochastic process *e,* the decision problem of the firm is to maximize the net present value of cash flows from the perspective of period 1.

The conditions are as follows:

First period:
K1 = capital installed in period 1, at unit cost b
R(K1) = return on K1 (strictly increasing and concave in K1; satisfying Inada conditions)
Second period:
R(K, e) = the return on capital depending on the level of capital stock K and a stochastic process e; R(e) is strictly increasing in e.

Two critical values of e are defined as e_L (low) and e_H (high) so that marginal return equals marginal cost at each threshold:
$R_K(K_1, e_L) = b_L$
$R_K(K_1, e_H) = b_H$
b_L is the resale price of capital, and b_H is the purchase price of capital, both in period 2.
It follows that:

- when $e > e_H$, it is optimal to purchase capital ($K_2(e) > K_1$) until its marginal return will decline to the new (higher) purchase price;
- when $e < e_L$, it is optimal to sell capital ($K_2(e) < K_1$) until its marginal return will increase to the new (lower) sell price;
- when $e_L \le e \le e_H$, it is optimal to keep the same level of capital ($K_2(e) = K_1$, neither sell nor buy)

In period 1, the decision problem is to maximize the expected net present value of the project: $\max_{K1} V(K_1) - bK_1 \Leftrightarrow V'(K_1) - b = 0$

$$V(K_1) = r(K_1) + \int_{-\infty}^{e_L} [R(K_2(e), e) + b_L(K_1 - K_2(e))]dF(e) + \int_{e_L}^{e_H} R(K_1, e)dF(e) +$$

$$\int_{e_H}^{\infty} [R(K_2(e), e) - b_H(K_2(e) - K_1)]dF(e)$$

$b_L(K_1 - K_2(e))$ = revenue from selling capital in period 2 when $e > e_H$
$b_H(K_2(e) - K_1)$ = cost of buying capital in period 2 when $e < e_L$
dF(e) is the probability distribution function of e (gives the expected value);
F(e) is the c.d.f. of e; $F(e_L) = \Pr(e < e_L)$ and $1 - F(e_H) = \Pr(e > e_H)$
$V(K_1)$ can also be written as:

$$V(K_1) = r(K_1) + \int_{-\infty}^{+\infty} R(K_1, e)dF(e) + \int_{-\infty}^{e_L} \{[R(K_2(e), e) - b_L K_2(e)] - [R(K_1, e) - b_L K_1]\}dF(e)$$

$$- \int_{e_H}^{\infty} \{-[R(K_2(e), e) - b_H K_2(e)] + [R(K_1, e) - b_H K_1]\}dF(e) \Leftrightarrow$$

$$V(K_1) = G(K_1) + P(K_1) - C(K_1)$$

The term $G(K_1) = r(K_1) + \int_{-\infty}^{+\infty} R(K_1, e)dF(e)$ is the expected present value of returns if the investment/disinvestment takes place in period 2 ($K_2 = K_1$)

The next term *$P(K_1)$ is the value of the put option, option to reverse investment or sell capital in period 2 at a price b_L if $e<e_L$.*

The next term *$C(K_1)$ is the value of the call option, option to invest in the future or buy capital at a price b_H if $e<e_H$.*

The optimal amount of capital in period is given by:
$G'(K_1) + P'(K_1) - C'(K_1) = b$

$$P'(K_1) = \int_{-\infty}^{e_L} [b_L - R'(K_1, e)] dF(e); \quad C'(K_1) = \int_{e_H}^{\infty} [R'(K_1, e) - b_H] dF(e)$$

The effect of a change in the sale price on the value of the marginal put option is given by: $\frac{\partial P'(K_1)}{\partial b_L} = F(e_L) \geq 0$

The effect of a change in the sale price on the value of the marginal call option is given by: $\frac{\partial C'(K_1)}{\partial b_H} = -[1 - F(e_H)] \leq 0$

Appendices to Chapter IV

AIV.1. Dynamic panel models

The difference and system GMM estimators are widely used for dynamic panel models. ***The difference GMM estimator (Arellano-Bond 1991)*** is derived by first differencing the regression equation to eliminate fixed effects and then using lags of the dependent variable, as well as of pre-determined/endogenous variables, and differences of exogenous explanatory variables as instruments.

The system GMM estimator (Blundell-Bond 1998) is used when the dependent variable is highly persistent since its lag is not a good instrument for the first-difference. In this case, the system GMM estimates an additional level equation (in a system of equations, hence its name) using lagged differences as instruments for levels. These estimation methods assume that there is no second order (or higher) autocorrelation in the error term.

The bias-corrected LSDV dynamic panel data estimator (Bruno 2005a) is used when the number of cross-sectional units is small. As it is well known, the least square dummy variable (LSDV) estimation or fixed effects is biased in dynamic panel models (Nickell 1981). Bruno (2005a) proposes a bias corrected FE estimator for estimation and inference in dynamic unbalanced panel data models with a small number of individuals. In our paper, the Arrelano-Bond consistent estimator is chosen to initialize the bias correction, which is up to the order $O\left(\frac{1}{NT^2}\right)$. In this way, I can still estimate an

autoregressive model with fixed effects, and thus limit the potential for omitted variable bias by eliminating factors specific for each economy that are constant in time or whose changes are insignificant during the period of our analysis. Bruno (2005b) performed a Monte Carlo simulation to evaluate the finite-sample performance of the bias corrected LSDV estimators in comparison to the original LSDV estimator (or FE) and three dynamic panel models estimators: Arellano-Bond, Anderson-Hsiao and Blundell-Bond. The author found strong support for the bias-corrected LSDV estimator according to bias and root mean squared error criteria when the number of individuals is small.

AIV.2. Count data models

For count data, the appropriate distributions (and base for empirical models) are Poisson and Negative Binomial (NB).

The Poisson distribution is frequently employed to model the probability of a certain number of events occurring over a given interval of time (e.g., concluding a given number of PPP project in a year). As pointed our in Cameron and Trivendi (1986), the Poisson regression model is based on strict assumptions, namely, the independence of events (events are assumed to occur independently in time), and the equality of the conditional mean and variance $E(Y_i/X_i) = Var(Yi/Xi)$. These assumptions are unlikely to be strictly met in practice by economic data. Cameron and Trivendi propose either to relax the first assumption by using alternative methods from the biometric literature, or to retain the independence assumption, but choose a distribution different from Poisson. The negative binomial model "as developed and applied in the econometric literature is essentially the 'apparent contagion' model of biometrics […] according to which

individuals have constant but unequal probability of experiencing an event" [i.e. the negative binomial (NB) regression models between-group heterogeneity] (Cameron and Trivendi 1986, pg. 34).

The negative binomial distribution solves the second problem, being used as an alternative to Poisson for discrete nonnegative data whose sample variance exceeds the sample mean (the variance of a NB-distributed random variable is larger than the mean by a factor $1/\pi$, where π is the probability of success in a Bernoulli trial[54]). In our case, the (unconditional) variance of our proposed dependent variable—total number of PPP projects per year per country—is much larger than the (unconditional) mean (32.8 compared to 1.6). In terms of conditional variance, the NB regression model accounts for the overdispersion (the extra-Poisson variation)[55]. This overdispertion can be modeled as clustered, i.e. to adjust standard errors assuming that the observations are independent across group, but not necessarily within group.

Various tests have been implemented in Stata to deal with model selection (Stata manual 2003). As a post-estimation tool, a goodness-of-fit test (estat gof) after Poisson gives a deviance statistic (between the predicted values and the actual), which, if significant, indicates that the Poisson model is inappropriate and a negative binomial should be investigated.

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[54] If $X \approx NB \Rightarrow E(X) = \frac{r(1-\pi)}{\pi}$ and $Var(X) = \frac{r(1-\pi)}{\pi^2}$, r = no of successes

[55] Say Y is Poisson $\Leftrightarrow$ $y_i \sim$ Poisson (μ_i), where $\mu_i = \exp(x_i\beta)$ for observed counts y_i with covariates x_i for the i^{th} observation.

If Y ~ NB, the individual units follow a Poisson regression model, but there is an omitted variable u_i, such that e^{ui} follows a gamma distribution with mean 1 and variance α =>
$\mu_i = \exp(x_i\beta + u_i)$ and $Var(y_i) = \mu_i(1+\alpha\mu_i)$. α is referred in Stata as the dispersion parameter. If $\alpha = 0$, the model is Poisson. (Stata Manual 2003).

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CURRICULUM VITAE

Cristina D. Checherita was born on October 13, 1975, in Corabia, Romania. She graduated from the Mathematics-Physics High-School of Corabia in 1994 and studied International Economics at the Academy of Economic Studies, Bucharest. After having obtained her BA, she participated in the post-graduate program in European Economic Integration offered by the same university. She started to work as an economist at the Ministry of Finance of Romania in March 1999. While in the Ministry, she had attended several training courses in macroeconomic policies and participated in conferences in Austria, Japan, the U.S., Turkey, and France. In 2003, she studied in the Masters Program in Economic Policy Management at Columbia University, School of International and Public Affairs, benefiting from a full scholarship. After graduation, she returned to the Romanian Ministry of Finance and assumed the position of Advisor to the Minister of Finance. In fall 2005, she started the PhD program at the School of Public Policy at George Mason University, where she also worked as a Research Assistant. While in the PhD program, she attended various conferences, presenting papers on several areas of research. Since December 2008, she has been employed by the European Central Bank in Frankfurt, Germany, as Economist in the Fiscal Policies Division, Department of Economics. The focus of her research is on public-private partnerships, economic convergence, and the role of fiscal policy in shaping markets' reaction to government risk.